DLR

The Institute of Aerospace Medicine

Research Report 2021–2025

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I. The Institute of Aerospace Medicine

Improving health span in space and on Earth

The DLR Institute of Aerospace Medicine operates at the vital interface between medicine, psychology, biology, and advanced technologies. Our mission is to enhance human health, performance, and safety in space, aeronautics, and on Earth. We create groundbreaking knowledge and technologies that address critical societal challenges, drive economic growth, and inform evidence-based policymaking.

With decades of experience in selecting and caring for pilots, air traffic controllers, and astronauts, the Institute is uniquely positioned to carry out impactful, interdisciplinary research and development. We design, evaluate, and implement tools to assess and mitigate health risks and psychological challenges faced by flying personnel – whether pilots, astronauts, or individuals affected by traffic. By applying biomedical and psychological research from space and aviation to everyday challenges on Earth, we address aging-related health and performance limitations, improve radiation protection for workers, and enable sustainable living in resource-constrained settings.

A hallmark of our Institute is its sophisticated human research program, supported by the state-of-the-art :envihab facility. In aerospace biology, we combine successful space-based investigations with extensive ground-based studies in dedicated simulation environments. These efforts also leverage opportunities in the evolving low Earth orbit (LEO) economy. Our long-standing expertise in space radiation dosimetry and experiment hardware development has made us a trusted partner for aerospace radiation protection.

We conduct research and development in close collaboration with leading national and international research institutions, agencies, and industry partners, ensuring that our work has a far-reaching impact.

The DLR Institute of Aerospace Medicine comprises seven departments located in Cologne and Hamburg, with internationally recognized expertise and unique infrastructure. The Departments for Cardiovascular Aerospace Medicine, Sleep and Human Factors Research, Clinical Aerospace Medicine, Metabolism and Human Performance, Radiation Biology, and Applied Aerospace Biology are based at the DLR campus in Cologne near the European Astronaut Centre, the German Air Force Centre of Aerospace Medicine, the LUNA facility (which simulates the lunar surface), and Cologne-Bonn Airport. The Department for Aerospace Psychology is located near Hamburg Airport.

Jens Jordan, Director of the Institute of Aerospace Medicine, and Christine Hellweg, Vice Director of the Institute

Institute of Aerospace Medicine

DEPARTMENTS AND CONTACT PERSONS

I.1 Scientific key activities

Our Institute runs an integrated, interdisciplinary biomedical and psychological research and development program addressing unmet needs for people in space, in aeronautics, and on Earth. We organize our research into seven cross-sectional topics, each designed to tackle specific challenges across these domains.

Mechanisms by which gravity and atmospheric conditions impact human health and performance in space, in aviation, and on Earth

Genome-environment interactions effects on sleep, performance, and cardiometabolic disease in the mobile society

From molecular mechanisms to individualized risk assessment and radiation exposure prevention

Human, environment, and microbiome interactions: From aerospace research towards sustainable economic management on Earth

Human-human and human-machine interactions: Challenges and opportunities in the light of demographic change

Our expertise covers both field and laboratory research across diverse environments, including space, aviation, public transportation, and even residential settings affected by environmental and traffic-related stressors. Our fieldwork encompasses experiments on space missions such as Artemis 1, aboard the International Space Station (ISS), on compact satellites, sounding rockets (DLR MAPHEUS® program), and during parabolic flights. These efforts are complemented by carefully controlled medical, psychological, and biological studies on Earth under highly standardized conditions.

We develop and validate psychological selection procedures and provide medical certification and astronaut care in collaboration with the European Astronaut Centre. Our complex human studies integrate highly-controlled environmental simulations with detailed human phenotyping, supported by advanced biomedical imaging and artificial intelligence (AI)-based analysis from cellular to whole-body levels. In addition, we design mobile, self-sufficient diagnostic systems for extreme environments including space exploration, low Earth orbit commercialization, aviation, and emergency medicine.

Our research directly supports and improves the psychological and medical selection and care of aerospace personnel, creating a feedback loop that continuously enhances our methods and findings. We integrate biological and engineering expertise to develop advanced radiation detectors, models, and countermeasures based on cellular responses like DNA repair.
Beyond aerospace, we apply our expertise to challenges on Earth, addressing age-related declines in muscle and bone mass, cardiopulmonary fitness, coordination, and eye health. Our research in bioregeneration, essential for both space exploration and waste management on Earth, exemplifies these dual applications. Furthermore, we monitor and manage microbial contamination in transport systems—from spacecrafts to commuter trains—through development of effective decontamination processes and antimicrobial surface technologies.

I.2 Programmatic involvement and cooperation at DLR

As part of the Helmholtz Association, the Institute of Aerospace Medicine receives program-oriented funding. Our primary support comes from the DLR Space and Aeronautics programs with additional contributions from the DLR Transport program. Within these priority areas, the Institute acts as crucial interface between humans, the environment, and DLR's high-tech expertise, collaborating closely with other DLR institutes.
In the Space program, we conduct biomedical experiments on the ISS, focusing on radiation, muscle and bone loss, cardiovascular deconditioning, sleep, and human-machine interactions. We also study microorganism colonization and biofilm formation, developing countermeasures through surface modifications and decontamination. Looking beyond ISS, we collaborate with future players in the LEO economy and support astronautical exploration within the Artemis program. Furthermore, we develop sustainable life support systems for space exploration, with spin-off benefits Earth-based applications like plant production and bioeconomy.
Within the Aeronautics program, we enhance selection procedures for pilots, air traffic controllers, and other critical operators. We examine physical strain on aviation personnel and study effects of air traffic noise on health and sleep. In addition, we investigate public acceptance of drones, medical safety in aircraft cabins, and radiation protection for flight crews related to space weather. Finally, we develop methods to detect microbial contamination and design decontamination procedures tailored for aviation environments.
In the Transport program, we study the impact of road and rail traffic noise on residents' health and the effects of shift work on performance. We explore the human factor in autonomous driving and develop innovative decontamination technologies for passenger areas, including air conditioning and ventilation systems.
Finally, in the Security program, we contribute to the development of advanced capabilities for the air force, including technologies for rescue helicopters, telemedicine, and telesurgery.

I.3 Knowledge exchange

At DLR, we conduct research with the mission to make results and data accessible to public stakeholders and industry, thereby advancing society and the economy. Relevant stakeholders include the German Space Agency at DLR (RFA), federal and state authorities with security responsibilities, the German Armed Forces, municipalities, and policymakers at various government levels.
Ensuring the usability and availability of DLR knowledge, data, and technologies, and maintaining engagement with public stakeholders, are key responsibilities across DLR institutes and facilities. These efforts enable partners to develop new solutions and innovations, while providing feedback for further research. Knowledge exchange is central to the design, implementation, and dissemination of research projects. The institute actively participates in scientific advisory bodies that support policy decisions, and in standardization and norm-setting.
The DLR Institute of Aerospace Medicine plays a vital role in supporting research organizations, the scientific community, and public decision-makers. We organize conferences, symposia, and workshops that foster knowledge exchange and promote advancements in Aerospace Medicine. We collaborate with ESA, NASA, and JAXA on joint research and expertise sharing. Through memberships in scientific working groups, commissions, and scientific organizations national and international levels, we help shape policies and standards in the field.
At the national level, we contribute to the Radiation Risk Committee ("Ausschuss Strahlenrisiko") of the Radiation Protection Commission (SSK) of the Federal Ministry for the Environment (now BMUKN). We serve as scientific representative in the § 32a Air Traffic Act committee to the Federal Ministries of Digital Affairs (BMDS), Transport (BMV), and Environment (BMUKN) on aircraft noise. Regionally, we promote exchange, for example, by presenting the Matroshka AstroRad Radiation Experiment (MARE) (see p. 41) at the North Rhine-Westphalia state representation.
In security, we work closely with the Medical Center for Air and Space Medicine of the German Armed Forces, the Military Medical Advisory Board, and the Federal Ministry of Defence (BMVG) Joint Committee Support. We also contribute to a Horizon 2020 project for the European Union Aviation Safety Agency (EASA) and the European Commission, evaluating the effectiveness of flight and duty time limitations and rest requirements in the European Union (EU). Within this framework, we assess cardiovascular risks to protect flight safety and the well-being of pilots and air traffic controllers.
We conduct medical examinations for pilot and air traffic controller selection and annual check-ups for the federal police, provide fitness evaluations, and train special units in high-altitude physiology to help personnel recognize hypoxia symptoms during operations.
Through these collaborations, we embed scientific findings in political and security-related decision-making, ensuring effective knowledge transfer.

Contributions to educational institutions and special topics

- Events for teacher training in the field of biology
- European Society of Aerospace Medicine Academy: Training of European flight physicians and contributions in ophthalmology
- Academy for Medical Education Rhineland-Palatinate
- Children's Rehabilitation Center, University Hospital Cologne
- Radiation Safety Courses

I.4 Technology transfer

At DLR, we conduct research to promote prosperity and create market value through innovations. We focus on both generating knowledge and applying its results. Through our research, we aim to strengthen the German and European economies. By identifying added value from the perspective of business partners and defining corresponding action areas, we have realigned our approach in an integrated way.
"Transfer" describes the process of identifying, developing, refining, and disseminating the market potential of research through cooperation, licensing, or spin-offs. Successful transfer leads to innovation. By introducing new products, services, or features to the market, innovation creates economic value and benefits society.
The DLR Institute of Aerospace Medicine actively drives technology transfer, working with partners to apply innovations from space medicine to human medicine on Earth. For example, we have developed an AI-supported mobile retinal diagnostic system—an intelligent, high-tech ophthalmoscope designed for emergency medicine—and advanced real-time cardiac Magnetic Resonace Imaging (MRI) techniques for imaging congenital heart defects. In rehabilitation medicine, we created the KNIMS (Kompetenznetzwerk Immobilisationsbedingte Muskelstörungen) rehabilitation algorithm to support healthy aging through exercise programs tailored for nursing homes.
We also advance initiatives in disaster protection, mobility, and population resilience. For example, we design and validate equipment developed for the aerospace sector and antimicrobial surfaces. The SpacePatchSystem demonstrates cutting-edge health and performance monitoring with integrated risk assessment, supporting Artemis missions by combining Tiny AI technology for astronauts, first responders, and healthy aging individuals. We also partnered with a health insurance provider to develop an environmental stressor map, further connecting space medicine research to public health.

Examples of successful technology transfer achievements

- NUNOS is a DLR spin-off, originating from technology developed at the DLR Institute for Aerospace Medicine. Initially designed to recycle nitrogen-rich wastewater in closed habitats like lunar or Mars stations, the technology converts human urine into plant fertilizer to grow fresh food in space. Recognizing Earth's urgent challenges—such as nitrate groundwater pollution and climate-driven extreme weather—we adapted this process for treating agricultural waste like manure and digestate. NUNOS exemplifies successful technology transfer from space research to practical solutions on Earth, demonstrating how innovations from aerospace medicine can directly benefit sustainable agriculture today.

- A trusted partner was established in Milan to conduct psychological aptitude assessments for pilot candidates from the Italian-speaking region. This collaboration focuses on managing personnel selection processes for cockpit applicants through a dedicated test center offering computer-based cognitive performance tests. The establishment of this test center for computer-based cognitive assessments in Milan (the "DLR Certificate") has greatly eased the process for airlines, candidates, and the testing organization. This certified facility ensures high-quality and efficient evaluations, significantly simplifying the selection procedures.


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II.1
Cardiovascular Aerospace Medicine

Prof. Dr. med. Dipl. Biophys. Jens Tank (Head)

Dr. rer. nat. Darius Gerlach (Deputy)

Mission Goal

The Department for Cardiovascular Aerospace Medicine investigates gene-environmental influences on the human cardiovascular system. We focus on real and simulated weightlessness, atmosphere conditions, nutrition, and exercise. Our major aim is to elucidate mechanisms of cardiovascular structural and functional adaptation and how these responses are integrated by the autonomic nervous system. We flank our human space experiments with highly controlled terrestrial studies in healthy persons and in patients in close collaboration with leading university medical faculties. We combine physiological or pharmacological challenges with high-fidelity human phenotyping including state-of-the-art functional imaging and biomedical engineering. Moreover, we translate observations in patients with rare cardiovascular conditions and defined genetic variants to astronauts confronting spaceflight challenges and vice versa. Our ultimate goal is to improve diagnostics, cardiovascular countermeasures, and treatments in space, in aeronautics, and on Earth.

Cardiovascular Aerospace Medicine

Unique selling points of the department

Highly controlled mechanistic studies applying high-fidelity cardiovascular phenotyping in healthy persons, in selected patient cohorts, and in astronauts

Unique expertise and infrastructure combining PET/MRI imaging with human physiological profiling with a focus on the brain-heart axis

International leadership in clinical autonomic research in space and on Earth

Strong regional and national networking with universities and university hospitals

Interdisciplinary collaboration in AI application and development of new methods in image analysis

Current and future challenges

Combine high-fidelity cardiovascular phenotyping with advanced functional and molecular imaging to study the brain-heart axis

Translate the results into terrestrial medicine

Attract young physicians/scientists to the field

Cardiac function in extreme environments

Long-term spaceflight profoundly challenges the cardiovascular system. In weightlessness, blood volume and interstitial fluid rapidly shift towards the head. The response triggers compensatory changes in blood and plasma volume, left ventricular muscle mass, cardiac geometry, and cardiac function. Moreover, atmospheric conditions on spaceships, in space suits, and in future habitats differ from those on Earth. With increasingly ambitious space missions and longer durations, the risk for impaired cardiovascular fitness and health increases, demanding more effective countermeasures. Broader understanding of how space environment and gene interactions shape cardiovascular structure and function will help attenuating potential health risks for people in space and cardiovascular patients on Earth.

Mechanisms of orthostatic intolerance in astronauts and in patients

The ability to stand upright while maintaining blood pressure is an evolutionary advantage of human beings. When standing, 500 – 1000 ml of blood are pooled below the diaphragm and plasma volume decreases 10 – 20 %. Failure of proper blood pressure regulation may cause profound hypotension and loss of consciousness (syncope). Post-spaceflight orthostatic intolerance poses risks for astronauts and data on cardiovascular responses to active standing on other celestial bodies is lacking. We have extensive expertise in passive and active orthostatic testing and are internationally recognized for evaluating and clinically managing patients with orthostatic dysfunction. To evaluate these issues, we employ a broad repertoire of methods, including non-invasive assessment of autonomic cardiovascular control complemented by invasive measurements such as microneurography. We apply advanced cardiovascular imaging including real-time MRI for beat-by-beat monitoring of cardiac functions during orthostatic challenges.

Cardiovascular control in health and disease

Several mechanisms interact in a complex fashion to regulate the cardiovascular system. To unravel their individual and collective effects, we apply high-fidelity cardiovascular phenotyping in healthy persons undergoing highly controlled interventions and in patients with autonomic nervous system diseases. Our goal is early detection and development of targeted interventions to preserve cardiovascular performance and health in aerospace and terrestrial medicine:

- We determine cardiovascular control mechanisms through high-fidelity physiological profiling.
- We apply physiological challenges, such as head-down bed rest, head-up tilt table testing, lower body negative pressure (LBNP), and pharmacological interventions to elucidate cardiovascular control systems including the central autonomic network.
- We develop functional Magnetic Resonance Imaging (fMRI) techniques to elucidate individual brainstem/hypothalamus physiology.
- We translate findings between the clinic and space research to gain mechanistic insight and to improve health in space and on Earth.
- We develop and improve hard- and software for cardiovascular medicine in space and on Earth.

Functional imaging of cardiovascular reflexes at the brainstem and hypothalamic level

Brainstem and hypothalamus control vital functions such as heart rate, blood pressure, respiration, energy metabolism, body temperature, and fluid homeostasis. These regions integrate incoming information from baro- and chemoreceptors and adjust efferent signals that regulate breathing, heart rate, and blood pressure. Previous studies, during and after spaceflight showed that abnormalities in the cardiovascular system during weightlessness and after landing may partly stem from altered central nervous cardiovascular regulation. However, knowledge about human brainstem and hypothalamus regulation is limited. Moreover, car-

Working Groups/Teams

Cardiovascular Control and Atmosphere Conditions | Dr. med. Ulrich Limper and Dr. rer. nat. Stefan Möstl

- High fidelity cardiovascular phenotyping in healthy subjects and in patients with defined disorders under extreme atmospheric conditions and under simulated microgravity (bed rest studies)
- Pre-, post-, and inflight experiments (parabolic flights and ISS missions)
- Validation of non-invasive new methods using wearable devices
- Application and development of physiological and pharmacological challenges
- Determine the efficacy of drug therapy as well as nonmedical treatments including countermeasures and physical training
- Improving early detection of pathological changes and translation of those methods into terrestrial medicine
- Development and improvement of hard- and software
- Goal-driven combination of inhouse and external methodological expertise to further probe the cross talk between endorgans

Advanced Functional Imaging | Dr. rer. nat. Jorge Manuel and Dr. rer. nat. Darius Gerlach

- State of the art neuroimaging methods
- Functional MRI assessment of the brainstem and hypothalamus, the centers of autonomic control
- Autonomic testing within the MRI scanner, to characterize the function and neuroplastic adaptations in response to immobilization, diseases, and life style
- Cardiac MRI under extreme environments, including hypoxic condition and immobilization
- Detection of cardiovascular deconditioning and impairment in immobilization and diseases
- Probing the cross talk between endorgans with brain, cardiac and renal imaging

diovascular and metabolic diseases including arterial hypertension, heart failure, obesity and type 2 diabetes mellitus often involve changes in central autonomic cardiovascular control and impaired reflex mechanisms, which may influence disease progression and therapeutic response. Our major research interest is to gain deeper insight into the function of this brain-heart axis.

Effective cardiovascular countermeasures for space and for Earth

LBNP, developed in the early 1960s, counteracts blood volume shifts towards the head and helps maintain cardiovascular reserve. However, current protocols and techniques onboard the ISS remain suboptimal and need to become more effective, mobile, and comfortable. Therefore, we aim to develop and test new LBNP concepts for use in space and on Earth. This research includes new concepts for real-time cardiovascular function measurements. We developed the SpacePatchSystem, a universal open platform to receive wireless data from different state-of-the-art wearable sensors. SpacePatchSystem will receive, safely store, and provide synchronized data in real time for subsequent individual self-learning algorithms to enable immediate and independent mission support for crew health and performance.

Main projects 2021-2025

Hypoxia and myocardial regeneration (MyoCardioGen 2 and 3)

In collaboration with the University of Texas Southwestern (UTSW), we applied aerospace technology and expertise to advance cardiovascular regenerative medicine. We translated animal research findings suggesting that sustained severe hypoxia, similar to Mt. Everest conditions, induces cardiac regeneration and enhances cardiac function to humans. A 2018 feasibility and safety study (MyoCardioGen 1) at DLR in Cologne with two professional mountaineers showed the feasibility of the approach, published in Circulation in 2020.
Building on this, a 2021 study (MyoCardioGen 2) involved four myocardial infarction patients with high-altitude experience and one healthy

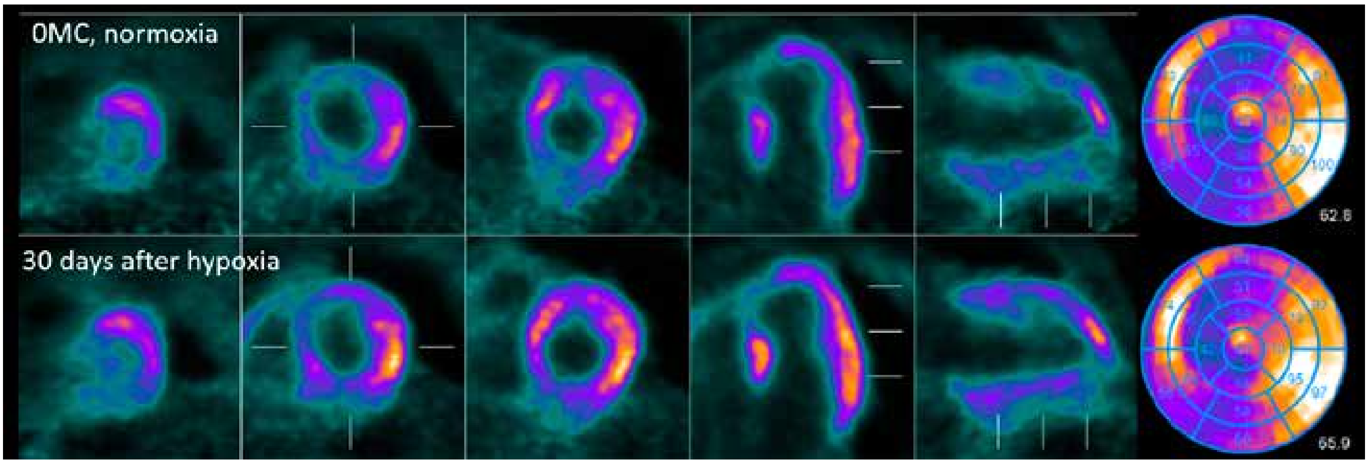

Figure 1: Example of 18F-fluorodeoxyglucose (FDG)-PET images of the left ventricle before and after severe sustained hypoxia in one patient. Color intensity reflects the amount of glucose uptake. The right images summarize the uptake for all left ventricular segments and show an increase in global uptake.

control. They stayed at :envihab for three weeks, with oxygen gradually reduced to 11.8 % (4,554 m altitude equivalent) for the final 4.5 days. Participants underwent extensive physiological testing, and all tolerated hypoxia well. One patient showed significant improvement in left ventricular ejection fraction, with findings published in Circulation Research in 2023. The 2022 MyoCardioGen 3 study further extended this research. After pre-acclimatization in the Alps, three patients and one healthy control (participants of MyoCardioGen 2) stayed at :envihab for five weeks, with oxygen reduced to 9.5 % (6,554 m equivalent) for the final two weeks. Testing included [^{18}F]-fluorodeoxyglucose ([^{18}F]FDG)-cardiac PET-MRI, late gadolinium enhancement, and metabolic profiling. Cardiac function remained stable despite decreased physical performance. Notably, glucose uptake increased in myocardial scar-adjacent areas (see figure 1), and metabolic phenotyping revealed enhanced mitochondrial activity and DNA damage response. Overall, these studies confirm that severe hypoxia research in humans is safe and feasible, providing a foundation for future trials. The upcoming HypoNorm-HIF (Hypoxia-inducible factor) study, planned for 2025 with the University Clinic Bonn, will examine whether less pronounced hypoxia combined with drugs stabilizing hypoxia-inducible factors elicits similar effects.

Adaptation to hypoxia: Lessons learned from patients with univentricular hearts (HypoFon study) and with severe pulmonary hypertension (ICAROS study)

In healthy individuals, the right ventricle maintains pulmonary blood flow under hypoxia. Patients with Fontan circulation lack this ventricle, which challenges cardiac output and oxygenation during hypoxic pulmonary vasoconstriction. Many patients with Fontan circulation wish to pursue activities in hypoxic environments, like airplane rides or vacations to higher altitudes. Yet, evidence to guide these activities is lacking. The HypoFon study addressed this issue, focusing on nighttime oxygenation due to reduced ventilatory drive during sleep. A feasibility trial with 18 patients in 2021–2022 involved a 4-day stay at :envihab, with baseline normoxia followed by 15.2% normobaric hypoxia (~2.440m). Measurements included cardiorespiratory parameters, pulmonary artery pressure via central venous catheter, pulmonary artery blood flow using real-time MRI, capillary oxygen saturation, and exercise performance. All tolerated hypoxia well, with no overnight desaturation below 75% (Figure 2), providing critical evidence for managing Fontan patients.

The ICAROS study, in collaboration with the University Hospitals of Cologne and Bonn, investigated acute effects of hypobaric hypoxia (~2.440m) in patients with severe pulmonary hypertension in 2024. By combining clinical assessments, cardiac imaging, and molecular analyses, the study aimed to fill the knowledge gap on air travel risks for these patients. Our findings will inform recommendations for managing air travel and enhance understanding of hypoxia adaptation through imaging and molecular studies.

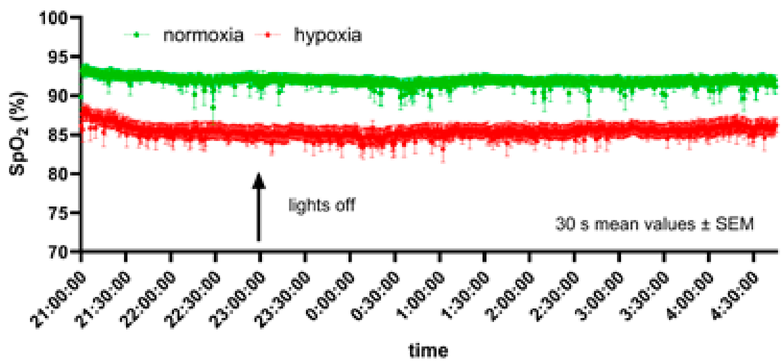

Figure 2: Mean group values of blood oxygen saturation SpO_2 ± SEM (n=18) measured at nighttime sleep during normoxia (green) and during hypoxia exposure (red). A stable SpO_2 trend was observed in normobaric hypoxia without significant or abrupt reductions.

Cardiac deconditioning – From bedside to space

An important consequence of cardiovascular deconditioning in space and on Earth is the reduced ability to cope with physiological challenges such as standing or physical exertion. We investigated cardiovascular adaptation to a spaceflight analog, -6° head-down-tilt bed rest, over four SANS_CM campaigns (2021 – 2023) led by DLR and NASA. Participants were assigned to four groups: daily six-hour LBNP training (-25 mmHg), a positive control (six hours sitting), a negative control (no countermeasure), and an exercise group (cycling followed by thigh cuffs). Before and after bed rest, we conducted orthostatic testing until presyncope with echocardiographic left ventricular stroke volume and cardiac output measurements.

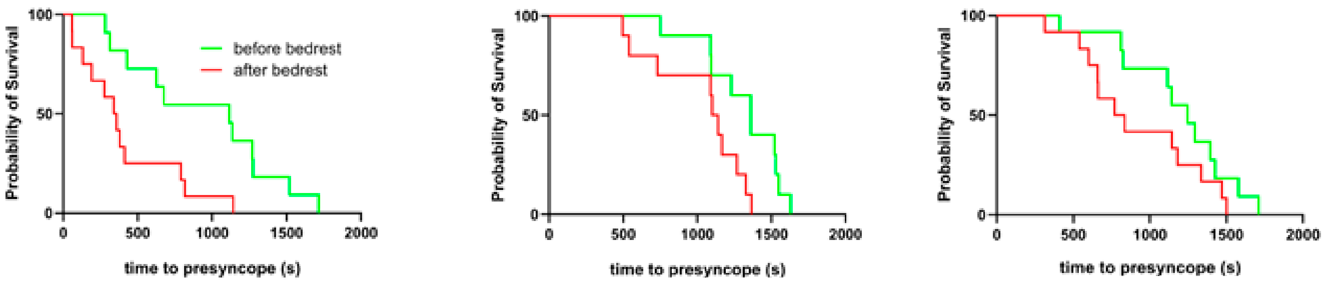

Figure 3: Kaplan-Meier plots illustrating the time to presyncope during tilt-table testing in the control (left), seated (middle), and LBNP (right) groups before (green) and after bed rest (red).

Our results suggest that six hours of LBNP mitigate orthostatic intolerance, comparable to the positive control group (Figure 3). The following bed rest study will evaluate sensorimotor countermeasures (SMC-study) starting in 2024.
Additionally, we initiated a cardiac MRI pre-post flight experiment with ESA astronauts (two weeks or six-month missions) in collaboration with the University Hospital of Brussels. The first two astronauts have been successfully studied, with examinations using the same protocols as the bed rest studies to characterize cardiovascular responses to spaceflight.

Real time cardiac MRI to study human physiology in health and disease
Orthostatic intolerance – characterized by blood pressure drops, increased heart rate while standing, and syncope – can result from systemic hemodynamic changes, altered cerebrovascular control, or both. Astronauts may experience similar symptoms post-spaceflight, posing risks during landings without medical support. Current diagnostics struggle to differentiate underlying mechanisms, so we developed a novel approach combining cardiac and cerebral real-time MRI, beat-to-beat physiological monitoring, and orthostatic stress testing via LBNP.
We tested this method in a patient with severe orthostatic hypotension due to pure autonomic failure, demonstrating significant decreases in left ventricular stroke volume, middle cerebral artery flow, and pulmonary artery flow under LBNP. This case study, published in Journal of the American Heart Association (2022), highlights the potential of this approach (Figure 4). It has since been applied in the SANS_CM and Sensorimotor Control bed rest studies.

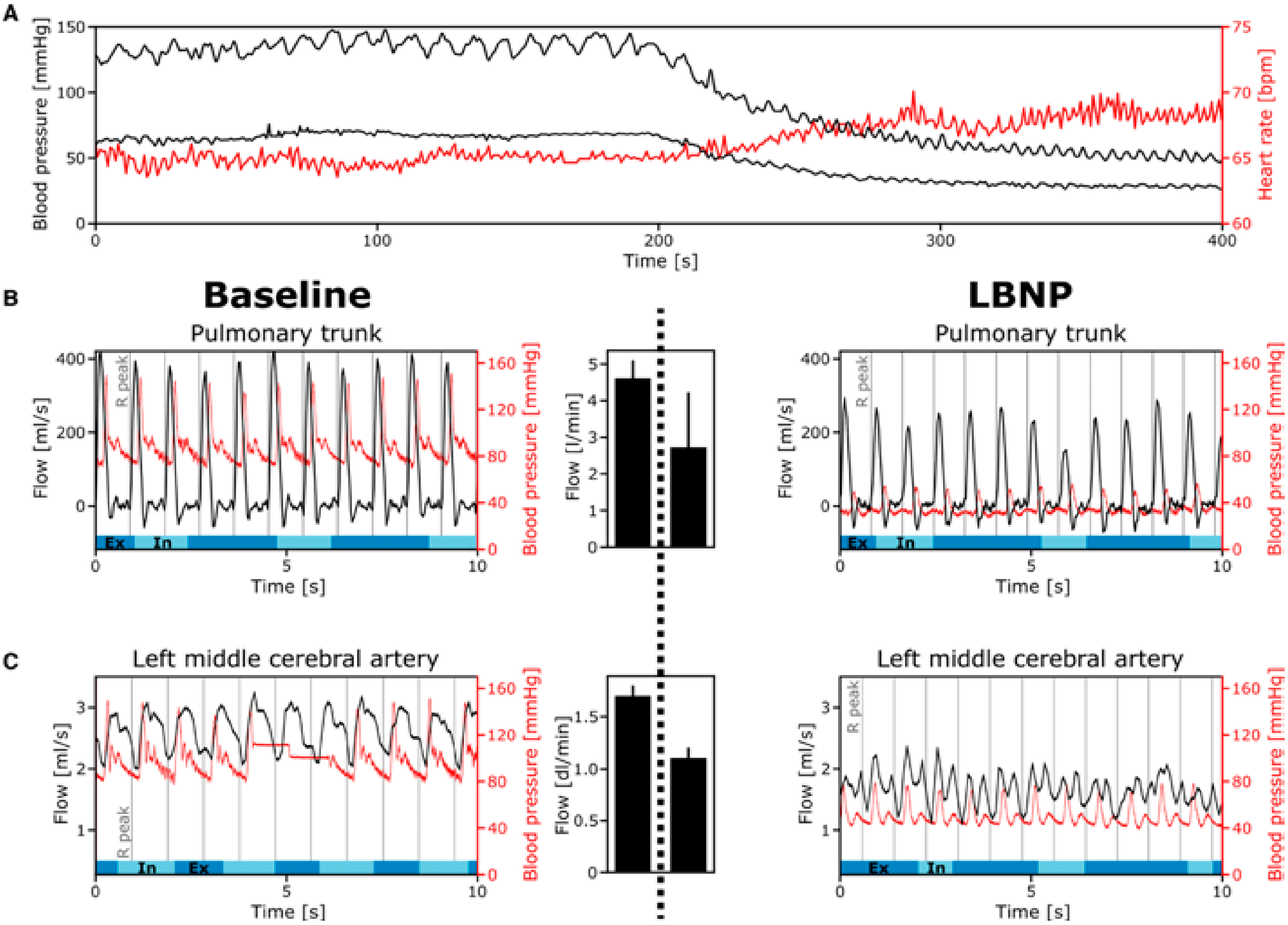

Figure 4: Systolic, diastolic blood pressure (black lines), and heart rate (red line) responses to LBNP in a pure autonomic failure patient (A). Pulmonary blood flow and finger blood pressure at baseline and during LBNP (B). Left middle cerebral artery blood flow and blood pressure at baseline and during LBNP.

Additionally, we used this technique to investigate orthostatic intolerance in patients with the hypermobile Ehlers-Danlos Syndrome. By integrating fMRI, cardiac MRI, plasma volume measurements, and direct muscle sympathetic nerve activity recordings during passive tilt, we aim to identify contributing mechanisms. Real-time cardiac MRI, combined with LBNP testing in the scanner, assessed the cardiovascular effects of LBNP training versus exercise during 30 days of bed rest (SANS_CM study). Future research will use real-time cardiac and renal MRI during LBNP to assess long-term bed rest effects on renal function, which strongly affects volume control and blood pressure.
As real-time cardiac MRI is a new technology, no image analysis software currently exists. To address this, we launched the AI-based evaluation of real-time cardiac MRI project in collaboration with the Institute of DLR Software Technology. The long-term goal is to fully automate real time MRI image segmentation and breathing detection which allows direct assessment of respiratory variability of cardiac function (Figure 5).

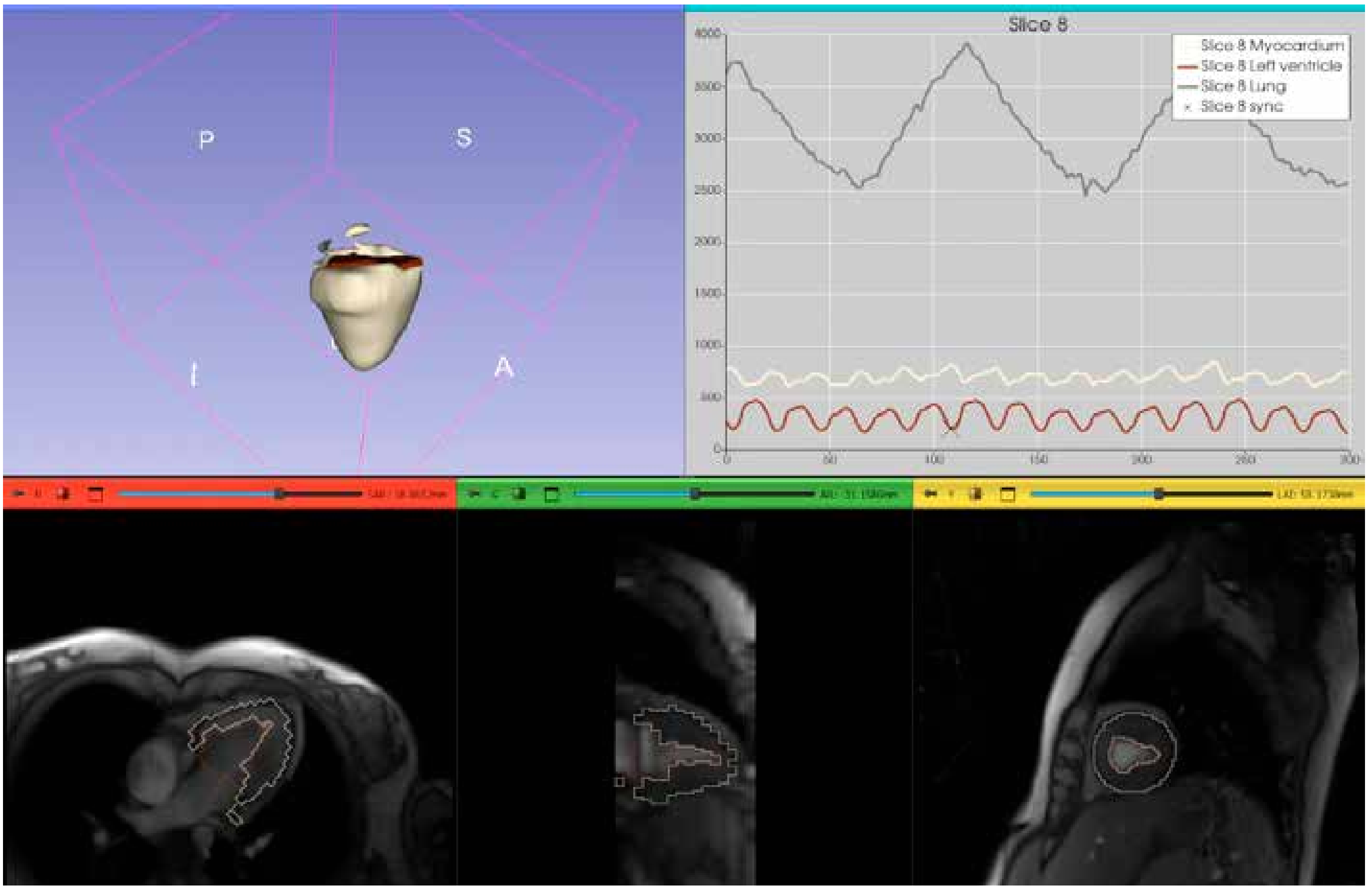

Figure 5: The synchronized segmented univentricular heart in 4D (upper left). Automated detection of the breathing- and cardiac cycles (upper right). Images at a selected time point in three different imaging planes representing the short and the long axis (bottom).

State-of-the-art functional MRI (fMRI) of subcortical regions: paving the road for individualized measurements

Studying the hypothalamus and brainstem is challenging due to their deep location and small nuclei. However, advances in fMRI now enable us to investigate these critical regions. We apply these methods to medical conditions like orthostatic intolerance, affecting, both, returning astronauts and bedridden patients. After prolonged bed rest, we observed changes in six brain regions, including the lateral hypothalamus, a key regulator of metabolism, sleep, and cardiovascular function.

We are also investigating patients with Ehlers-Danlos-Syndrome and orthostatic intolerance, a poorly understood condition characterized by connective tissue weakness and cardiovascular autonomic symptoms. Beyond group studies, we aim to identify individual biomarkers for precision medicine. Using repeated glucose ingestion, we demonstrated that individualized measurements can be more effective than group designs when responses vary.

Additionally, we are developing MR-compatible neck suction cuffs for rapid cardiovascular stimulation. This personalized imaging approach holds promise for both clinical patients and individuals facing extreme space environments.

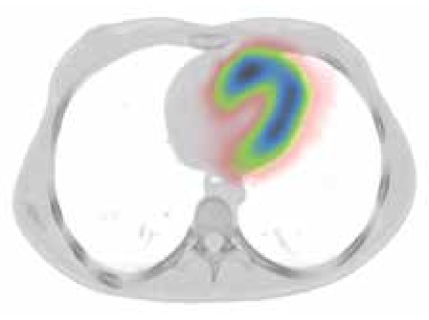

Figure 6: Accumulation of a noradrenaline analog in cardiac sympathetic nerve fibers which cannot be released since these fibers are functionally disconnected from their central autonomic input.

Translation between laboratories and clinics

The deconditioning effects of prolonged bed rest or spaceflight on cardiovascular regulation mirror certain patient pathologies. We identified a previously undescribed compound heterozygous mutation in the cholinergic receptor nicotinic alpha 3 subunit (CHRNA3) gene, impairing central autonomic signal transmission to peripheral nerves (Figure 6).

Heart failure is associated with increased sympathetic activity, forming a vicious cycle. We tested whether left-ventricular assist device (LVAD) implantation reduces sympathetic drive, but intra-neural recordings before and after implantation did not support this hypothesis.

Both lack of gravitational stress and diuretics reduce plasma volume. In collaboration with the Profil GmbH, we compared the diuretic hydrochlorothiazide (HCT) with empagliflozin, a glucose-excreting agent that induces diuresis. Preliminary findings suggest lower sympathetic activity with empagliflozin compared to HCT.

Collaboration partners within the Institute

- Dept. of Applied Aerospace Biology
- Dept. of Clinical Aerospace Medicine
- Dept. of Metabolism and Human Performance
- Dept. of Radiation Biology
- Dept. of Sleep and Human Factors Research
- Study Team

Collaboration partners within the DLR

- Institute for Software Technology
- Institute of Material Physics in Space

Collaboration partners in Germany

- Charité Berlin-Buch
- BundswehrZentralkrankenhaus Koblenz
- German Sports University Cologne
- Fraunhofer Institute for Toxicology and Experimental Medicine (ITEM)
- Heinrich Heine Universität Düsseldorf (HHU)
- Max Delbrück Center (MDC) Berlin
- Medizinische Hochschule Hannover (MHH)
- Max Planck Institute of Biophysical Chemistry
- Profil Institute for Metabolic Research GmbH
- Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)
- Universität Bonn
- Universität zu Köln

Collaboration partners worldwide

- Austrian Institute of Technology, Vienna, Austria
- Johns Hopkins University, Baltimore, USA
- Penn-State University, Philadelphia, USA
- Politecnico di Milano, Italy
- Université Libre de Bruxelles, Belgium
- University of Colorado, USA
- University of Texas Southwestern Medical Center, Dallas, Texas, USA
- Vanderbilt University Nashville, Tennessee, USA

Publications

Müller, N., Härtel, J.A., Schmitz, J., Baur, U., von der Wiesche, M., Rieger, I., Gerlach, D.A., von Stritzky, J., Bach, A., Hart, C., Bros, J., Seeger, B., Zollmann, E., Grau, M., Dragutinovic, B., de Boni, L., Hönemann, J., Bloch, W., Aeschbach, D., Elmenhorst, E.-M., Herberg, U., Hess, A., Schumann, M., Kratz, T., Jordan, J., Breuer, J., Tank, J. (2024) *Peripheral oxygenation and pulmonary hemodynamics in individuals with Fontan circulation during 24-hour high-altitude exposure simulation.* Circulation. 2024;149(18):1466-1468. Lippincott, Williams & Wilkins. doi: 10.1161/CIRCULATIONAHA.123.067601. ISSN 0009-7322.

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DLR
AirZeroG
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II.2
Sleep and Human Factors Research

Prof. Dr. sc. nat. Daniel Aeschbach (Head)

PD Dr. med. Eva-Maria Elmenhorst (Deputy)

Mission Goal
Our mission is to maintain optimal performance, sleep, and wellbeing of operators working under the specific challenges of a mobile, 24-hour society. Shift work and extended work hours are highly prevalent in aeronautics, space travel and transport, impacting individuals short-term (cognitive decline) and long-term (health). We study how homeostatic and circadian processes regulate cognitive performance as well as the quality, duration, and timing of sleep, and how they are impacted by acute and chronic sleep loss, circadian misalignment, and specific behavioral and environmental factors. By combining molecular neuroimaging, physiological, and behavioral research, we strive to uncover mechanistic pathways that help us understand the conditions of human performance and its individual vulnerability, and to derive adequate countermeasures against cognitive impairment and adverse health outcomes.
Our society's mobility demands often conflict with local residents' need for undisturbed recreation and sleep. To address this conflict, we investigate how sleep, cognitive performance, and annoyance are affected by air, rail, and road traffic noise, and share protection concepts with stakeholders. Aircrews and astronauts work and sleep under conditions of hypobaric hypoxia or hypercapnia. Thus, we have a specific interest in studying, both, in the laboratory and inflight how atmospheric conditions affect performance, sleep and well-being. Finally, our digital health expertise enables medical support for air travelers and patients through remote applications.

Sleep and Human Factors Research

Unique selling points of the department

Sleep and circadian rhythms research under highly controlled laboratory and ecological field conditions and its real world applications in shiftwork, aeronautics, space travel, and disease

Predicting individual vulnerability of cognitive performance to sleep loss based on molecular neuroimaging

Exposure response functions of traffic noise effects on sleep

Human-machine and human-human interactions in teams

Inflight monitoring of pilots' performance/fatigue

Figure 1: Around-the-clock blood sampling to assess the circadian timing of the melatonin rhythm in dim light before and after ambient hypoxia exposure.

The Department focusses on the conditions and factors impacting human performance, sleep and wellbeing in the modern, mobile 24-h society. Within DLR, our research has been funded mainly by the Aeronautics program and to a lesser extent by the Space and the Transport programs. Among the factors we study are sleep loss, circadian disruption, workload, noise, atmospheric pressure, hypoxia, and hypercapnia. Our work is aimed at understanding and ultimately improving the conditions for operators on Earth and in space, but also for residents impacted by transport systems, particularly by noise.
We use our highly controlled laboratory environment to elucidate underlying mechanism, such as the role of the brain's adenosine system in sleep-wake regulation, and the interaction between the hypoxia-sensing pathway and circadian clocks. In a translational/applied approach, we examine the influence of circadian, barometric, and atmospheric conditions in the operational environment and assess factors such as fatigue in aircrew, and derive and test adequate countermeasures like improved rostering and controlled inflight rest. We also develop traffic noise protection concepts derived from ecologically valid field studies and evaluate their effectiveness.
Extending this work, we are currently investigating the effects of new aircraft designs – including supersonic airplanes, unmanned aerial vehicles and electric aircraft – using new auralization tools to quantify the noise impact on humans. Another exciting new aspect in our work through the past funding cycle has been the study of sleep loss effects on human-human interaction in teams operating in control rooms. Building on this work, we are currently exploring how artificial intelligence can be integrated as a "partner" in human teams, and to what extent this may be effective in protecting against human fatigue.

Main projects 2021-2025

Resetting of the human circadian clock by ambient hypoxia

Circadian clocks in the body drive daily cycles in physiology and behavior. A master clock in the brain maintains synchrony with the environmental day-night cycle and uses internal signals to keep clocks in other tissues aligned. Work in cell cultures uncovered cyclic changes in tissue oxygenation that may serve to reset and synchronize circadian clocks. We showed in healthy humans, following a randomized controlled single-blind counterbalanced crossover study design (Figure 1), that one-time exposure to moderate ambient hypoxia (fraction of inspired oxygen ($FiO_{2)}$ ~15 %, normobaric) for ~6.5 h during the early night advances the dim-light onset of melatonin secretion by 9 min (95 % confidence interval (CI): 1-16 min). Exposure to moderate hypoxia may thus be strong enough to entrain circadian clocks to a 24-h cycle in the absence of other entraining cues. Together, the results provide direct evidence for an interaction between the body's hypoxia sensing pathway and circadian clocks. The finding offers a mechanism through which behaviors that change tissue oxygenation like exercise, fasting/eating, or long-haul air travel can affect circadian timing, and through which hypoxia-related diseases (e.g., obstructive sleep apnea, chronic obstructive pulmonary disease) can result in circadian misalignment and associated pathologies.

Oxygen supply in the aircraft: mechanisms and risks for flight personnel and passengers

To maintain sufficient oxygen supply in an airliner at cruising altitude, a minimum cabin pressure of 753 hPa is prescribed. The limit corresponds to a stay at an altitude of 2438 m above sea level or breathing air with an oxygen content of only 15 %. Under these conditions, cardio-vascular compensation mechanisms keep blood oxygen saturation (SpO_2) in the normal range during wakefulness, i.e. well above the hypoxia threshold of 90 %. We investigated whether SpO_2 and heart rate remained in a safe range also during sleep. This is an important question in aviation in several respects: 1) pilots on (ultra-) long haul flights need to sleep on board during their rest periods for recovery of cognitive performance and alertness, 2) passengers frequently sleep on board who are potentially vulnerable (e.g. older age, multi-morbid, under the influence of medication and/or alcohol).
Participants slept in our altitude chamber in which we simulated realistic inflight conditions

Working Groups

Performance and Sleep | PD Dr. med. Eva-Maria Elmenhorst

- Effects of sleep loss, irregular timing of sleep, adverse work hours, and workload
- Effectiveness of flight time limitations and mitigation factors
- Effect of environmental conditions (e.g. hypoxia)
- Neuromolecular mechanisms conveying individual (trait) vulnerabilities
- Developing (individualized) countermeasures

Teams

Noise Effects Research | Dr. rer. nat. Susanne Bartels

- Effects of conventional transport noise on sleep, performance, annoyance, and cardiometabolic health
- Effects of noise from novel aeronautics systems and concepts (urban air mobility, electric propulsion, supersonic transport) on human health and well being
- Exposure-response relationships and physiology-based noise protection concepts
- Determination of noise impact in vulnerable groups (e.g. children, older individuals)

Digital Health | Dr. med. Markus Lindlar

- Developing and evaluating biomedical systems and care concepts
- Supporting aircrew with in-flight medical monitoring and incapacitation detection

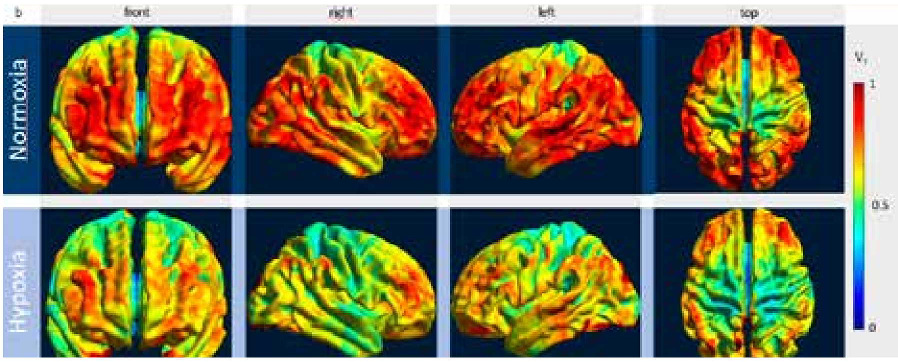

Figure 2: A_1 adenosine receptor availability decreases under acute hypoxia exposure. Upper panel: normoxia; lower panel: hypoxia. Warm colors represent increased receptor availability.

(753 hPa, 70 dB(A) inflight noise). During sleep, SpO_2 fell below the hypoxia threshold of 90 % and stayed there for 75 % of the sleep time. Sleep was less recuperative as it contained less deep sleep and was shorter in duration. Even more worrisome was the combination with moderate alcohol intake (0.04 % blood alcohol concentration) before sleep. SpO_2 dropped on average to 84.8 %, i.e., below the threshold which identifies a diseased passenger to require supplemental on-board oxygen. At the same time heart rate, which usually decreases during sleep, was increased to 89 bpm. Together alcohol and sleep inflight burden the cardiac system which might increase inflight medical emergency risks for passengers with pre-existing medical conditions. Mechanistically, the acute drop in oxygen supply activates protective pathways in the brain which we identified with positron emission tomography and magnetic resonance imaging (Figure 2). Brain perfusion was increased, while energy consumption was decreased via adenosinergic downregulation of neuronal activity. This led to higher oxygen supply and decreased oxygen need, but came at the cost of decreased vigilance performance. Together with the decreased recuperative value of sleep inflight, these findings show that pilots' cognitive performance is more challenged inflight as previously expected. We showed that the increase of the oxygen content of the cabin air to 27.8 % could be used as countermeasure.

Sleep and performance in space

Disturbed sleep poses a hazard in human spaceflight. Astronauts report short and restless sleep in space. This situation is perceived as stressful. Use of sleep medications is increased in space, which, however, does not have a sufficient effect. The causes of these sleep disorders are probably multifactorial, but the search for causes and countermeasures is limited by the number of astronauts available for sleep studies in space. We, therefore, used an analogue scenario on Earth to test in 24 participants whether microgravity impairs sleep. We used the established model of the 6° head-down position, which was maintained continuously over a period of 60 days and nights. In the head-down position, sleep was shorter in duration and of decreased quality. These impairments did not improve with time and put participants in a state of chronic sleep restriction. Sleep loss is a potential safety risk as cognitive functions depend on adequate sleep quantity and quality. Indeed, we showed in 62 participants that sleep deprivation impaired the accuracy in a spacecraft docking simulation with six degrees of freedom of motion which was partly explained by deficits in sustained attention. Improving sleep is thus safety-relevant for future long-duration space missions.

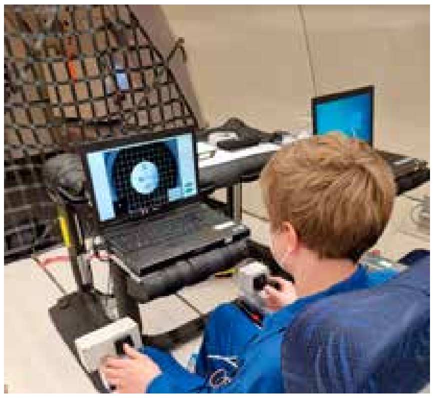

Figure 3: Spacecraft docking task with six degrees of freedom of motion

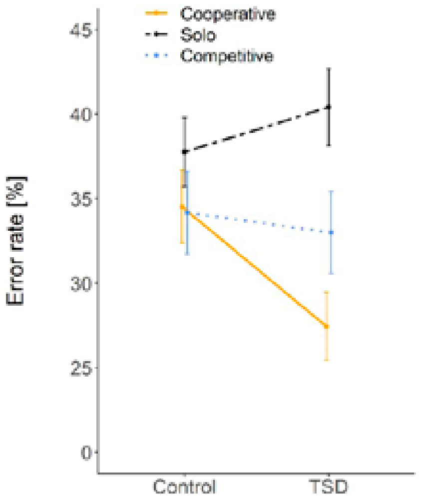

Figure 4: Error rate of participants completing a control room task when well rested (control) and after total sleep deprivation (TSD); cooperative teamwork protects against negative effects of fatigue in contrast to competitive teamwork or solo work.

Cooperative teamwork in a control room as a countermeasure against performance impairment due to sleep loss

Working together in a team is very common in the workplace. Prior research, however, has focused mainly on the effect of sleep loss on individual performance. We, therefore, investigated whether cooperative teamwork in a control room setting attenuates performance impairments caused by sleep loss. We randomly assigned 66 healthy volunteers to teams of three to undergo a laboratory study for five consecutive days. They completed tasks in a simulated control room setting calling on different cognitive domains (sustained attention during monitoring, logical reasoning during problem diagnosis) once after 19 hours awake (sleep deprivation, circadian low) and once following eight hours of scheduled sleep (control) in counterbalanced order. Participants completed the tasks on their own (solo work) and in teams with each member instructed to work to their own advantage (competitive work) or to the team's advantage (cooperative work). We analyzed performance, communication, decision behavior, and team cohesion.

During problem diagnosis, sleep-deprived participants were slower, whereas error rate depended on the work mode: contrary to solo and competitive work, error rate decreased during cooperative work compared to control. Transcripts revealed that sleep-deprived participants shared fewer incorrect information and reported higher team cohesion than when rested (Figure 4). We conclude that in a control room, teams can compensate some fatigue effects on logical reasoning by working cooperatively and adapting their communication behavior.

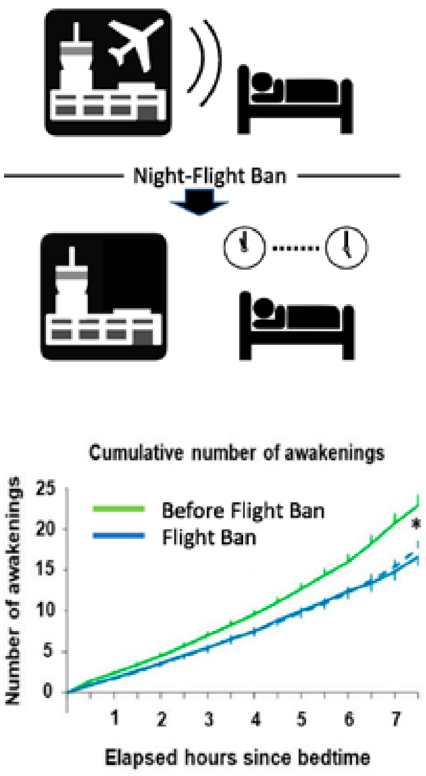

Figure 5: Night-flight ban decreases the cumulative number of aircraft noise associated awakenings

Effectiveness of a six-hour night-flight ban to preserve sleep in airport residents

Mobility demands often conflict with the need of people living near airports for peace and quiet especially in the evening and at night. The World Health Organization (WHO) has identified nightly traffic noise as a considerable health burden, and advocated effectiveness testing of real-world noise mitigation strategies. One such mitigation strategy could be the implementation of a night flight ban. However, the increased traffic density around the curfew might minimize its protective value.

We showed that the implementation of a six hours night-flight ban between 23:00 h and 5:00 h at Frankfurt Airport, indeed, decreased the number of aircraft noise events and the number of awakenings without causing residents' disturbance to fall asleep in the evening or stay asleep in the morning, i.e., during the so-called shoulder hours with increased traffic density. We also derived an exposure-response function for aircraft-noise associated awakening probability that has been applied to inform noise mitigation protocols at airports.

Road traffic noise impacts sleep in suburban residents

While prior work has focused mainly on the impact of aircraft and railway noise on sleep, we conducted a field study to establish an exposure-response relationship for the awakening probability due to intermittent road traffic noise in suburban residents. We showed that awakening probability increased with the maximum sound pressure level, the slope of the increasing sound pressure level of a vehicle pass-by, and age of exposed individuals. Compared to sleep stage 2, awakening probability was higher during rapid eye movement sleep (REMS) and lower during slow wave sleep. The protective effect of, both, stage 2 and slow wave sleep against awakenings decreased with age, whereas no age-dependent change was observed for REMS. These established physiological exposure-response functions will guide the development of a concept to protect residents from intermittent road traffic noise at night.

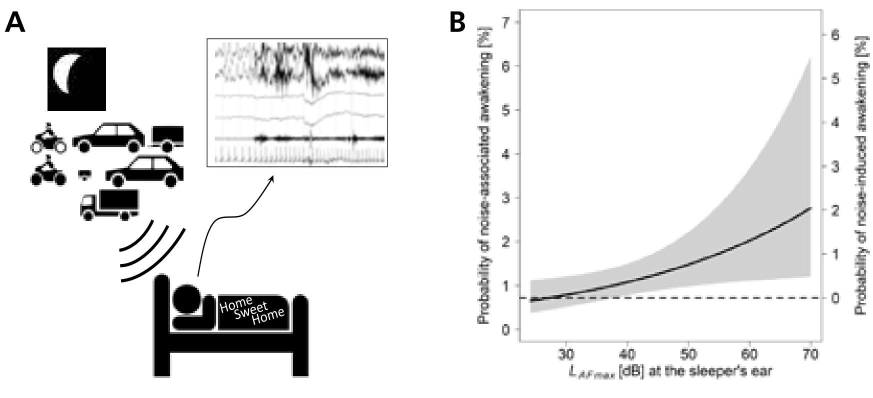

Figure 6: A: Recording of nocturnal vehicle pass-by associated awakenings in suburban residents using polysomnography. B: Exposure-response function of road traffic noise associated awakenings in suburban residents. Point estimates (black line), 95% confidence intervals (grey areas), and spontaneous awakening probability (dashed horizontal line) are shown.

Collaboration partners within the Institute

- Dept. of Aerospace Psychology
- Dept. of Cardiovascular Aerospace Medicine
- Dept. of Clinical Aerospace Medicine
- Dept. of Metabolism and Human Performance
- Study team

Collaboration partners within the DLR

- Institute of Aerodynamics and Flow Technology
- Institute of Flight Guidance
- Institute of Flight Systems
- Institute of Air Transport and Airport Research

Collaboration partners in Germany

- Fraunhofer Institute for Digital Media Technology (IDMT)
- Forschungszentrum Jülich
- Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)
- Universität zu Köln
- Universität Bonn
- ZEUS GmbH

Collaboration partners worldwide

- Anotec Engineering, Spain
- Budapest University of Technology and Economics (BME), Hungary
- Centre for Human Drug Research (CHDR), The Netherlands
- CY Cergy Paris Université, France
- Environnons, France
- Finnish Institute of Occupational Health, Finland
- Harvard Medical School, USA
- Manchester Metropolitan University, United Kingdom
- NASA Ames Research Center Fatigue Countermeasures Laboratory, USA
- Royal Netherlands Aerospace Center, The Netherlands
- Stockholm University, Sweden
- University of Pennsylvania, USA
- University of Zurich, Switzerland

Publications

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OVHD
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VIDEO
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SQUARE

II.3
Clinical Aerospace Medicine

Prof. Dr. med. Claudia Stern (Head)

Dr. med. Martin Trammer (Deputy)

Mission Goal

The Department of Clinical Aerospace Medicine is responsible for medical qualification and individual health maintenance strategies in aviation, spaceflight, and other occupational settings. We primarily target private and professional pilots, aircrew members, astronauts as well as personnel in the other fields of aerospace, air traffic control, and transportation. We apply our experience in medical qualification examinations supporting the Institute's departments in selecting test subjects for various clinical and physiological investigations. One key factor for flight safety is a healthy and well-trained cockpit and cabin crew. A central component of this process is the medical qualification examination according to national and international requirements. We translate our findings to other occupational settings like spaceflight, terrestrial medicine, scientific research, traffic and transportation. We also serve as the occupational health service for DLR sites in the Western region (> 3.800 employees), all new DLR Institutes without an occupational health service and DLR residencies abroad (Brussels, Paris, Tokyo and Washington D.C.). We are certified for medical specialist training in occupational health and are responsible for all hygiene-related topics. Our overall goal is to support aerospace safety and maintain the health of aerospace personnel during their working life time. To attain this goal, we closely collaborate with the Institute's research departments to foster the translation of science to applications in aerospace medicine.

Clinical Aerospace Medicine

Unique selling points of the department

Aeromedical Center (AeMC), one of five in Germany

High altitude physiology advice and training, certification, high altitude simulation chamber

Selection, certification and follow-up examination of all European astronauts until retirement and beyond

Clinical data collection in astronauts returning from space (Direct Return)

Advising and on-site support during astronaut training

In-flight advice in medical experiments and health related questions via console operation

Leading aerospace ophthalmologist

Only ophthalmological team with knowledge and experience in eye changes in astronauts and in head-down tilt bed rest research studies

Occupational Health Service for DLR sites in the western region

Engineering, bioastronautics, machine learning, and human subjects research experience

The Department of Clinical Aerospace Medicine specializes in medical qualification and preventive health care of flying personnel to improve flight safety. A key factor is a healthy and well-trained cockpit and cabin crew, for which the aeromedical fitness examination is crucial. We also support other professional groups with different tasks and responsibilities that contribute to flight safety, such as air traffic controllers and aircraft technicians. We are a recognized AeMC by the National Civil Aviation Authorities.
For the European Space Agency (ESA), we carry out selection tests and annual medical examinations and certifications of European astronauts, whom we also advise, support and treat medically. The department has a unique role in Europe in the care of European astronauts. Before, during and after space missions, we monitor the health and support the rehabilitation of the astronauts as well as support their families. Since 2014, European astronauts have been brought to :envihab immediately after landing (so-called "Direct Return"), where we evaluate their physiological responses to spaceflight and deliver tailored rehabilitation.
As an employer, DLR is responsible for providing occupational medical care for its approximately 11,000 employees. Our department manages the care of all DLR sites in the western region (Cologne-Porz, Cologne-Wahn, Sankt Augustin, Rheinbach, Bonn-Oberkassel with Uedem, Bonn, Jülich and Aachen). We look after over 3,800 employees and the associated locations. The Institute of Aerospace Medicine is recognized as a training center for physicians seeking specialist qualification in occupational medicine.
We advise the DLR and the Institute in hygiene topics, in particular for long-term bed rest studies and isolation studies. We provide the Institute's hygiene officer. We are researching eye changes in astronauts as part of the Spaceflight Associated Neuro-ocular Syndrome (SANS). In an ISS medical technology demonstration, we tested a mobile device and small, lightweight lens for monitoring SANS. This technology is relevant for deep space missions (e.g., Artemis and Gateway) with limited cargo capacity and remote guidance. We developed an app that enables untrained users, such as astronauts or clinicians in remote areas, to easliy identify the optic disc. By using artificial intelligence (AI), we also created a program that shows astronauts in real time whether they are affected by optic disc edema. We also diagnose optic disc edema in head down tilt bed rest studies, where it serves as critical biomarker for evaluating countermeasures.
Our overarching goal is to promote safety in aerospace and to maintain the health of personnel throughout their working lives.

Main projects 2021-2025

Retinal Diagnostics

On long duration ISS missions, over two-thirds of astronauts experience SANS, considered a likely and consequential risk for future human Mars missions. SANS often manifests as optic disc edema, which may herald increased intracranial pressure. On Earth, patients with suspected increased intracranial pressure are treated as emergencies. Possible SANS countermeasures are currently being tested in our head-down tilt bed rest studies with NASA and ESA, but no routine solution currently exists for ISS operations. Therefore, SANS symptoms are routinely monitored aboard ISS as part of medical operations. In the future, a diagnostic tool to detect SANS could inform the need for countermeasures.
In a prospective study, we conducted a technology demonstration to test the hypothesis that crew members aboard the ISS could perform ophthalmoscopy using mobile devices with minimal training and no ground support. We recruited crew members assigned to long duration missions (six months) aboard ISS. During their missions, they performed monthly ophthalmoscopy using their mobile devices. Our study demonstrates that mobile ophthalmoscopy aboard ISS is feasible with minimal training and without ground support. The findings inspired the design of real-time AI applications to help crew members automatically and independently diagnose SANS during their missions. Following the mission, we trained AI

Working Groups/Teams

Aeromedical Center | Dr. med Martin Trammer

- The DLR Aeromedical Center has been offering comprehensive medical care for flying personnel (cockpit/cabin crew/ air traffic controllers) over decades, starting with the initial examination, certified physician for patient information due to the federal genome diagnostic act (Gendiagnostikgesetz GenDG). In addition to aeromedical examinations (EASA/ FAA) this also includes vaccinations, individual preventive checks and occupational health care on request.

Aerospace Ophthalmology | Prof. Dr. med Claudia Stern

- Ophthalmological research and examinations of astronauts, aviation personnel and test subjects
- Retinal Diagnostics and AI in space and terrestrial brain damage
- Reduction of intraocular pressure through inverted head-down tilt bed rest

Occupational Medicine | Peter Tuschy

- Prevention and managing health of DLR staff and test subjects, medical specialist training in occupational medicine
- Responsible physician for hygiene related topics
- Certified physician for patient information due to the federal genome diagnostic act (Gendiagnostikgesetz GenDG)

models to help crew members automatically locate and diagnose the optic disc as normal or affected by edema. We prototyped a user-friendly mobile application to make these models accessible for terrestrial applications supporting ocular health in remote regions without Internet or specialist clinicians e.g. emergency medicine. We also developed new, device agnostic lens hardware for future space or commercial applications.

As a result of this research, several institutions approached us for future projects. The European Knowledge Center (EKC) in Hungary has purchased our technology and services for integration during their commercial Axiom space missions to help monitor short-term ocular changes. NASA has shown interest to integrate the Retinal Diagnostics device into their Moon and Mars program. The Humans In Space Challenge has preliminarily awarded us a future space launch opportunity in exchange for a commercial partnership (pending legal agreements). We are in contact with additional companies for future technology transfer partnerships. The Helmholtz Information and Data Science Academy (HIDA) awarded us external research staff funding, which supported development of further AI tools for optic disc edema detection from optical coherence tomography (OCT).

European Astronaut Selection

In 2009, we conducted, together with MEDES in Toulouse, the medical part of the European Astronaut Selection. 8413 Europeans applied, 15,5% were women. Finally, Samantha Christoforetti, Alexander Gerst, Andreas Mogensen, Luca Parmitano, Timothy Peake and Thomas Pesquet were nominated as European astronauts, Matthias Maurer followed a few years later.

In 2021, the European Space Agency published a vacancy for four to six career astronauts and additional reserve astronauts (Figure 1). For the first time, applicants with disabilities such as a lower limb deficiency and/or height below 130 cm were considered for parastronaut selection. 22.589 Europeans applied.

Figure 1: The ESA astronaut class of 2022, who we medically selected together with MEDES

Following a comprehensive screening phase, 1361 applicants (530 female), entered the first psychological phase, completing basic knowledge tests, cognitive performance tests, and personality questionnaires. About 400 applicants progressed to further psychological examinations. Fewer than 100 applicants were invited to the medical selection phase and additional interviews, which took place in Cologne and Toulouse from May to September 2022. Applicants were examined across anthropometry, dentistry, dermatology, gynecology, internal medicine, neurology, ophthalmology, orthopedics, otolaryngology, psychiatry, and urology.
The standard medical requirements are set by all Space Agencies represented on the International Space Station (Canadian Space Agency, European Space Agency, JAXA, NASA and Roscosmos). The requirements ensure that astronauts are medically fit to successfully complete training and multiple missions without endangering themselves, other astronauts, or the mission.

From space to Earth – Head-up tilt sleeping lowers intraocular pressure in patients with glaucoma

Elevated intraocular pressure is the hallmark of glaucoma, a leading cause of blindness worldwide. Intraocular pressure responds to gravity, and astronauts often experience increased intraocular pressure during the initial phase of space missions. The microgravity analogue head-down tilt bed rest also increases intraocular pressure. In a controlled, prospective study, we tested the hypothesis that head-up tilting the entire bed by 10° during the night could reduce intraocular pressure in patients with glaucoma (Figure 2). We recruited 16 patients with difficult-to-control glaucoma including a nocturnal increase of intraocular pressure from the patient pool at the Department of Ophthalmology of the University Hospital Cologne. In a cross-over design, we assigned patients to two groups: Group A remained in a flat, horizontal position throughout the first night, followed by 10° head-up tilt of the whole body throughout the second night; In group B, nocturnal positions were reversed. Our study demonstrated that sleeping in a 10° head-up tilt position attenuates nocturnal intraocular pressure in patients with glaucoma. The finding highlights the importance of gravity in intraocular pressure regulation and may have practical applications for ocular health in astronauts and in patients on Earth.

Figure 2: 10° head-up tilting can reduce intraocular pressure

Collaboration partners within the Institute

- Dept. of Aerospace Psychology
- Dept. of Applied Aerospace Biology
- Dept. of Cardiovascular Aerospace Medicine
- Dept. of Metabolism and Human Performance
- Dept. of Radiation Biology
- Dept. of Sleep and Human Factors Research
- Study Team

Collaboration partners within the DLR

- Flight Operations
- Institute of Solar Research
- Safety Department
- Technology Transfer and Innovation

Collaboration partners in Germany

- Bundesaufsichtsamt für Flugsicherung (BAF)
- Deutsche Flugsicherung (DFS)
- European Astronaut Center (EAC)
- European Wind Tunnel
- German airlines (Lufthansa, Eurowings, TUI)
- German Social Accident Insurance Institution for Commercial Transport
- Helmholtz Information and Data Science (HIDA) Academy
- Heine Optotechnik
- Hospital Cologne Porz
- Landes- und Bundespolizei
- Luftfahrt-Bundesamt (LBA)
- Luftwaffe
- Postal Logistics and Telecommunication (BG Verkehr)
- Technische Universität Braunschweig
- Universität der Bundeswehr
- Universitäts-Augenklinik Bonn
- Universitäts-Augenklinik Köln
- Universitäts-Augenklinik Wuppertal
- Verkehrsministerium

Collaboration partners worldwide

- All international space agencies (ESA, NASA, Roskosmos, JAXA, CSA)
- Austrian Space Forum
- Axiom Space
- European airlines (Star Air, Ryanair, Easyjet, Cargolux)
- European Aviation Safety Agency (EASA)
- European Knowledge Center
- European Society of Aerospace Medicine
- Federal Aviation Administration (FAA)
- Humans In Space (Boryung)
- International Space University (ISU)
- SpaceMed

Publications

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GREAT MASTERS BRITAIN
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ITALIA

II.4
Metabolism and Human Performance

Prof. Dr. Dominik Pesta (Acting Head)

Dr. oec. troph. Petra Frings-Meuthen (Acting Deputy)

Mission Goal

Humans have evolved as a species uniquely capable of long-lasting physical performance. Conversely, physical inactivity leads to deconditioning, metabolic impairments and compromised health. The Department of Metabolism and Human Performance investigates the impact of physical activity and inactivity under mission-relevant environmental conditions such as microgravity, altered atmospheres, circadian disruption, and space radiation. Our research also considers genetic predisposition, metabolic disorders, muscle degeneration and the ageing process. Additional investigations on muscle and bone biomechanics and mechanophysiology is essential to understanding physiological effects of muscle contractions and exercise.

Our goals are the prevention and rehabilitation of inactivity- and immobilization-related musculoskeletal disorders and preservation of muscle function throughout the entire lifespan. Therefore, we develop efficient measures to counteract muscle and bone atrophy and metabolic derailments in space and on Earth. Our efforts span all levels of biological organization – from cellular mechanisms and tissue dynamics to whole-body physiological responses. This work is complemented by research into skeletal muscle metabolism and its systemic interactions with other organs. By combining this knowledge with genetic model systems, we aim to develop novel exercise and other countermeasures optimized for space and specific terrestrial applications.

Metabolism and Human Performance

Unique selling points of the department

We study immobilization-related problems of the musculoskeletal system from bench to bedside. Our approach encompasses genetic, mechanic, metabolic, radiation-related, and functional aspects – across different populations including astronauts, patients, and older adults.

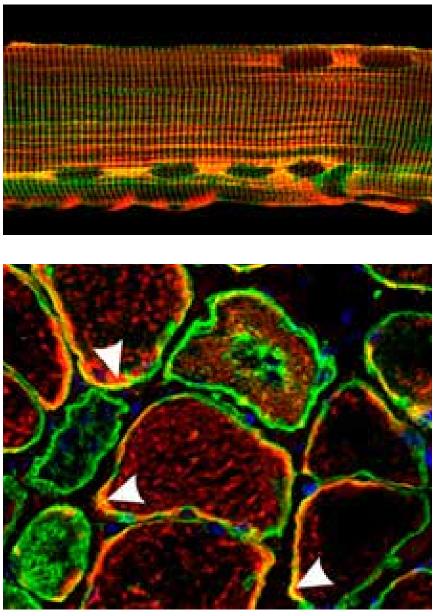

Figure 1: Aberrant subcellular distribution of mitochondria as well as presence of desmin intermediate filament pathology shown by COX IV and desmin immunofluorescence analysis of R349P desmin knock-in mice. Note the markedly reduced sarcoplasmic COX IV signal in multiple homozygous muscle fibers, and the presence of small subsarcolemmal and sarcoplasmic desmin protein aggregates (modified from Winter and Wittig et al., Acta Neuropathol, 2016).

Muscle wasting impacts on muscle metabolism
Muscle function and mass decline when muscles are underutilized, leading to metabolic disruptions with systemic consequences. Inactivity and inadequate muscle training contribute to metabolic disorders such as type-2 diabetes, which in turn impairs muscle health. Subsequent deteriorations in metabolic flexibility, muscle function, and muscle regeneration diminish quality of life while increasing the risk of premature mortality. Here, we aim to better understand the link between metabolic disorders and impaired muscle health, with the goal of preserving muscle function throughout the lifespan, both, in space and on Earth.

Muscle wasting impacts on muscle mechanics
Muscle's stress-strain behavior constitutes the foundation for its mechanical output, i force, power and elastic stiffness. We develop and validate mechanical models to understand these principles. For example, we recently elucidated the determinants of fascicle curvature and assessed contraction-generated muscular stress effects on muscle perfusion, including how these mechanisms are affected by bed rest.

Insights from genetic diseases
At the molecular level, we investigate muscle tissue and cells, comparing results from patients with desminopathy and filaminopathy and corresponding mouse models. We subject these mice to physical exercise and treatment with small-molecule drugs, while exposing derived tissues and cells to electrical pulse stimulation, hypoxic conditions, or space-like radiation. Samples are then analysed morphologically, biochemically, and genetically. To date, our work has deciphered a complex pattern of early and late pathological changes in the diseased muscle and demonstrated a disease-promoting effect of strenuous exercise.
At the functional level, we study patients with abnormal intramuscular connective tissue, including Ehlers-Danlos syndrome hyperflexibility-spectrum disorder and cerebral palsy.

Countermeasure development for space
Long-duration spaceflight is associated with a significant decline in astronaut fitness, making it a mission-critical issue. Studies have highlighted parallels between spaceflight effects, sedentary lifestyles, and aging. As a result, there is a growing need for innovative training concepts to maintain human fitness under challenging conditions, while improving our understanding of the underlying adaptive processes in space and on Earth. We are developing and evaluating a diverse range of technologies, from compact systems designed for deep space missions to ground-based training using human centrifuges.

Clinical spin-off
Countermeasure exercise can mitigate numerous disorders, including cancer, type-2 diabetes, and heart failure. However, acceptability and feasibility often limit implementation in clinical practice. To overcome these barriers, we have studied the circadian effects of training in type-2 diabetes, the acceptability and feasibility of resistance training in nursing homes, and the feasibility of muscle testing in pediatric patients with cerebral palsy.

Main projects 2021-2025
Intramuscular fat accumulation in space and on Earth
Intramuscular fat accumulation is a hallmark of metabolic disorders and aging, contributing to metabolic dysfunction and impaired muscle function. This process significantly affects quality of life and overall well-being. Recent research from our department on sprint-trained master athletes demonstrates their ability to decrease age-related increases in intramuscular fat by 50%, highlighting the crucial role of lifelong exercise in mitigating fat accumulation. We further find that it is not just the total amount of intramuscular fat, but its subcellular distribution that matters. Athletes show higher levels of bioactive lipids in their muscles,

Working Group

Translational Metabolic Research | Prof. Dr. Dominik Pesta

- Clinical and translational aspects of energy metabolism, tissue-specific mitochondrial function, euglycemic-hyperinsulinemic clamp test, biosample management
- Non-invasive metabolic imaging of muscle and liver metabolism and advanced in vivo imaging for body composition assessment

Team

Training and Countermeasures | Dr. rer. biol. hum. Timo Frett

- Studies on the effect of altered gravity conditions (e.g. short-arm centrifugation) on performance and trainability, development of training countermeasures

which are sequestered into the mitochondrial compartment. This targeted localization may prevent insulin signaling inhibition, explaining the superior metabolic efficiency observed in trained individuals.
At the other end of the spectrum, mitochondrial dysfunction – exemplified by pathologies such as desminopathy, results in muscle weakness and degeneration – further impairing muscle health and systemic metabolism. A 30-day bed rest study simulating extreme inactivity revealed sex-specific differences in fat accumulation, with women showing more pronounced intramuscular fat increases than men. Further research will explore whether men compensate by accumulating ectopic fat in other organs, like the liver, leading to different but equally harmful outcomes.
We also showed that lipids accumulate not only inside muscle cells but also outside, as extramyocellular fat. This fat likely exerts distinct metabolic effects compared to intracellular fat, highlighting the complexity of fat accumulation in muscle tissue and its role in insulin resistance and muscle dysfunction.
In the MuscleDiab study we further investigate the link between metabolic dysfunction and muscle health. We aim to uncover mechanisms linking fat accumulation to muscle function decline and impaired recovery, considering factors like fat location, sex, and physical activity. In this way, we aim to develop personalized strategies to preserve muscle health and metabolic function throughout life, in space and on Earth.
In a large cohort study with 3.85 million persons of Baden-Württemberg we analyzed the health effects of environmental stressors such as temperature, precipitation, and air pollution on influenza incidence using Earth observation data. The results showed that both low ambient temperature and increased particulate matter were strongly associated with higher influenza rates, highlighting the value of satellite-based environmental monitoring for public health applications.

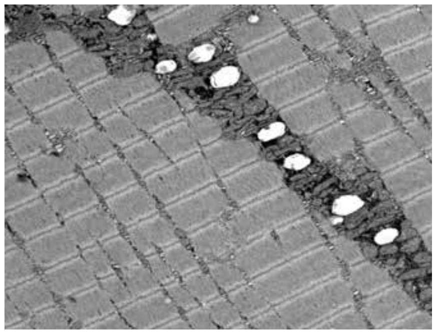

Figure 2: Regular sarcomere structure with clearly visible Z-lines, A-bands, and I-bands. Mitochondria (dark structures) are densely clustered in the intermyofibrillar space, and lipid droplets (bright white spherical inclusions) are visible between the contractile elements. This high-resolution image illustrates the ultrastructural organization relevant for energy metabolism and muscle performance. (modified from Pesta et al., Sci Adv, 2025).

Molecular muscle studies

To better understand the effects skeletal muscle pathologies and countermeasures, we use human skeletal muscle biopsy specimens, animal models such as desminopathy mice, explanted murine muscles and derived cultured muscle cells. In human soleus muscle, we found that the amount of intramuscular connective tissue increased with power training only in young study participants. In murine soleus muscle, acute treadmill exercise and the expression of mutated desmin caused increased densities of focal myofibrillar damage. Eccentric and high-intensity physical activity may, therefore, promote disease progression in patients with desminopathy. Combined morphological, transcriptomic and proteomic analyses helped decipher the complex pattern of early pathological changes induced by mutated desmin in murine skeletal muscle tissue. In muscle cells and tissue, mutated desmin altered the abundance of proteins related to the cytoskeleton, extracellular matrix, protein quality control and mitochondrial energy metabolism. In desminopathy mouse myotubes, long-term electrical pulse stimulation augmented characteristic myofibrillar irregularities.
As a next step, we will analyse muscle biopsy specimens from human bed rest studies and compare the results with the findings in mice to identify patterns, early changes and mechanisms common to muscle inactivity-induced deconditioning and genetically determined degeneration, and to evaluate and optimize the efficacy of countermeasures and treatments.

Artificial gravity & exercise

On Earth, maintaining human health depends on regular exercise, but replicating this crucial stimulus in space remains a significant challenge. In the future, this challenge could be addressed by combining artificial gravity via short-arm centrifugation with targeted exercise regimens.

Previous studies demonstrated the feasibility and acceptability of artificial gravity as a countermeasure. Moreover, our findings suggest that exercise performed under artificial gravity exerts beneficial effects at both the cellular and whole-body levels. We systematically investigated exercises such as squatting, plyometric training, trunk and back exercises, and high-intensity rowing ergometry during centrifugation. All exercises were well tolerated, with either no or negligible motion sickness symptoms. Notably, artificial gravity not only provided an equivalent stimulus for some exercises (e.g., trunk and back training) but also enhanced cardiovascular and muscular activation in others, such as rowing. These results suggest that physical training under artificial gravity, induced by centrifugation, could serve as an effective strategy to maintain—and potentially even improve—fitness in space.

Based on these results, we are now conducting a 12-week resistance training study comparing short-arm human centrifuge-based exercise with traditional resistance training. We hypothesize that the combination of resistance training with artificial gravity will provide a potent hypertrophic stimulus, potentially surpassing the effectiveness of conventional resistance training.

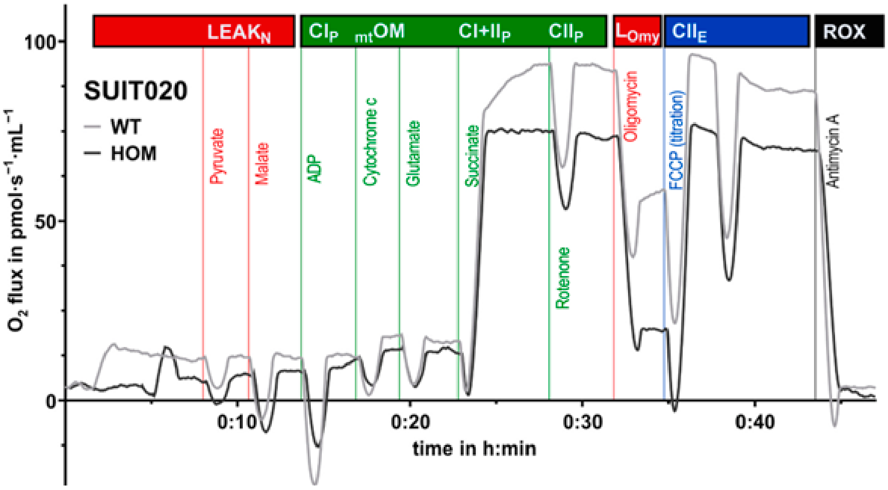

Figure 3: Analysis of mitochondrial function of intact mitochondria isolated from homozygous R349P desminopathy and wild-type murine myotubes. The traces shown were obtained using specific substrate-uncouple-inhibitor protocols and were normalised to total protein content of the mitochondrial suspension used. Note the significantly reduced proton leak (L_{Omy}, $p=0.03$) in the mitochondria of the homozygous myotubes (modified from Berwanger and Terres et al., Eur J Cell Biol, 2024).

Novel exercisers for missions to Moon and Mars

In collaboration with ESA and Space Applications Systems (SAS), we have developed and validated two prototypes for gravity-independent training of the leg and back muscles. In addition to conventional resistance training, they offer novel training principles that are highly relevant for space. Thus, both ATHLETIC and Nex4Ex allow for plyometric exercises, which are effective to prevent immobilisation-induced muscle and bone loss. Nex4Ex, in which the company Anybody and the University of Konstanz were also involved, enables sensorimotor training of muscle reflexes that are needed to stabilize posture and balance when standing.

On both devices, the user works against a constant force mechanism during strength or jump training. After setting an individualized training force, the exercisers can then work purely passively, i.e. without power consumption and with negligible heat generation. These features make them ideal for human missions into deep space.

We have tested both prototypes, and are now elaborating on their further refinement. Thus, we plan to improve details of the human-machine interface, especially for the coordinatively demanding jump training as well as test instructions for users.

Figure 4: Prototype of a gravity-independent training device for the leg and back muscles offering novel training modalities such plyometric exercises, which are highly relevant for space.

Novel training approach for rehabilitation

For countermeasures to succeed, they must be acceptable, feasible, and effective—yet no stringent solutions currently exist for spaceflight, bed rest, or clinical rehabilitation. We have therefore exploited our experiences from structured scientific training programs and from pediatric rehabilitation medicine to develop an algorithmic approach to deliver resistive exercise in nursing homes. We do this in collaboration with a companies that run nursing homes in Europe. A first study has validated acceptability and feasibility of our novel approach in the setting of nursing homes. Next, we have devised a course and a brochure that we are using to educate and train nursing home staff, so that they can administer the resistive training to nursing home residents. Moreover, we are currently performing a market and business study, so that we can better understand the needs and limitations of future customers outside the nursing home branch.

Collaboration partners within the Institute

- Dept. of Applied Biology
- Dept. of Cardiovascular Aerospace Medicine
- Dept. of Clinical Aerospace Medicine
- Dept. of Radiation Biology
- Dept. of Sleep and Human Factors Research
- Study Team

Collaboration partners within the DLR

- German Remote Sensing Data Center (DFD)
- Institute for Software Technology
- Institute for Frontier Materials on Earth and in Space

Collaboration partners in Germany

- AOK Baden Württemberg
- Cologne Excellence Cluster for Aging and Aging-Associated Diseases (CECAD)
- Eberhard Karls Universität Tübingen
- FH Aachen – University of Applied Sciences
- Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)
- German Diabetes Center Düsseldorf
- German Sports University Cologne
- Universitätsmedizin Greifswald
- Universität zu Köln
- Universität Konstanz

Collaboration partners worldwide

- Manchester Metropolitan University, United Kingdom
- Northumbria University, United Kingdom
- Space Application Services, Belgium
- University of Bologna, Italy
- University of Graz, Austria
- University of Milan, Italy
- University of Padova, Italy
- University of Pavia, Italy
- University of Sasketchewan, Canada
- University of Texas, Austin, USA

Publications

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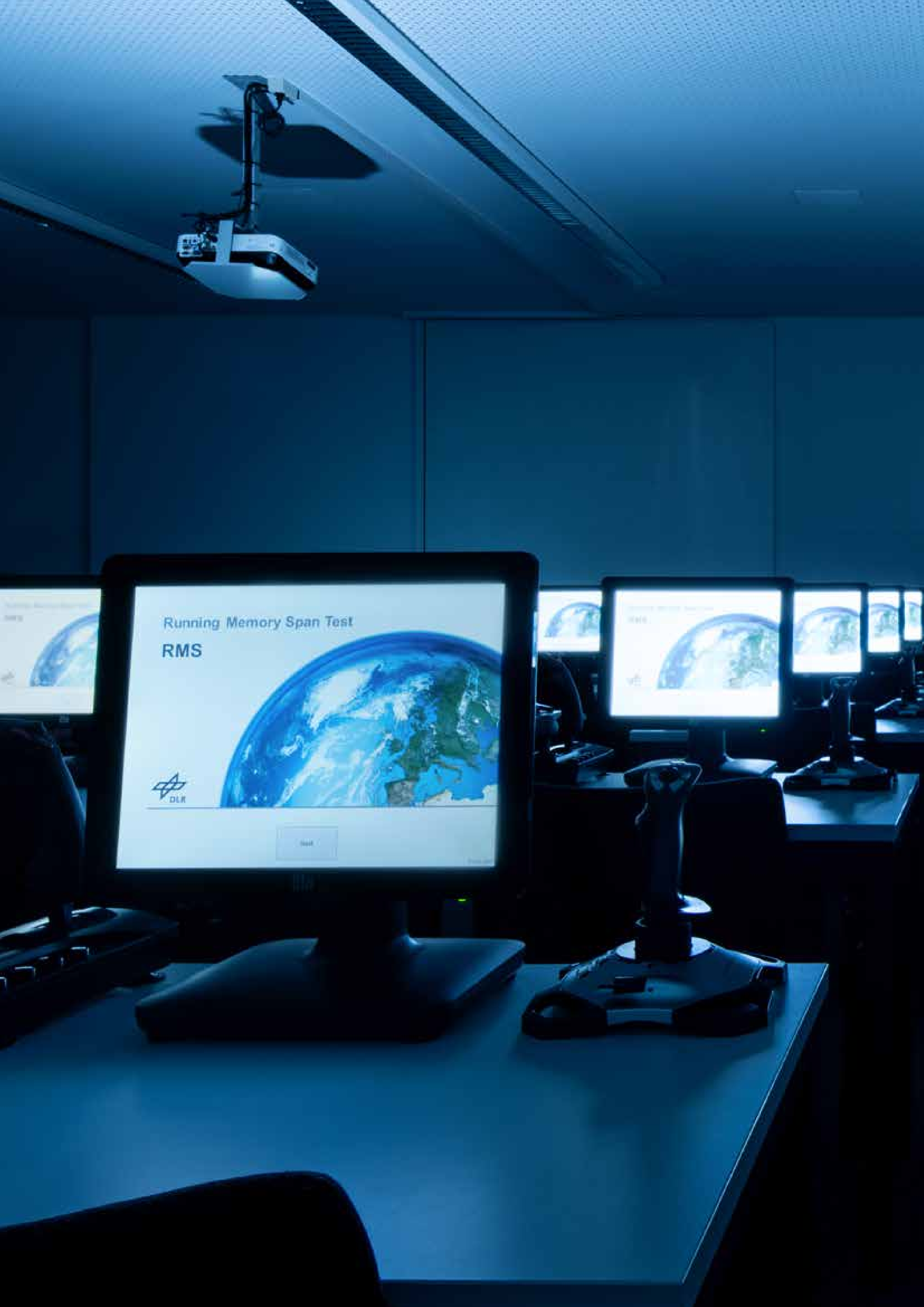

Running Memory Span Test
RMS
DLR

II.5
Aerospace Psychology

Prof. Dr. phil. Katharina Utesch (Head since 2024)

Dr. phil. Dipl.-Psych. Viktor Oubaid (Deputy head; Acting head 2022-2024)

Mission Goal
Pilots, air traffic controllers, astronauts, and other skilled professionals are vital to aerospace safety. While effective decision-making and collaboration with technology improve system reliability, human error remains a leading cause of incidents in aviation and space. Across our decades of research experience, we continuously aim to understand these factors, improve human-machine interfaces, and enhance safety by refining personnel selection, training, and deployment. The Department of Aerospace Psychology has a twofold mission:

1. Personnel Selection: We develop and validate systems to ensure the right individuals are selected for critical roles, improving safety and performance across the aerospace industry.
2. Human Factors Research: We study human factors in aviation, spaceflight, and air traffic management, focusing on how human-machine interactions and teamwork can enhance safety, performance, and well-being. We aim to reduce barriers to the adoption of emerging technologies for smoother integration.

As part of DLR, we embrace our societal responsibility. In aeronautics, space, transport, and security, we address key challenges like transport transitions and security structures. Collaborating with research and industry partners, we drive innovations in human factors. Our work supports Flightpath 2050's goal of reducing aviation accidents by 80%, while enhancing performance, well-being, reducing training costs, and contributing to economic growth.

Aerospace Psychology

Unique selling points of the department

Unrivalled intensive cooperation with the aerospace industry for over 70 years

Setting global standards in aerospace psychology by applying extensive expertise in conducting over 10,000 psychological evaluations annually for airline pilots, air traffic controllers, and astronauts, with the entire selection process being ISO 9000 certified since 2002 to meet the highest quality standards in the aviation industry

Leveraging extensive expertise in human factors and assessment research within the aerospace sector

Contributing significantly to safety, performance, well-being, and economic efficiency in the industry

Our department's research program is embedded within the DLR research fields of aeronautics, space, transport, and safety. We maintain a strong track record of third-party funded projects, working closely with airlines, air traffic control, and space agencies worldwide, as well as in scientific collaborations with universities and research institutions. Our efforts cover a broad variety of relevant topics:

Psychological requirements & human performance
New technologies and automation will continue to reshape the requirements of aviation operators and influence the broader socioeconomic landscape. We conduct in-depth research to understand the specific demands of roles such as pilots, air traffic controllers, Unmanned Aircraft System (UAS) operators, astronauts, and other operational professionals. We also analyze the impact of system changes, like remote tower control, single pilot operation, and socio-economic shifts, ensuring ongoing operational effectiveness and stable human performance.

Selection & training of aerospace operators
We develop, validate, and adapt selection and training methods for pilots, air traffic controllers, UAS operators, astronauts, and other operational professionals based on job-specific requirement analyses, ensuring they meet the evolving demands of the global aviation and space flight industry. and beyond Our leadership in UAS human factors provides a competitive advantage in this rapidly growing segment. Additionally, we explore innovative methods, such as eye-gaze analysis and virtual reality simulations, to enhance the precision of operator selection, assessment, and training.

Human factors & human-machine interaction
We study human factors in aviation to improve safety, efficiency, and the interaction between operators and technology. As Artificial Intelligence (AI) becomes more prevalent in aviation, we investigate how AI systems can be integrated to ensure effective human-machine collaboration. Our goal is to enhance human and system performance jointly, maintaining – or even improving – operational effectiveness.

Passenger comfort & acceptance of new technologies
New cabin concepts in air and rail travel, alongside emerging technologies, must be tested for passenger and public acceptance. We study passengers' responses to these innovations, as acceptance is essential for growing tourism and business travel. Technological advances bring new challenges, so understanding passenger reactions is crucial to successfully integrating these innovations into modern travel experiences.

Main projects 2021-2025
Psychological selection of pilots, air traffic controllers, and astronauts
We develop, refine, and validate advanced selection and training methods for pilots, air traffic controllers, UAS operators, and astronauts tailored to the evolving of aviation and space flight industries. By aligning our assessment processes with the latest job-specific requirement analyses, we ensure these procedures identify operators who can handle the complexities of their roles. Our multimethodological, multistep selection procedures consider cognitive and psychomotor performance, knowledge, social skills, and critical personality traits. We validate these selection procedures to ensure that only the most suitable candidates are identified and can reliably perform in high-stakes, safety-critical roles. Our focus is on objectivity, reliability, predictive validity, as well as on norms, fairness, transparency, and efficiency. We evaluate both, individual assessment instruments and overall selection processes to identify areas for refinement. As in 2008/2009, we successful carried out the ESA astronaut selection in 2021/2022. Assessing almost 1,500 candidates in just a few months despite the COVID-19 pandemic, thanks to our standardized and robust assessment process.

Working Groups/Teams

Air Traffic Control | Dr. phil. Yvonne Pecena & Dr. phil. Hinnerk Eißfeld, until 05/2022
- Job requirement analyses of air traffic controllers and UAS operators
- Selection of air traffic controllers as well as development and validation of diagnostic methods
- Inter team cooperation
- Eye tracking methods
- Urban air mobility and acceptance of aviation systems

Crew Performance and Transport | Prof. Dr. phil. Dirk Stelling
- Job requirement analyses of pilots, astronauts, and other operational professionals
- Selection of airline pilots as well as development and validation of diagnostic methods
- Development and validation of diagnostic methods
- Cabin comfort
- Virtual reality
- Selection of bed rest candidates

Space Psychology | Prof. Dr. phil. Katharina Utesch & Dr. phil. Dipl. Psych. Viktor Oubaid
- Isolation and bed rest research for long term space missions

Research on the reliability of aviation personnel
Repeated cognitive assessments often lead to score improvements, especially when test preparation is provided. In personnel selection, these gains are amplified by commercial test preparation, raising fairness concerns. In our study, we offered free computer-based training to all candidates. Analysis of 212 candidates showed cognitive scores were influenced by prior training during the first assessment but not during the second. Retest effects persisted, with score gains negatively correlated with initial training and unrelated to training between assessments. However, changes in training amount were positively correlated with retest effects. We conclude that offering preparatory training before the first assessment significantly enhances fairness in the selection process.

VALIS: Validating Air Traffic Controller (ATCO) Selection and Training
The role of an ATCO is demanding, requiring the management of aircraft in complex airspace while maintaining strict safety standards. Selecting suitable personnel involves adapting cognitive as well as intrapersonal and interpersonal requirements for the position. Our ab initio ATCOs selection process follows a multi-phase procedure, starting with cognitive tests and ending with an interview, certified under DIN EN ISO 9001:2015. The VALIS project validated the quality and predictive validity of this process, confirming its effectiveness in forecasting training success and suggesting opportunities for further refinement and automation. In 2024, we received the "Best Paper Award" at the European Association for Aviation Psychology (EAAP) conference.

Psychological requirements and human factors in future aviation
Technological advances and automation will continue to reshape aviation operator roles and the broader socio-economic landscape. We study how changing demands affect pilots (Figure 1), air traffic controllers, UAS operators, and astronauts, considering factors like remote tower control, single pilot operations, adaptive automation, and AI integration. We also examine socio-economic shifts, including a shrinking applicant pool. Our research addresses explainability, trust, and demands on personnel in future operational environments.

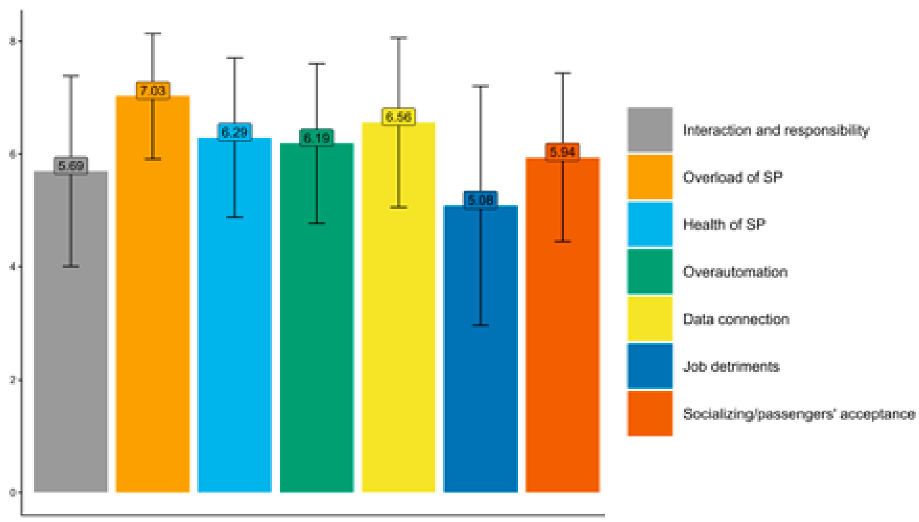

Figure 1: Pilots' initial views on single pilot operation in 7 areas of relevance (SP = single pilot; y-axis: 1 = no problem to 8 = very severe/serious problem)

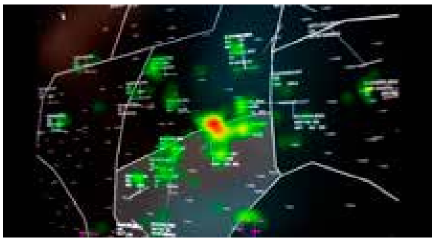

Figure 2: Expert view (of an experienced air traffic controller) as a heat map on a radar screen [Color-coded areas reflect duration of dwell time and fixation frequency in this area: red = long duration, high frequency, yellow = medium duration and frequency, green = short duration and low frequency]

Horizon UAM (Urban Air Mobility)

Unmanned aerial vehicles (UAVs), such as civilian drones, are advancing rapidly, making public acceptance crucial. Building on previous research, we conducted a telephone survey in Germany in 2022 to examine public attitudes towards civilian drones and air taxis. Results showed slightly more positive view of drones compared to earlier findings, while attitudes towards taxis remained more skeptical. Statistical analyses linked attitudes to factors like hands-on experience, noise sensitivity, and environmental concerns. Prediction models showed up to 71% accuracy, highlighting privacy concerns and animal welfare as the strongest predictors. These insights will guide future air mobility concepts.

Eye gaze and virtual reality research

Our eye-tracking research explores visual processes related to monitoring performance, aiming to identify eye movement parameters that differentiate good from poor monitors, with applications in selection and training (Figure 2). We also use Virtual Reality to examine user performance and well-being during Virtual Reality interaction, particularly nausea symptoms. Additionaly, we apply Virtual Reality to study public acceptance of drone traffic.

Research on human factors in air traffic control

The role of air traffic controllers (ATCOs) is evolving, requiring them to oversee automated systems and intervene when issues arise. We explored potential benefits of using eye tracking in ATC training, developing a model to guide attention allocation during system malfunctions. One group of ATC novices received targeted training while a control group did not. We tracked eye movements to analyze attention distribution and training effectiveness.

Psychological aspects of human-AI collaboration

Our research supports aviation's digital transformation by developing trustworthy, transparent, and explainable AI systems for effective human-AI teaming. We investigate AI-based classification of cognitive states such as attention, fatigue, and emotions and create guidelines for selecting and training operators for successful human-AI interactions and optimize the design of AI-supported work environments.
The Collaboration of Aviation Operations and AI Systems (LOKI) project, launched in 2022, focuses on air traffic management and the integration of AI systems with operators. LOKI examines how to ensure AI system acceptance, transparency, satisfaction, and predictability. The project develops prototypes of digital air traffic controllers, copilots, and human AI interfaces, to study human-machine collaboration. These systems integrate AI techniques to enhance decision-making. Key goals include ensuring operator control and transparent system information, supported by feedback from air traffic controllers and pilots gathered through workshops and validation experiments.

Figure 3: Individual heating elements for a local thermal comfort zone: Test person sitting on one of the equipped seats with two of the infrared elements visible in front of the test person. Sketch of the zones with infrared elements in dark red and seat heating elements in light red (Zierke et al., 2023).

Thermal passenger comfort

Thermal comfort is essential for increasing rail transport's attractiveness. We designed experiments to compare novel low-momentum ventilation concepts with conventional systems, finding significant differences in perceived comfort that support using energy-efficient systems without sacrificing passenger comfort.

RoSTo: Rolling Stock

Personal control over indoor climate is known to improve thermal comfort, but its mechanisms remain unclear. In a long-distance train study with 84 participants under simulating winter conditions, we compared two scenarios: In one condition, participants could adjust their preferred temperature using infrared panels and seat heaters. In the second, their preferred settings were restored automatically (Figure 3). We observed no differences in perceived temperature, air draught, or thermal satisfaction, suggesting that the correct thermal settings mattered more than who controlled them.

Head-down tilt bed rest studies: Participant selection and research

Head-down tilt bed rest studies are an established model to simulate microgravity. We select suitable participants and analyze longitudinal affect and group dynamics during these studies to identify potential support strategies. Because personality is often overlooked, we studied traits predicting participant performance among 68 study participants. Generally, a variety of personality traits such perseverance, modesty, and social adaptation predicted performance, with emotional stability exhibiting the strongest link. Our findings offer insights into how personality affects performance for challenging and aversice contexts.

Collaboration partners within the Institute

- Dept. of Clinical Aerospace Medicine
- Dept. of Sleep and Human Factors Research
- Study Team

Collaboration partners within the DLR

- Institute of Aerodynamics and Flow Technology
- Institute of Flight Guidance
- Institute of Flight Systems
- Institute of System Architectures in Aeronautics

Collaboration partners in Germany

- Allgemeiner Deutscher Automobil Club (ADAC)
- German Armed Forces
- Deutsche Flugsicherung (German Air Traffic Control; 2022: 40th anniversary of our partnership)
- German Federal Police
- Hamburg University of Technology (TUHH)
- Industrie Design Studio
- Luftfahrtbundesamt (LBA)
- Technische Universität Dresden
- Universität Hamburg (UHH)
- Universität zu Lübeck

Collaboration partners worldwide

- European Union Aviation Safety Agency (EASA)
- European Space Agency (ESA)
- International Federation of Air Traffic Controllers' Associations (IFATCA)
- Lufthansa Group including European group airlines (Deutsche Lufthansa AG, Lufthansa CityLine, City Airlines, SWISS Airlines, Austrian Airlines, Air Dolomiti)
- Luxair
- Royal Jordanian Airlines
- Saudi Aramco
- Swiss Army
- Turkish Airlines

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NOT A STEP

II.6
Radiation Biology

Dr. techn. Thomas Berger

Mission Goal

As two sides of the same coin, radiation can be beneficial when used for tumor radiotherapy, but radiation exposure can also be harmful, triggering or contributing to carcinogenesis, genetic defects, degenerative diseases, or even acute radiation sickness. These detrimental effects make space radiation the major limiting factor for long-term space missions. Radiation exposure at aviation altitudes is monitored to protect health and safety, while natural and artificial radiation sources on Earth are also observed with concern. Therefore, the Radiation Biology department addresses the experimental and theoretical prerequisites needed to provide effective protection from ionizing and non-ionizing radiation in aviation and spaceflight. At the same time, we share findings from space radiobiological research to help answer questions relevant to tumor radiotherapy.

Radiation Biology

Unique selling points of the department

Radiation research with a focus on aerospace

Sophisticated technologies for application-oriented radiation protection in aviation and spaceflight

3D: design, development and deployment of space radiation detectors

Long-term experience with space radiation modeling and data evaluation

The Department of Radiation Biology deals with aerospace-related questions on the effects of radiation on humans. In addition to recording radiation exposure and developing radiation protection recommendations for astronauts and flying personnel, this includes investigating the effects of radiation on humans using suitable modelling systems, investigating protective mechanisms and factors that influence radiation sensitivity, and developing suitable countermeasures. Based on long-standing expertise in hardware development, radiation dosimetry and modeling, space and heavy ion accelerator experiments, and field and mechanistic studies, the department contributes to DLR's long-term goals to create physical and physiological knowledge to support astronauts' presence in space and to explore our solar system. The unique radiation fields at aviation altitudes and for different space mission scenarios are characterized using active and passive dosimetry and modeling to derive radiation exposure. New dosimeters are developed, tested, and operated in low Earth orbit (LEO) and on Moon missions. In addition, radiation protection guidelines and suitable countermeasures are developed. This challenging task requires the investigation of the biological effects of space radiation (especially heavy ions) and other environmental stressors (e.g. hypoxia) on different test systems at the cellular and molecular level in target organs, such as the brain. Depth-dependent dose distribution and a better understanding of the cellular radiation response and of protective mechanisms such as DNA repair are also vital to improving cancer radiotherapy. Human studies offer opportunities to study the variability of individual radiation sensitivity under space-relevant conditions.
The radiation environment in free space constitutes the most complex radiation environment humans can encounter. It consists of galactic cosmic radiation (GCR) with extremely high energies acting as the radiation background in space. Long-term exposure to GCR can lead to an increase in cancer risk. The Sun contributes to the radiation load due to sporadic solar particle events (SPE) whose probability of incident is higher during solar maximum conditions. High levels of highly energetic protons emitted during a SPE can lead to the Acute Radiation Syndrome (ARS) which needs to be avoided for astronauts traveling in free space. GCR and SPE impinge on Earth, which is protected by its magnetic field and atmosphere. Therefore, radiation exposure as for example on-board the ISS depends on the relevant orbit location of the space station. Additionally, the Earth's magnetic field traps radiation in the so-called Van Allen Belts. The ISS passes through the inner belt around 6-8 times a day thereby increasing the radiation load inside the ISS. When flying to the Moon, a spacecraft would also have to cross these belts. This all can be summarized as "radiation is everywhere, but it changes in relation to where humans will go". Therefore, it is immanent to quantify the radiation load in dependence on the relevant flight pass and generate scientific data to further enhance our knowledge of the radiation loads in dependence on location and time. This also to enable a safe long-term human space exploration.

Main projects 2021-2025

Does the South Atlantic Anomaly affect radiation exposure at flight altitudes?

The South Atlantic Anomaly is a geographical region over the south Atlantic Ocean where the inner Van Allen radiation belt extends down closer to Earth (Figure 1). This leads to increased ionizing radiation and impacts on spacecrafts in LEO, including increased astronaut exposure on the ISS. To identify and quantify any additional contributions to the omnipresent radiation exposure due to the galactic cosmic radiation at flight altitudes, we performed comprehensive measurements while crossing the South Atlantic Anomaly region at 13 km altitude during the unique Atlantic Kiss mission.
Atlantic Kiss took place on flight from Hamburg, Germany, to Mount Pleasant, Falkland Islands, UK overseas territory, in March 2021, during the transition between solar cycle 24 and 25 despite the worldwide SARS-CoV-2 pandemic crisis. Operational conditions were optimal since the entire geographical region of interest was crossed at 13 km altitude under

Working Groups/Teams

Biophysics | Dr. techn. Thomas Berger

- Space radiation dosimetry and modeling

Radiation Protection in Aviation | Dr. phil. nat. Matthias M. Meier (until 2021)

- Radiation effects in the atmosphere
- Development of products and services for the aviation industry and the society

Genome Maintenance Mechanisms | Prof. Dr. rer. nat. Boris Pfander (12/2021 – 08/2023), Dr. Özdemirhan Serçin (since 03/2025)

- Mechanisms of DNA replication and repair
- Radiation response mapping through high-throughput knock-out screening

Cellular Protection Mechanisms | PD Dr. Christine E. Hellweg, until 2025

- Biological effects of space-relevant radiation qualities
- Interindividual differences of DNA repair capacity
- Effects of hypoxia and hyperthermia on radiosensitivity of human cells

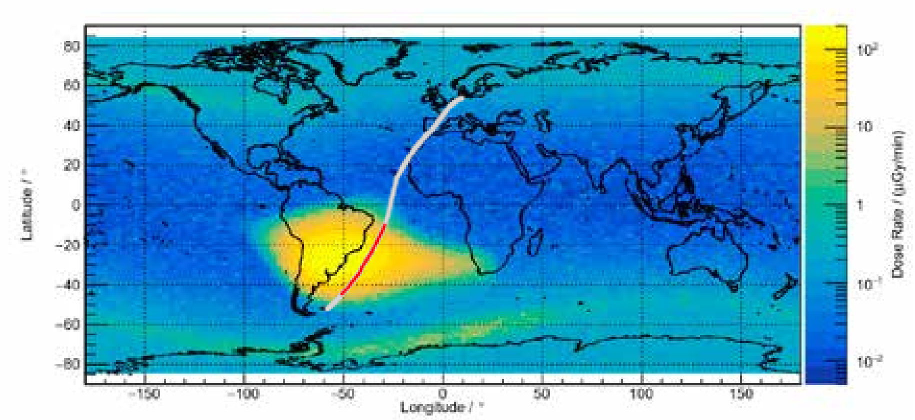

Figure 1: Absorbed dose rate in silicon measured with the RAMIS instrument aboard the DLR Eu:CROPIS satellite flying at a height of around 600 km in March and April 2021. The gray line represents the flight trajectory of the mission Atlantic Kiss. The red section of the flight route is considered as region of interest.

quiet space weather. We did not observe an impact of the inner Van Allen radiation belt on radiation exposure in this geographical region. In summary, the Atlantic Kiss mission helped debunk the urban legend of increased ionizing radiation at flight altitudes over the geographical region of the South Atlantic Anomaly, which had caused unnecessary concern among crew members and passengers.

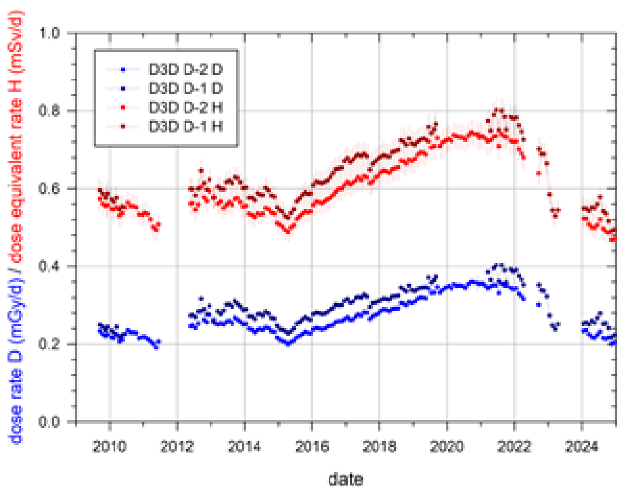

Figure 2: The variation of the absorbed dose rate (mGy/d) and the dose equivalent rate (mSv/d) as measured with the two DOSTEL (D-1 and D-2) instruments inside the Columbus laboratory of the ISS from July 2009 up to the end of 2024 (D3D, DOSIS 3D).

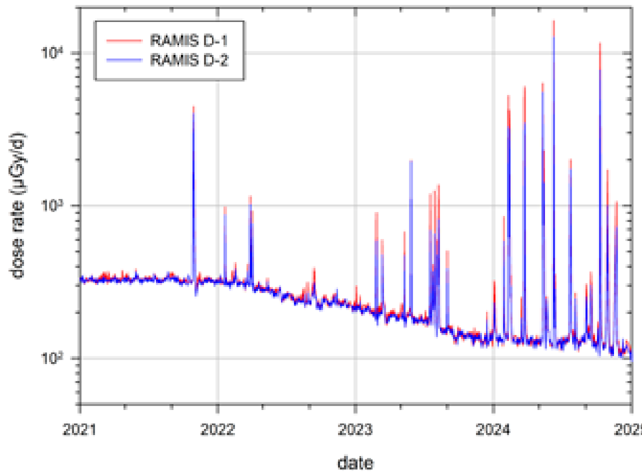

Figure 3: The variation of the GCR dose rate over the North- and South Poles as measured with the RAMIS D-1 and D-2 detectors from 2021 to 2025 as well as the solar particle events (SPE) (spikes) seen by RAMIS from October 2021 onwards.

The ISS, DOSIS 3D and RAMIS on Eu:CROPIS

On-board the ISS we monitor the radiation environment inside the Columbus Laboratory with one of the longest lasting ESA experiments: DOSIS (2009 – 2011) and DOSIS 3D (2012 – ongoing). We measured variations in radiation load at eleven positions using passive detectors and verified difference in dose values depending on local shielding, with up to 40% variation.

In cooperation with Christian-Albrechts-Universität, Kiel, Germany, two powered DOSTEL instruments mounted at a fixed position in Columbus monitor changes in radiation load over time, including influences from ISS attitude and altitude, solar cycle variations, and solar particle events. This data also serves as reference for biological experiments in Columbus and as benchmark data for radiation transport code calculations. From July 2009 to the end of 2024, we observed maximum dose equivalent values of up to over 0.8 mSv/day during the solar minimum in 2020, which decreased to about 0.5 mSv/day by the end of 2024 (Figure 2). The dataset represents a unique long-term record of radiation measurements on-board the ISS.

At roughly 600 km altitude, the DLR Eu:CROPIS satellite is flying since December 2018, equipped with in-house developed RAMIS radiation detector. Its orbit crosses the inner and outer Van Allen belts and passes over the North and South Poles. This enabled us to measure variations in the belts and galactic cosmic radiation environment over the solar cycle. At high latitudes with minimal geomagnetic shielding, we observed long-term galactic cosmic radiation variation (Figure 3). While dose rates at the poles remained stable in 2021, a downward trend was visible by late 2024. All spikes in data relate to solar particle events recorded by RAMIS. The first event occurred in October 2021, with nearly monthly events seen throughout 2024. RAMIS thus provides long-term measurements of the radiation environment, with an ideal comparison dataset for future missions beyond LEO, such as missions to the Moon.

To the Moon and beyond with MARE and Astrobotic

Beyond LEO, we contributed to the NASA Artemis I mission with the Matroshka AstroRad Radiation Experiment (MARE), to measure radiation loads in female anthropomorphic phantoms, providing a baseline effective dose equivalent for exploration class missions. Two phantoms (Helga and Zohar) were mounted on crew seats in Orion (Figure 4 B) and flew from 16th November up to 11th December 2022, becoming the first "passengers" in Orion (Figure 4A). The phantoms were developed by DLR, NASA, the Israel Space Agency (ISA), Lockheed-Martin, and StemRad, which provided the novel radiation protection vest (AstroRad) worn by Zohar. They were equipped with thousands of passive dosimeters and 34 active instruments (DLR M-42 and NASA CAD) placed either on the surface or in radiosensitive organs.

Artemis I was the first flight of the human-rated Orion spacecraft beyond 500,000 km from Earth, with two close lunar flybys and a final landing in the Pacific Ocean. Using the DLR M-42 instruments, we determined location-dependent radiation exposure inside Orion. Results for two DLR M-42 instruments mounted on the skin (front SN126 / back SN127) of Helga are shown in Figure 5. The inner belt crossings (Figure 5B) contributed up to 2 mGy of absorbed dose in 30 minutes flight on the front, but only 0.8 mGy on the back of the phantom. During lunar flybys (C and D) the shielding through the Moon decreased radiation doses. The 25 days in free space (Figure 5A) provided a galactic cosmic radiation baseline data set with a maximum dose of 9.4 mGy. At mission end (Figure 5E), dose rates decreased sharply as Orion splashed down.

Artemis I provided valuable data for planning future human landings, such as Artemis III. In support of further lunar missions, we placed the DLR M-42 on Astrobotic's Peregrine Lander (Figure 6) launched in January 2024. Unfortunately, a propulsion failure prevented a Moon landing, but from January 08–18, 2024, while up to 400.000 km from Earth, the instrument performed flawlessly delivering valuable free-space data before reentry and burn-up on January 19, 2024.

Our continued development of measurement instrumentation and modeling tools (e.g., Monte Carlo transport codes) allows us to benchmark and interpret data while providing baseline estimates for future missions. Together, these capabilities let us characterize radiation fields, dose values, and mission-specific risks – addressing the central question of "what is the effect on humans?".

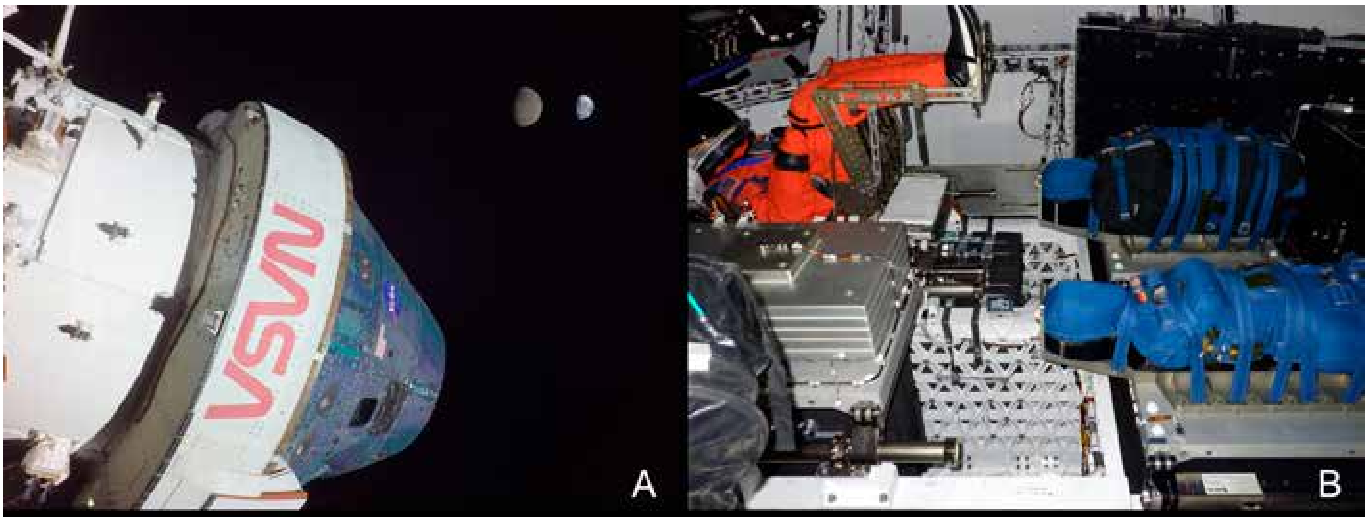

Figure 4 A: The Orion spacecraft at its farthest distance from Earth with the Moon and Earth in the background; B: The MARE experiment with Helga and Zohar inside the Orion spacecraft.

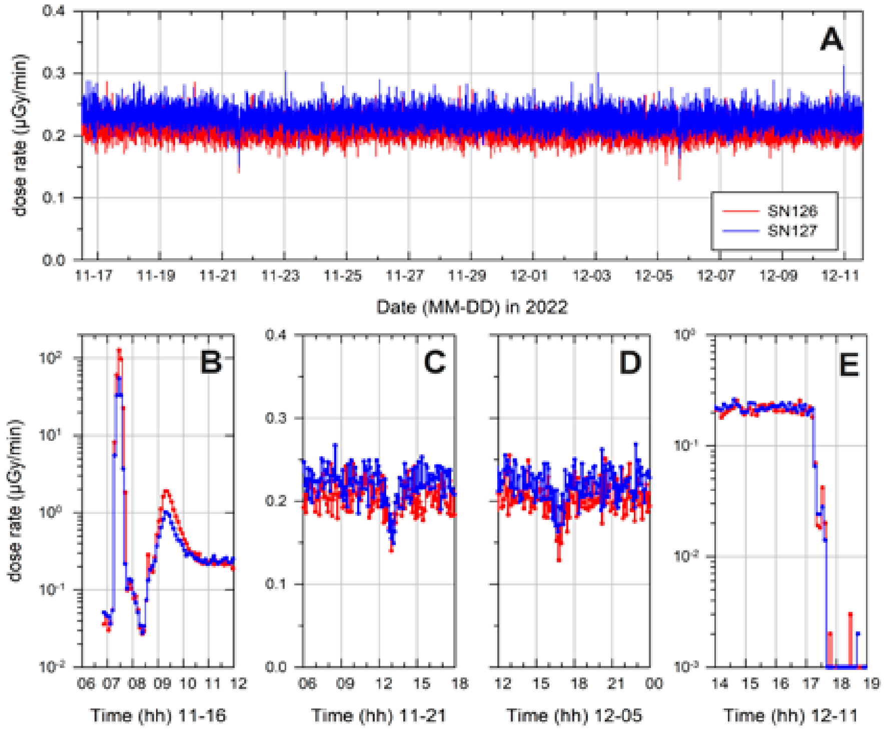

Figure 5: Dose rates measured during the NASA Artemis I mission with the DLR M-42 instruments SN126 and SN127 as mounted on the MARE Helga phantom, separated into mission phases. A: flying in free space; B: crossing the Earths Van Allen radiation belts; C and D: the two lunar flybys; E: the landing in the pacific ocean.

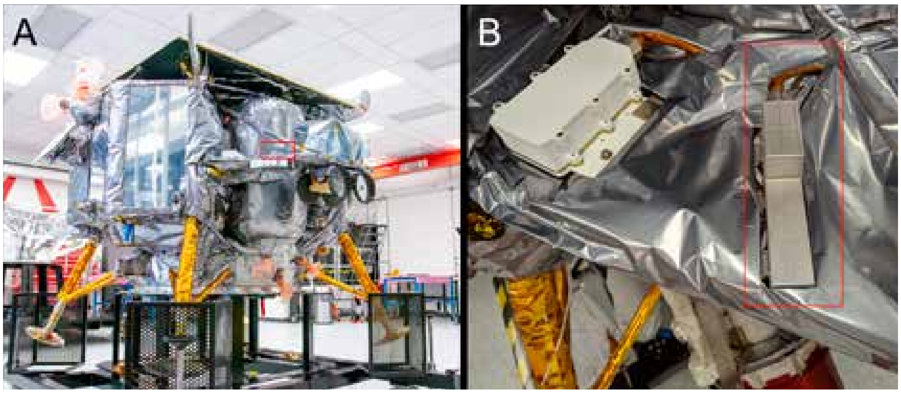

Figure 6: A: The Peregrine lander at Astrobotic, Pittsburgh, USA; B: The DLR M-42 Astrobotic radiation detector (framed in a red box) close to the NASA LETS radiation instrument on Deck D of the Peregrine lander.

Radiation effects on humans: from DNA to cells to tumors

The subject area "Genome Maintenance Mechanisms in Health and Disease" focuses on fundamental cellular mechanisms of DNA damage response, DNA repair, and genome stability. A stable genome is essential for life, while its loss is a common feature of cancer. Accordingly, DNA repair and the cellular response to DNA damage are increasingly targeted in modern cancer therapies. High-energy particles such as protons and carbon ions are used in cancer therapy due to their advantages over conventional radiation (e.g. X-rays). DNA damage and repair are also critical for spaceflight, as exposure to galactic cosmic rays and solar particle events is a major astronaut health risk. Radiation-induced DNA damage, if not repaired or not correctly repaired, increases the risk of cancer and degenerative diseases. These risks are influenced by the circumstances of radiation exposure (radiation quality, dose rate etc.), by inherent factors such as DNA repair capacity, and by environmental factors. Therefore, in the subject area "Cellular Protection Mechanisms", biological effects of space-relevant radiation qualities, environmental factors modifying radiosensitivity of human cells - such as hypoxia and hyperthermia, and interindividual differences of DNA repair capacity, are investigated.

Genome stability: From role of chromatin organization and remodeling in DNA replication and repair to interindividual differences of DNA repair capacity

Genome instability caused by over-replication has been linked to early stages of cancer development, therefore, we investigated mechanisms and markers of over-replication. Engineered systems were used to force DNA replication in the G1 phase of the cell cycle. This unscheduled G1 replication shows hallmarks of S phase replication, but leads to over-replication and DNA breaks from replication collisions. At low levels of sporadic G1 replication, a similar cellular response occurred indicating that our engineered systems reveal insights of physiological significance and that asymmetric accumulation of replication protein A (RPA)-bound single-stranded DNA is a highly sensitive marker of acute over-replication. Replication starts at defined origins within the chromosomes. Chromatin organization at such replication origins is characterized by nucleosome depletion at origin recognition complex-binding sites and flanking arrays of regularly spaced nucleosomes. Chromatin remodelers slide,

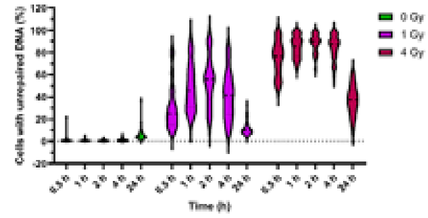

Figure 7: DNA repair kinetics in PBMCs from 39 human subjects. PBMCs were isolated, exposed to 1 and 4 Gy of X-rays and incubated at 37 °C for 0.5, 1, 2, 4 and 24 h to allow DNA repair. Percentage of cells with unrepaired DNA damage for the different repair times.

Figure 8: InVivO$_2$ Hypoxia Workstation.

position, evict, or edit the nucleosomes (~147 base pairs of DNA wrapped around the histone octamer). To determine how nucleosome organization at the origin is achieved and whether this organization is functionally important for replication, purified chromatin factors from budding yeast were screened in a genome-scale biochemical reconstitution. The origin recognition complex established the above mentioned chromatin organization by orchestrating several chromatin remodelers (INO80, ISW1a, ISW2 and Chd1), indicating its functional role as a master regulator of nucleosome organization at the replication origin, a crucial prerequisite for efficient chromosome replication. As nucleosomes play key roles in DNA replication and repair, understanding of regulation and function of their remodelers is crucial: The INO80 complex was shown to be regulated by extranucleosomal DNA – the linker DNA between nucleosomes; furthermore, the mechanism of activation of Fun30 nucleosome remodeler was elucidated. In future studies, these fundamental mechanisms in yeast will be elucidated in human cells. Using genome editing by CRISPR-Cas9, pooled knock-out screens of more than 100 DNA damage response genes are foreseen to determine their role in the recovery from DNA damage inflicted by space-relevant radiation qualities. These screens will also enable to identify drug targets and underlying mechanisms of radioprotective proteins, e.g. from Tardigrada.

These mechanistic investigations are flanked by a phenotyping assay of DNA repair capacity, integrating the interplay of DNA repair proteins and chromatin remodelers. It is based on *ex vivo* exposure of peripheral blood mononuclear cells (PBMCs) from human subjects to X-rays to induce DNA double strand breaks. Repair of these breaks is followed over 24 h after irradiation by immunofluorescence staining of phosphorylated histone variant H2AX (γH2AX) followed by flow cytometry. γH2AX fluorescence indicating DNA double strand breaks reached a dose-dependent peak value 2 h after X-rays irradiation. In cells exposed to 1 Gy X-rays, breaks were fully repaired after 24 h, while repair was incomplete in cells irradiated with 4 Gy X-rays. So far, more than 50 healthy humans were investigated, including subjects of the Spaceflight-Associated Neuro-Ocular Syndrome Countermeasures (SANS-CM) studies (Figure 7). Head-down tilt bed rest and countermeasures did not influence DNA damage induction and repair, while hypoxia reduced DNA damage induction.

Radiosensitivity and radiation response under hypoxia

To investigate how hypoxia modulates radiosensitivity, we used a state-of-the-art hypoxia workbench (Figure 8) to investigate prolonged hypoxia and reoxygenation in non-small cell lung carcinoma (NSCLC) cells, A549 (p53 wildtype), and H358 (p53 null), in combination with X-rays or carbon ion irradiation. Hypoxia increased survival after X-rays exposure (Figure 9A&B). This radioresistance persisted in A549 regardless of continued hypoxia, while H358 regained radiosensitivity with reoxygenation. Carbon ions, however, overcame hypoxia-induced radioresistance (Figure 9C).

Hypoxia alone upregulated genes involved in cell migration in A549 cells, and hypoxic response and angiogenesis genes in H358 cells. Exposure to X-rays under hypoxia additionally upregulated genes modulating immunosurveillance and epithelial-mesenchymal transition (EMT), which reoxygenation reversed this effect. Notably, hypoxia-induced radioresistance persisted even in the absence of functional p53 (H358 cells). Without rapid reoxygenation occurring after irradiation, radiotherapy with X-rays may increase tumor invasiveness. Carbon ion irradiation might be a better option for overcoming hypoxia-induced radioresistance in NSCLC.

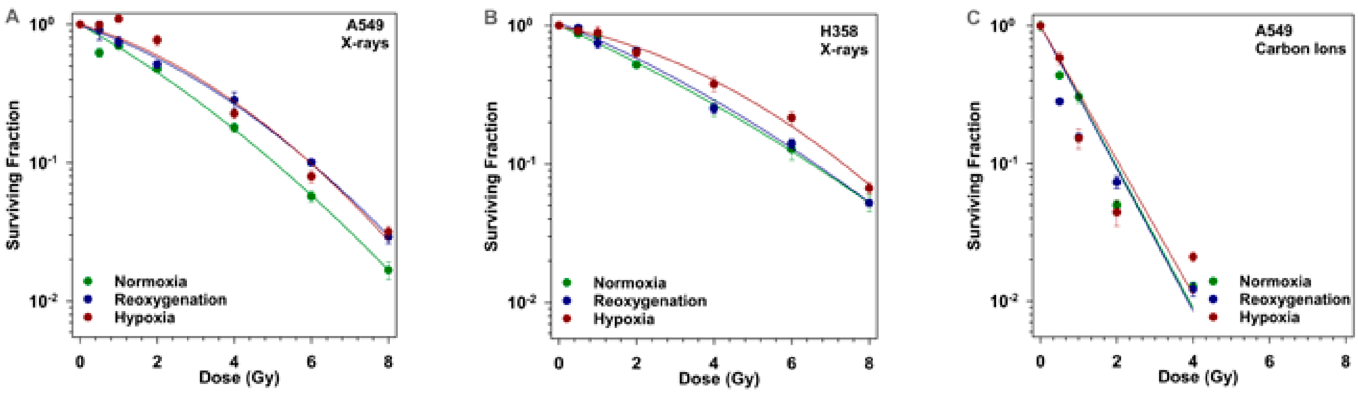

Figure 9: Survival of lung cancer cells 24 h after exposure to X-rays (A, A549 and B, H358 cells) or carbon ions (C, A549 cells) under normoxia, hypoxia (1 % O$_2$), and hypoxia (1 % O$_2$) & reoxygenation after irradiation. Arithmetical means and standard errors for n = 18.

Collaboration partners within the Institute

- Dept. of Applied Aerospace Biology
- Dept. of Cardiovascular Aerospace Medicine
- Dept. of Metabolism and Human Performance
- Study Team

Collaboration partners within the DLR

- Institute of Frontier Materials on Earth and in Space
- Institute of Space Operations and Astronaut Training
- Institute of Space Systems

Collaboration partners in Germany

- Christian-Albrechts-Universität zu Kiel (CAU)
- European Astronaut Center (EAC)
- GSI Helmholtzzentrum für Schwerionenforschung
- Technische Universität München (TUM)
- Universität zu Köln

Collaboration partners worldwide

- Belgian Nuclear Research Center, SCK CEN
- European Space Agency (ESA)
- Israel Space Agency (ISA)
- Massachusetts Institute of Technology (MIT), USA
- National Aeronautics and Space Administration (NASA), USA

Publications

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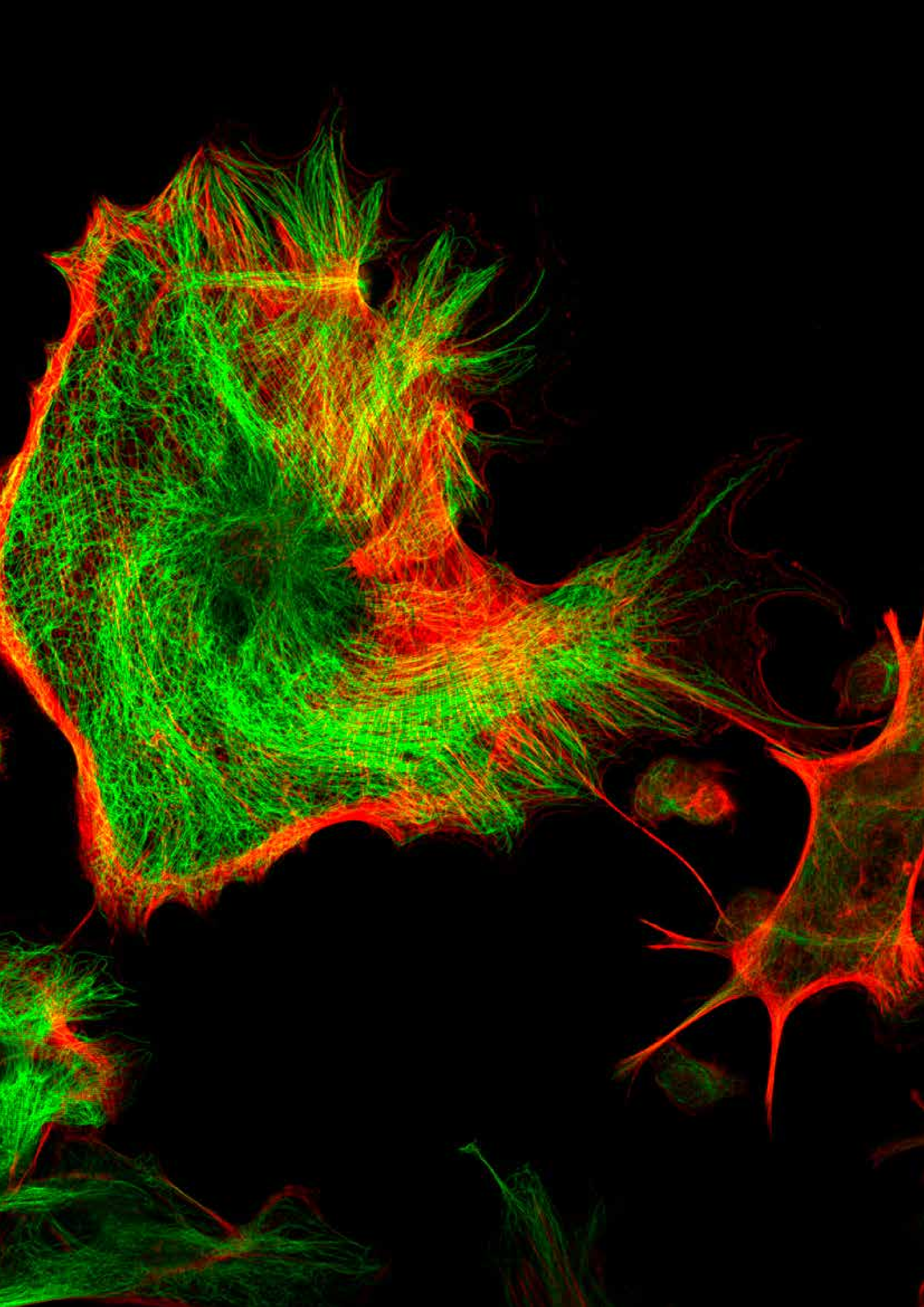


II.7
Applied Aerospace Biology

Dr. rer. nat. Christian Liemersdorf (Head)

Stefan Leuko, Ph.D. (Deputy)

Mission Goal

The Department of Applied Aerospace Biology conducts translational research and development at the intersection of biology and engineering, establishing the biological foundation for enhanced health and safety in space and on Earth. We leverage opportunities in the evolving low Earth orbit ecosystem for scientific and commercial applications.

We employ model systems relevant to human health such as microorganisms, mammalian cells, and organoids. Using biological samples from highly controlled human studies at :envihab, we investigate the cellular mechanisms and interactions between the microbiome and the environment. To gain further insights into cellular mechanisms and identify targets for countermeasures, we apply ground-based simulations of space conditions (ground-based facilities, GBF) such as microgravity, hypergravity, ionizing radiation, and altered atmospheric conditions.

Our microbiological research utilizes the knowledge of microbial adaptation to extreme conditions for spaceflight and develops strategies for the control of infectious agents in space, aeronautics, and public transport. The results are systematically validated with real microgravity experiments on board platforms such as the ISS and the DLR MAPHEUS® sounding rocket.

Applied Aerospace Biology

Unique selling points of the department

Custom-design of centrifuges and microgravity simulators to create altered gravity conditions combined with e.g. live-cell imaging or biochemical (Omics) analyses

Real spaceflight biological experiments by annual DLR MAPHEUS® sounding rocket flights

Host of the live-cell imaging microscope FLUMIAS science reference module (SRM) providing scientific support for external users

Microbial life in space, on Earth and other celestial bodies

Novel tracking and decontamination methods to control bioburden in public transportation

With decades of experience in elucidating molecular mechanisms of gravity perception and resulting biological responses, the Department of Applied Aerospace Biology lays the foundations to use the unique spaceflight conditions such as microgravity for advanced biomedical research and to translate findings into terrestrial applications.
While for some environmental factors of spaceflight, such as cosmic radiation and lunar dust, deleterious effects predominate, altered gravity and mechanical stimuli might advance the development of biological model systems such as organoids. So, on the one hand, space conditions might support organoid growth and differentiation. On the other hand, deconditioning of the human body under microgravity during space missions is well-known. Cellular and molecular mechanisms underlying these changes are not completely understood but often compared to ageing processes. Cognitive and motoric disturbances similar to ageing-related changes are frequently observed in spaceflight.
Therefore, we use space conditions as a model for accelerated neuronal aging or neurodegeneration at the synaptic level. We employ single cells and complex 3D models of the brain and retina to understand underlying mechanisms, to identify potential molecular targets, and to develop therapeutic interventions. Another important component of the central nervous system are astrocytes, which play key roles in the upkeep and maintenance of cellular neuronal networks. Astrocytes also are a key player in the brain's response to injuries or diseases. We investigate if astrocytes change their physiological responses as an effect of spaceflight stressors and what implications this has for astronaut brain health. Muscle deconditioning occurring during spaceflight and in head-down-tilt bed rest – a model for the multiple physiological changes experienced by astronauts during spaceflight – is attributed to mechanical unloading and physical inactivity. An open question is whether altered neuronal signaling contributes to decreased muscle activity. To answer this question, we generate personalized, re-programmed induced pluripotent stem cells (iPSCs) using blood samples from human studies at :envihab. From these iPSCs, we derive neurons, glial cells and skeletal muscle cells and combine them to neuromuscular junctions. Using these individual subject-derived organoids, we investigate cellular mechano-sensing and neuronal activity under altered gravity.
Human studies also offer opportunities to study changes in the microbiome under space-relevant conditions. Microorganisms, the earliest life forms on Earth, are fundamental to ecosystems and thrive in nearly every environment, including those considered extreme by human standards. Multicellular organisms have evolved in close association with their microbiomes, where most microbes are harmless or beneficial, while only a small fraction are pathogenic to humans, animals, or plants. To understand how microbial communities influence human health and the environment, we detect and characterize microbes present in different (extreme) environments, their adaptability and resilience, and their interactions with non-living and living environment. We apply this knowledge to develop novel approaches to limit spread of infectious agents, such as new decontamination methods with applications for both daily life and planetary protection. Furthermore, we develop new tracking methods and thereby investigate the bioburden of public transportation as well as public space like airports, to design innovative ideas to mitigate the microbial threat for the health of passengers. To encounter pandemic threats, we founded the DLR graduate school GANDALF.

Main projects 2021-2025

Counteracting neuronal alterations in space and on Earth

Space conditions impact neuronal structure and function. Thus, neuroprotective agents could represent important pharmacological countermeasures for long-term crewed space missions. As loss of synaptic plasticity in the brain has been linked to cognitive

Working Groups/Teams

The department Applied Aerospace Biology was founded in November 2024 by fusion of the Aerospace Microbiology group (formerly Radiation Biology Department) and the Cell Biology topic (formerly Gravitational Biology Department).

Aerospace Microbiology | Stefan Leuko, Ph.D., and Dr. rer. nat Kristina Beblo-Vranesevic

- Human microbiome research, biofilm formation, antimicrobial materials and decontamination approaches on Earth and on the ISS
- Limits of microbial life on Earth, adaptation mechanisms of extremophilic microorganisms to space-relevant parameters and the issue of Planetary Protection

Applied Cell Biology | Dr. rer. nat. Christian Liemersdorf and Dr. rer. nat. Patrick Lau

- Molecular mechanisms of mechano-sensing and resulting biological responses ranging from single cells to complex 3D retinal and cerebral organoid systems to the whole tissue level
- Personalized medicine: Understanding of disease-related mechanisms and response to space conditions (e.g., altered gravity, mechanical stimuli, stress & radiation) using personalized, re-programmed, induced pluripotent stem cells (iPSC)-derived cells, e.g. neurons, glial cells and skeletal muscle cells combined to form neuromuscular junctions (NMJs)

deficits, it is a promising target for therapeutic interventions. Ketamine is usually applied in treatment-resistant depression but shows substantial psychotropic side-effects. Recently, ketamine´s most relevant metabolite, hydroxynorketamine (HNK), has been attributed a similar stimulating effect on synaptic plasticity, while its weak affinity to N-Methyl-D-Aspartat (NMDA) glutamate receptors leads to a mitigation of the psychotropic side effects. Aiming to utilize this enhancing effect of HNK on synaptic plasticity, we tested novel HNK derivatives that were synthesized by the University of Applied Sciences Cologne.

We applied ketamine, HNK, and 19 different candidate compounds to primary hippocampal neurons. Synaptic plasticity was enhanced in a concentration-dependent manner. HW-774 had the highest stimulatory effect at the lowest dose (50x more potent than standard ketamine (Figure 1).

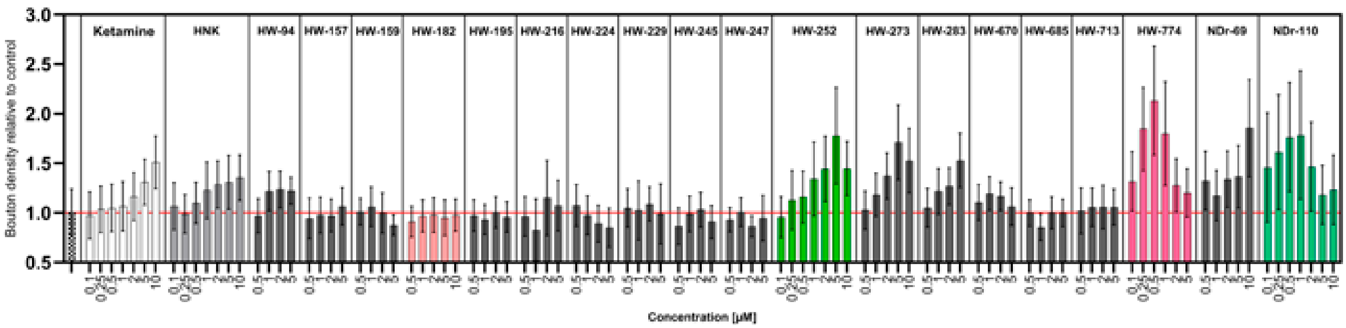


Figure 1: Synaptic plasticity – determined as bouton density – of primary neurons in vitro in response to ketamine-derivatives

Enhancement of synaptic plasticity was further verified by Stimulated Emission Depletion (STED) super-resolution imaging of ketamine-derivative treated neurons to visualize the dendritic spines which are primarily responsible for consistent signal transmission. The maturity of dendritic spines increased after treatment with the ketamine derivative HW-774 (Figure 2). Further, neuronal activity was measured by Multielectrode Arrays (MEAs). Using a custom-built experiment hardware with an integrated MEA system, we performed electrophysiological measurements of Ketamine and Ketamine-derivative treated neurons in hypergravity on the DLR Short-Arm Human Centrifuge and in microgravity on the drop tower, parabolic flights, and the MAPHEUS sounding rocket. Treatment with the compounds stimulated firing activity of neuronal cells. Microgravity and hypergravity were both identified to influence neuronal activity.

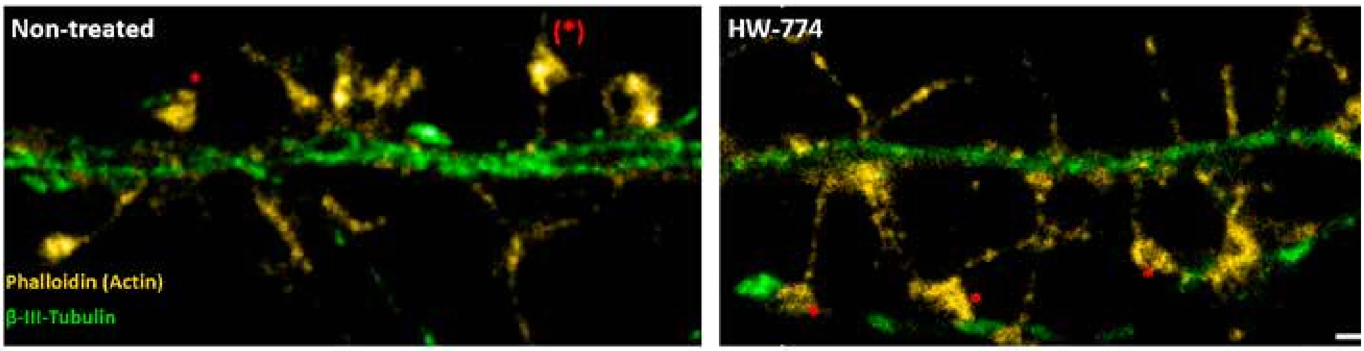


Figure 2: Synaptic structure and maturation in response to ketamine-derivative HW-774. Super-Resolution (STED) microscopy of immunofluorescence-stained primary neurons. Red asterisks mark mature synaptic contacts.

Human gut microbiome

The human gut microbiome constitutes a complex and dynamic ecosystem, harboring a microbial population that outnumbers the stars in the Milky Way. Recent advances in microbiome research have revealed its far-reaching impact on virtually all facets of human health – including immune regulation, metabolic function, neural activity, and overall physiological resilience. Far from being a passive resident, the microbiome actively modulates our responses to both physiological stressors – such as intense physical exertion or illness – and psychological challenges encountered in daily life. Among the most compelling discoveries is its sensitivity to stress-related neurochemicals, which, when dysregulated, can disrupt gut homeostasis and contribute to gastrointestinal dysfunction, systemic inflammation, and neuropsychiatric conditions such as anxiety and depression through the gut-brain axis.

This relationship becomes especially pertinent in extreme environments like spaceflight, where astronauts are exposed to a constellation of stressors: microgravity, elevated radiation levels, circadian rhythm disruption, high cognitive and physical demands, altered diet, isolation, and confinement. Despite the microbiome's critical role in maintaining health, the full extent of spaceflight-induced changes remains poorly understood. To address this gap, we examined microbiome dynamics during 6° head-down tilt bed rest studies – analog environments that simulate aspects of spaceflight – such as the Artificial Gravity Bed Rest with the European Space Agency (AGBRESA), the Spaceflight-Associated Neuro-Ocular Syndrome Countermeasures (SANS-CM) study, and the ongoing Sensorimotor Countermeasures (SMC) study. Our data reveal pronounced shifts in microbial composition and function during these protocols, characterized by notable inter-individual variability (Figure 3). By unraveling the intricate interdependencies between the gut microbiome and human physiology under spaceflight-analog conditions, we aim to inform the development of targeted countermeasures to support astronaut health during long-duration missions.

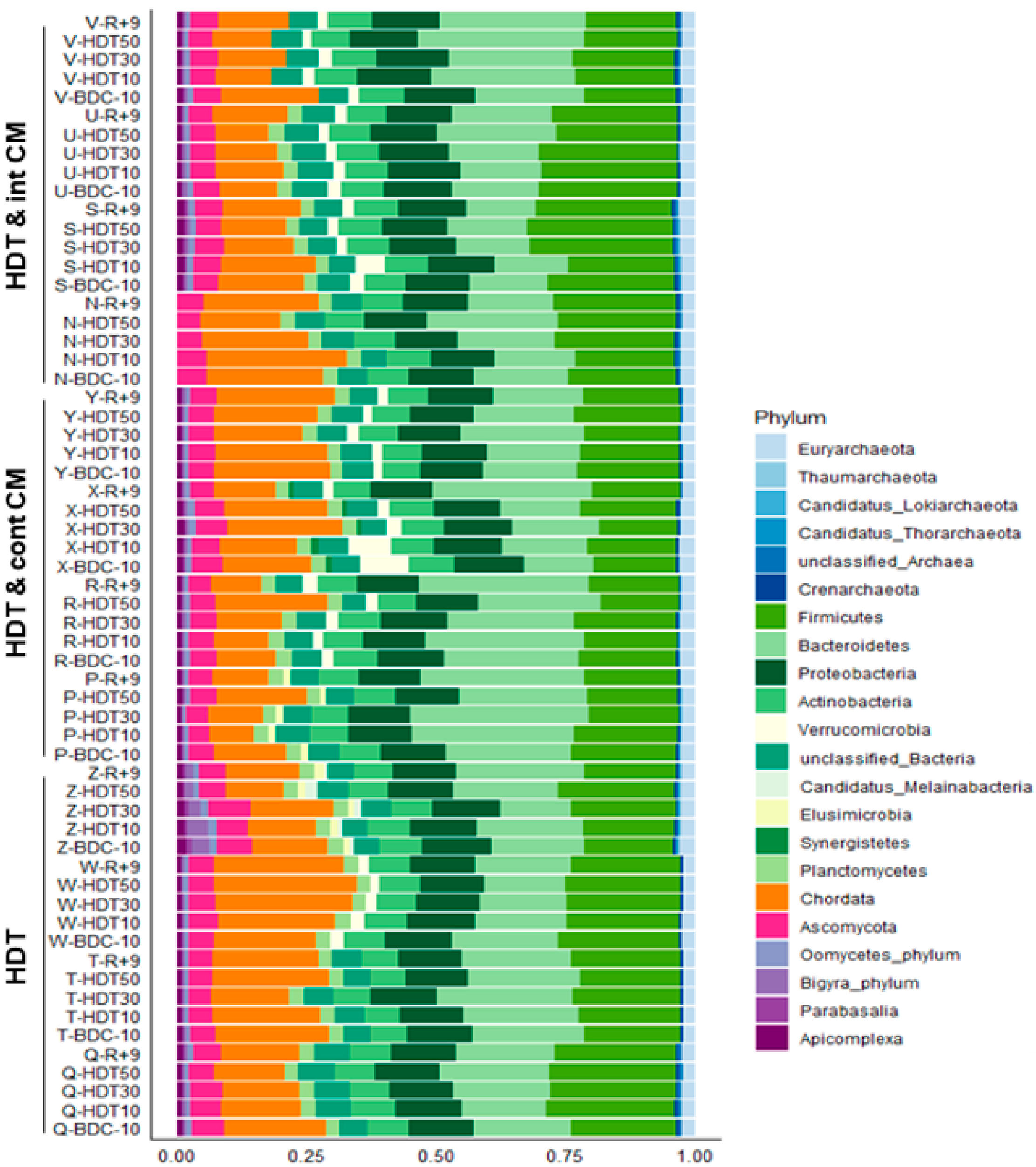


Figure 3: Gut microbiome before, during and after head-down tilt bed rest in 12 human subjects of the AGBRESA study. Metaproteomic output classification was performed according to phylum. Chordata represent exfoliated gut epithelial cells of the human subjects.

Figure 4: Matthias Maurer during the "Cosmic Kiss" mission holding one touch-array from the Touching Surfaces experiment

Anti-microbial surfaces – taming the microbial world

Wherever humans are present, microbial life inevitably follows. This relationship is not inherently detrimental; in fact, the number of microorganisms associated with the human body is roughly equivalent to the number of human cells. However, an overaccumulation of potentially pathogenic bacteria can pose significant risks, particularly to immunocompromised individuals such as astronauts. One promising strategy for mitigating microbial buildup in human environments is the implementation of antimicrobial surfaces. Copper, a well-known example, is widely used in healthcare settings due to its proven antimicrobial efficacy. Nonetheless, its application comes with limitations – including high cost and the development of a patina over time, which diminishes its aesthetic appeal. To address these shortcomings, we are exploring novel alloys and antimicrobial coatings that can be applied to existing materials. We evaluated these materials under real space conditions through the Touching Surfaces experiment. Conducted as part of ESA astronaut Matthias Maurer's Cosmic Kiss mission (Figure 4), the test devices were installed within the ISS and regularly touched by astronauts. This setup provided valuable data on the transmission and distribution of bacteria resulting from human contact. Concurrently, we carried out a citizen science initiative across various schools in Germany, to compare microbial communities on Earth and on ISS. The findings revealed notable similarities in microbial composition, yet underscored the critical need for strategically deployed antimicrobial surfaces, given the elevated presence of potentially pathogenic bacteria in both terrestrial and extraterrestrial environments.

Graduate School GANDALF: Awareness and fighting of pandemic threats

As part of the GANDALF Graduate School, seven doctoral students dedicated their research to a highly relevant and timely topic: Researching and combating current and pandemic threats in public transport and space travel. Our goal was to gain a deeper understanding of the composition and dynamics of microbial communities in public transit systems, the spread of droplets and aerosols in train and aircraft cabins as well as the development of novel strategies to mitigate the spread of bacteria and viruses.

A key feature of GANDALF was its interdisciplinary approach. The participating institutes – our Institute, Institute of Aerodynamics and Flow Technology, Institute of Vehicle Concepts, Institute of System Architectures in Aeronautics, Institute of Software Technologies and Institute of Technical Physics – contributed complementary expertise to the project. Our close collaboration allowed for a comprehensive exploration of technical, biological, and societal questions.

One focus was the development and evaluation of novel ventilation concepts for buses, trains and airplanes. By combining flow simulations, experimental measurements, and microbiological analyses, ventilation systems were optimized to reduce the spread of potentially pathogenic microorganisms. The studies showed that targeted air guidance and intelligent filtration technologies can significantly lower microbial loads (Figure 5).

To characterize microbial diversity, we applied both classical cultivation techniques and modern molecular biology methods. Particularly noteworthy, we used the Loop-mediated Isothermal Amplification (LAMP) method, a fast, cost-effective, and sensitive technique for detecting specific microorganisms. This method enabled on-site identification of relevant bacterial groups without the need for complex laboratory equipment.

In addition, we tested various disinfection methods, including UV-C irradiation, ozonation, and innovative biocompatible surface coatings. We evaluated the effectiveness of these approaches under realistic conditions and correlated them with microbial monitoring data. A combination of regular air purification and targeted surface disinfection was especially effective.

The GANDALF Graduate School exemplifies how interdisciplinary research can create sustainable solutions to current challenges in public spaces. The results of the seven doctoral projects provide valuable insights for public health services and offer important impulses for developing safe, hygienic, and forward-looking mobility concepts.

a)

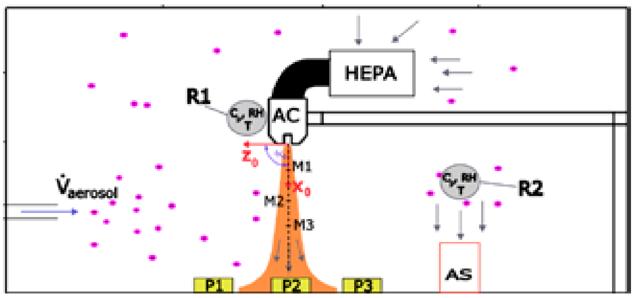
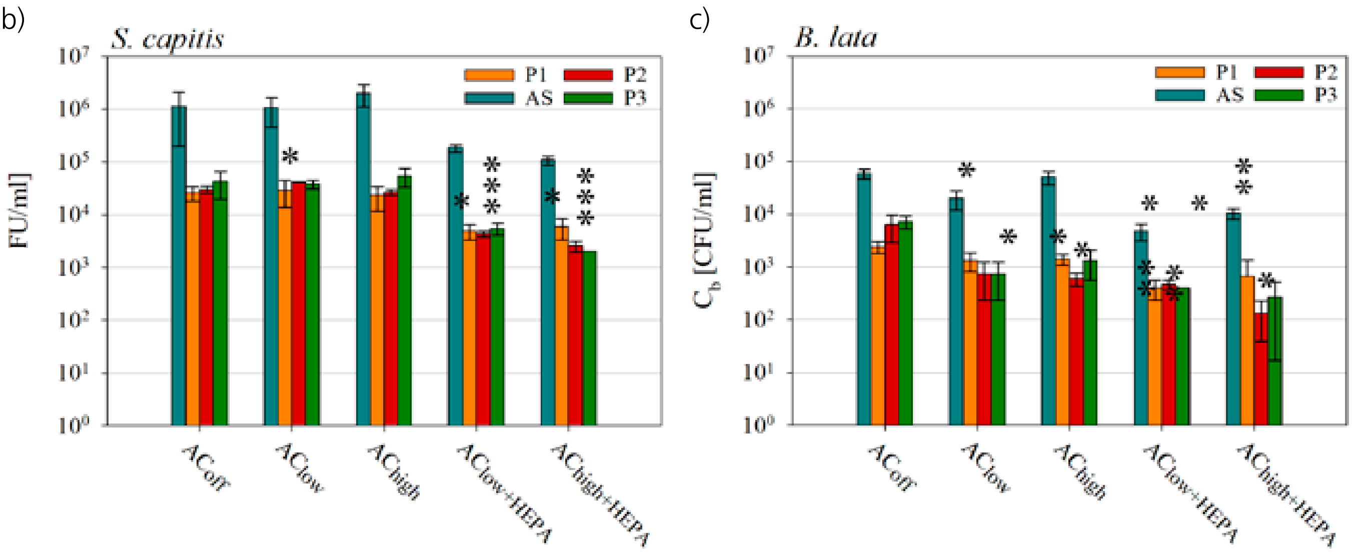


Figure 5: a) 2D Sketch of the experimental setup to test ventilation concepts, including bioaerosol source, air curtain (AC), active air sampling (AS) on agar plates (MAS-100 Eco) and passive surface sampling on petri dishes in front of, in and behind the air curtain (P1, P2, P3). Additionally, the positions for aerosol monitoring (*CP, RH, T*) are indicated in the room (R1) in front of the air curtain and next to the AS in R2; b) Growth [Cb, in colony-forming units (CFU)] of the two bacterial strains *S. capitis* DSM 111179 and c) *B. lata* DSM 23089T at different configurations of the air curtain.

b) c)



Collaboration partners within the Institute

- Aeromedical FabLab
- Dept. of Metabolism and Human Performance
- Dept. of Radiation Biology
- Study Team

Collaboration partners within the DLR

- Institute of Aerodynamics and Flow Technologies
- Institute of Frontier Materials on Earth and in Space
- Institute of Software Technologies
- Institute of System Architectures in Aeronautics
- Microgravity User Support Center (Space Operations and Astronaut Training, BIOLAB, XRF, Exobiology, FLUMIAS)

Collaboration partners in Germany

- Carl von Ossietzky Universität Oldenburg
- Charité Berlin
- German Collection of Microorganisms and Cell Cultures (DSMZ)
- Goethe Universität Frankfurt a.M.
- GSI Helmholtzzentrum für Schwerionenforschung
- Ludwig-Maximilians-Universität München (LMU)
- Otto-von-Guericke-Universität Magdeburg
- TH Köln – University of Applied Sciences
- Universitätsklinikum Bonn
- Universität Bonn
- Universität Duisburg-Essen

Collaboration partners worldwide

- AIRBUS
- European Space Agency (ESA)
- Hochschule Luzern, Switzerland
- Medical University Graz, Switzerland
- National Aeronautics and Space Administration (NASA), USA
- St. Andrews University, Scotland, UK
- University of Tokyo, Japan
- Universidad de Mayor San Simon, Bolivia
- Belgian Nuclear Research Centre (SCK·CEN)
- La Trobe University, Melbourne, Australia
-

Publications

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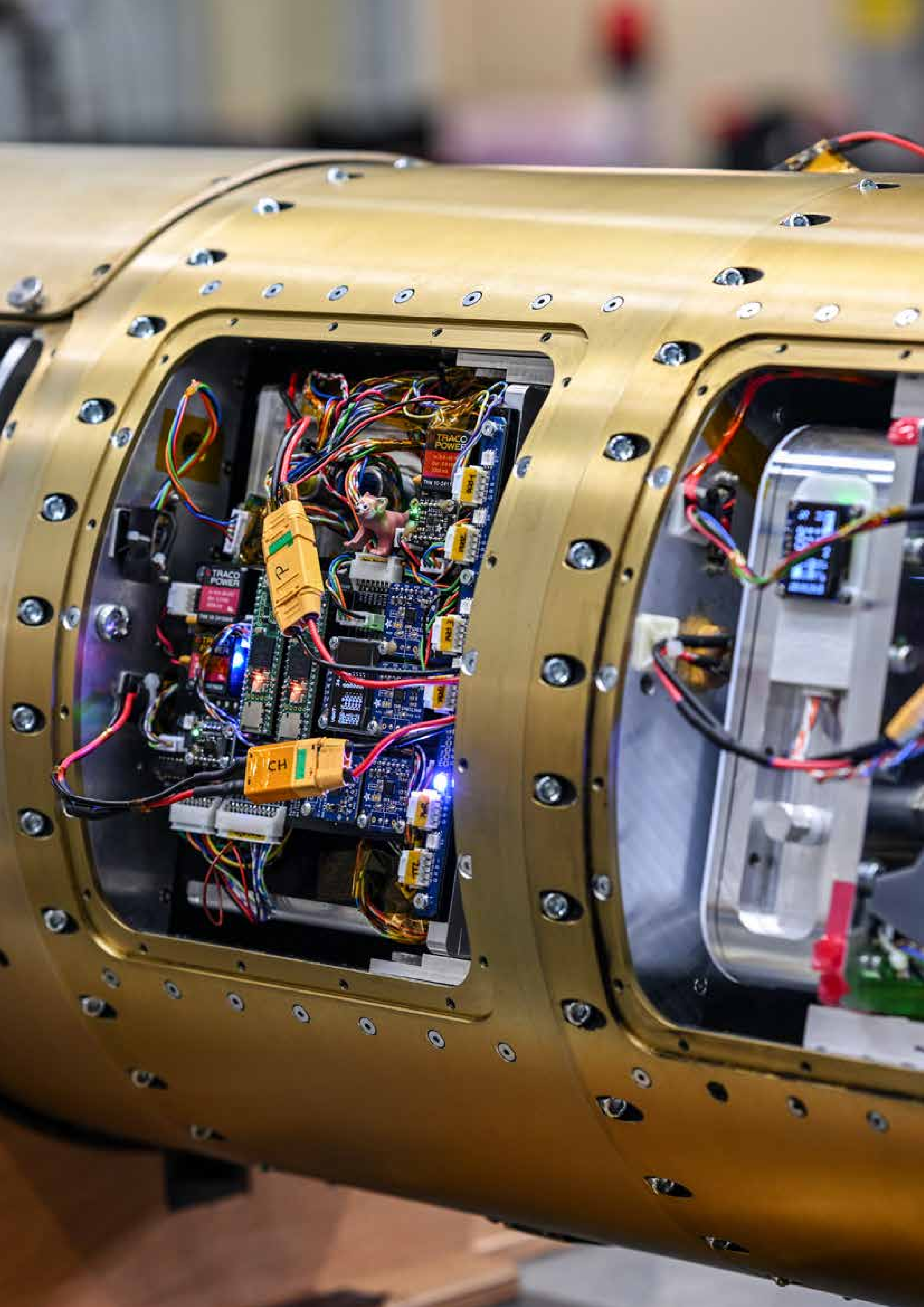

II.8
Aeromedical FabLab

Dr. rer. nat. Jens Hauslage (Head)

Mission Goal

The Aeromedical FabLab connects life sciences and technology within the Institute of Aerospace Medicine. We develop experiments to address research questions from the Institute's departments and deploy them under altered gravity conditions in the drop tower, during parabolic flights, and on sounding rockets. Drawing on years of experience and numerous successful missions, we rapidly deliver experiments using innovative technologies such as 3D printing and commercial off the shelf products.

Technologies for studies of cells and organoids in real and in simulated space conditions are an important focus of our work. In addition, we develop sensor technologies for human research and development in close collaboration with the departments of the Institute, universities and industry partners. We also advance closed loop biological life-support systems needed for long-term human space missions. Our innovation, the DLR C.R.O.P.®-filter technology, optimizes waste recycling for food production, benefitting both, space missions and sustainable agriculture on Earth. Overall, our work facilitates long-term space exploration, advances human health studies, and contributes to sustainable economic development on Earth.

Aeromedical FabLab

Unique selling points of the department

Agile Prototyping for Aerospace Experiments
3D Printing, meta-technologies, development of electronics and sensors, breadboarding with biological samples

MAPHEUS® sounding rocket program
Development, assembly, integration and verification of sounding rocket experiments for life and biophysical science

Custom-designed centrifuges and microgravity simulators
Altered gravity conditions for research

Live-cell imaging and biochemical analyses

Proof-of-concept experiments in real microgravity conditions in space

The Aeromedical FabLab develops technologies and conducts research across a wide range of topics. These include micro- and hypergravity applications in cells and humans together with the department of Applied Aerospace Biology, as well as biological life support systems. We base our work on internally developed and validated ground-based simulation facilities that replicate microgravity conditions for cells, organoids, small plants and animals. We validate these technologies through bioassays and experiments on real microgravity platforms. Hypergravity studies, advanced microscopy, human training programs, and access to real microgravity through the DLR MAPHEUS® sounding rocket program complement our research, creating a unique portfolio available to external collaborators.
One research highlight, achieved in collaboration with the department of Applied Aerospace Biology, is identifying gravity-induced changes in physiology, signaling pathways, and gene expression patterns in cellular systems like neuronal cells. We primarily focus on understanding how gravity interacts with mechanosensitive ion channels and the cell membrane. Our goal is to uncover fundamental mechanisms of gravity and mechanosensing, which influence cell migration, proliferation, regeneration, and aging. A future challenge will be to translate our findings from space research into medical applications on Earth.
In the field of bioregeneration, we have successfully developed an efficient biofiltration system, C.R.O.P.®-filter, which produces fertilizer from nitrogen-rich liquid organic wastes like urine or manure. Next, we plan to design and test a space-qualified prototype, address the removal of pharmaceutical residues and pathogens, and develop additional bio-based technologies for recycling of other materials to help close resource loops in space and enable a bioeconomy on Earth. To achieve these goals, the C.R.O.P.®-filter will be integrated into the EDEN LUNA greenhouse which is part of the LUNA Analog Facility in Cologne. In the third party funded project EULe, we will verify innovative technologies for hygienisation of urine derived fertilizers. Furthermore, we will develop and test a new technology that produces liquid fertilizer from plant residues, the RotoC.R.O.P.®. Our knowledge will contribute to designing closed loop infrastructure that supports healthy living in space and on Earth.

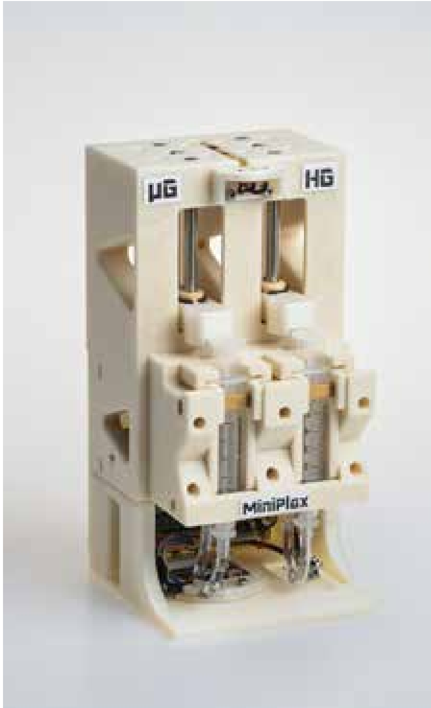

Figure 1: MiniFix – fixation hardware for investigating the influence of space flight on small organisms and cells. First completely 3D printed hardware that has conducted experiments in space.

Main projects 2021-2025

DLR MAPHEUS® sounding rocket program

The DLR MAPHEUS® sounding rocket program provides direct access to real microgravity for material and life science experiments. Launched by DLR MORABA from ESA Esrange in Kiruna, Sweden, this program conducted nine flight campaigns from 2020 to 2024 with 29 individual experiments that significantly contributed to our understanding of gravity perception mechanisms and gravi-sensitivity of biological processes. We developed and constructed scientific payloads for chemical sample fixation, online kinetics analysis using luminescence assays, and microscopy of various model systems, such as membranes, plants, yeast, protists, stem cells, and neuronal cells. These experiments demonstrated the feasibility of versatile 3D printed experiment units for life science experiments in space. Furthermore, the findings provided crucial information for design and rapid prototyping of future experiments under long-term microgravity conditions on the ISS and other platforms.

C.R.O.P.® (Combined Regenerative Organic-food Production)

The DLR project C.R.O.P.® focuses on nutrient recycling from biological waste using microbial filters and addresses research questions related to Bioregenerative Life Support Systems for planetary habitation. We developed an aqueous fixed-bed biofiltration system that converts human urine into plant-available fertilizer. The fertilizer can be used for crop plants in modern soilless cultivation systems, closing resource loops in space and reducing supply costs. Besides urine, the non-edible biomass of crop plants is a source of nutrients for food production in space. Non-edible crop biomass also serves as nutrient source. To process this biomass, we developed a prototype wet composting system that liquefies plant residues and dissolves the nutrients. In several cultivation experiments by external partners, the produced urine fertilizer demonstrated the potential to replace nearly 100% of industrial nitrogen reducing the ecological footprint of food production.

Bioloops

The Bioloops project transferred space technology developed in the C.R.O.P.® program to terrestrial applications. In this project, we have built the first C.R.O.P.®-toilet with an integrated C.R.O.P.®-filter for urine processing.

LUNA

Recycling fertilizers from urine and plants closely relates to epidemic control. In the C.R.O.P.®-project, we found that the treatment of urine in the C.R.O.P.®-filter removes pathogens and drug residues, though not completely. Since 2024, we have developed a urine filter with an extended post-processing unit for pathogen and xenobiotics removal in a space qualified configuration. We will integrate the system into the EDEN LUNA greenhouse in 2025 in collaboration with the DLR Institute of Space Systems.

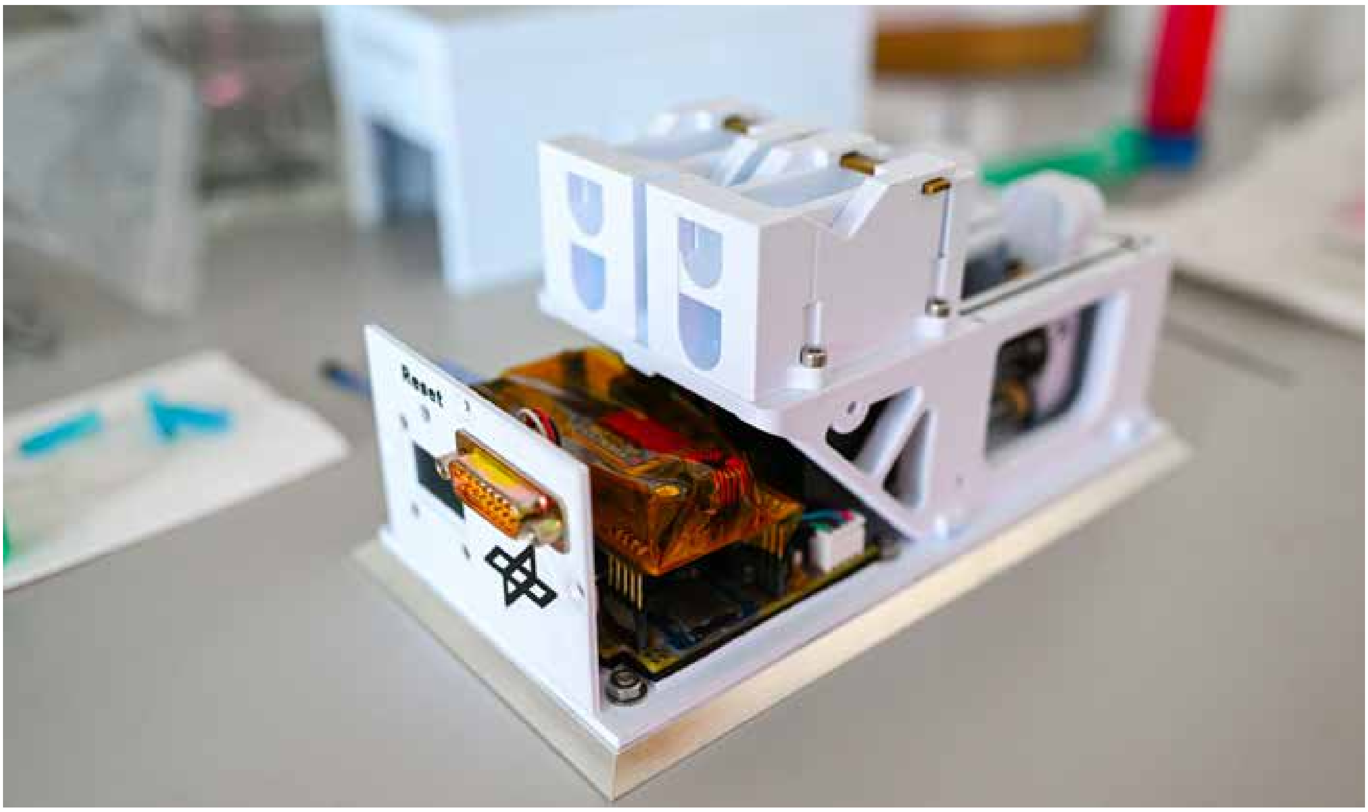

Figure 2: The DLR MiniFix module for fixation of biological and biochemical samples in sounding rocket flights. This this two liter volume unit can be used in various experiments setups and provides a microprocessor controlled fixation and temperature control of samples during the flight. A toolless handling simplifies the preparation in the lab during loading of samples.

EULe

Experiences with the EDEN LUNA filter led to the EULe project (Elektrochemische Nachbehandlung von Recycling-düngern aus Urin für die Lebensmittelproduktion) which evaluates and develops efficient post-processing technologies. The project tests electrochemical and photocatalytical processes for removing drug residues and pathogens. The goal is to design a single-step post-processing unit that does not require consumables.

BiG C.R.O.P.®

The DLR project BiG C.R.O.P.® (Biologische Gülleaufbereitung mit dem C.R.O.P.®-filter) adapted the C.R.O.P.®-biofilter for processing cattle slurry, with goal of developing a marketable agriculture system. Using the processed slurry reduces nutrient leakage and ammonia emissions, helping protect water bodies and limiting ammonia emissions, which are known sources of landscape eutrophication and fine particle pollution. The work resulted in the founding of the start-up NUNOS.

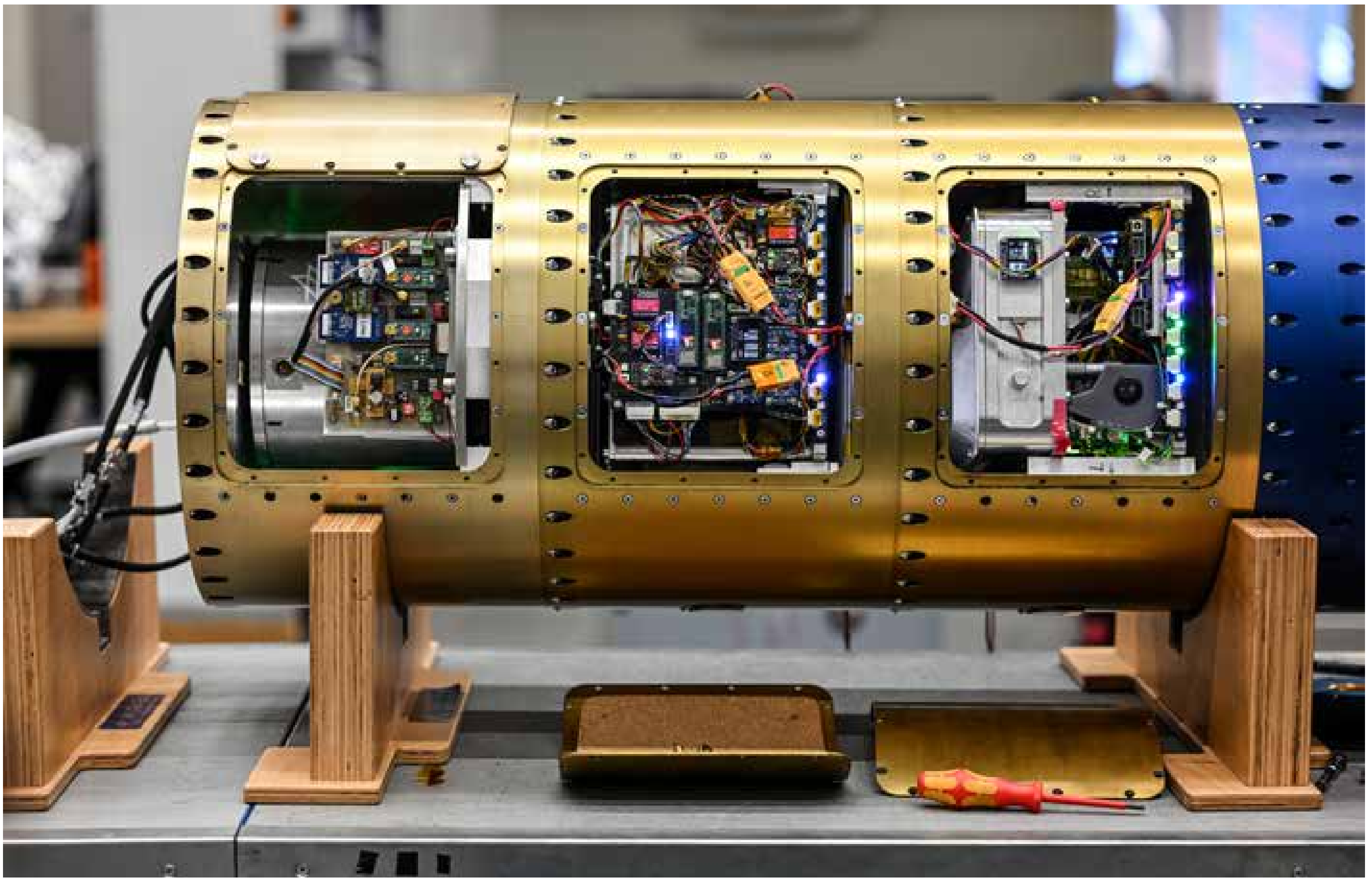

Figure 3: NyMEx, LIFT and BIODECODER (from left to the right) experiment modules developed in the AFL for investigating membrane fluidity, impact of altered gravity conditions on cell systems and the electrophysiological reactions of neurons under space flight conditions on sounding rockets.

Collaboration partners within the Institute

- Dept. of Applied Aerospace Biology
- Dept. of Cardiovascular Aerospace Medicine
- Dept. of Clinical Aerospace Medicine
- Dept. of Radiation Biology
- Study Team

Collaboration partners within the DLR

- Institute of Flight Systems
- Institute of Frontier Materials on Earth and in Space (MAPHEUS®)
- Institute of Space Systems (EU:CROPIS ®, C.R.O.P.®)
- Microgravity User Support Center (Space Operations and Astronaut Training, BIOLAB, FLUMIAS)
- Mobile Rocket Base MORABA (Space Operations and Astronaut Training)

Collaboration partners in Germany

- European Astronaut Center (SpaceShip EAC, C.R.O.P.® Bioreactor, Training)
- FH Aachen – University of Applied Sciences
- Hochschule Bonn-Rhein Sieg – University of Applied Sciences
- Hochschule Hof – University of Applied Sciences
- Humboldt-Universität Berlin
- Leibniz Centre for Agricultural Landscape Research (ZALF)
- Leibniz Institute of Vegetable and Ornamental Crops (IGZ) Großbeeren
- Ludwig-Maximilians-Universität München (LMU)
- Philipps Universität Marburg
- Universität Bonn
- Universität zu Köln
- Goethe Universität Frankfurt a.M.
- Technische Universität München (TUM)
- Eberhard Carls Universität Erlangen-Nürnberg
- Tierärztliche Hochschule Hannover
- Universität Witten/Herdecke
- United Nations World Food Programme (UN WFP) Innovation Accelerator

Collaboration partners worldwide

- European Astronaut Center (SpaceShip EAC, Lunar Habitat)
- La Trobe University, Melbourne, Australia
- International Space University (ISU), France
- University of Aarhus, Denmark
- University of Luzern, Switzerland

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SPLIT RESET
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II.9
Study Team

Dr. med. Laura de Boni (Head)

Alexandra Noppe (Deputy)

Mission Goal
The Study Team at DLR's Institute of Aerospace Medicine is a cross-sectional, mission-critical unit supporting human research across the institute and with external partners. We serve as a central hub for planning, coordinating, and implementing complex biomedical and clinical studies under highly standardized conditions. Our expertise enables research from space-flight analogs to neurodegenerative diseases, nutrition, and hypoxia studies. By providing infrastructure, skilled staff, and robust protocols, we connect fundamental science with operational and clinical applications, advancing space and terrestrial medicine. The team brings together experts in clinical research, neurology, nutrition, and biology. We enable and support both internal and external studies at DLR while pursuing our own projects. A significant focus of the team is on bed rest studies and isolation studies conducted at :envihab facility in Cologne, which simulate microgravity and confinement to gain insight into astronaut health and performance. Findings from these studies help develop countermeasures for long-duration spaceflights. We conduct metabolic studies with highly controlled diets and precise metabolic monitoring with applications in space and on Earth. We also work with institute departments and external partners on human hypoxia studies, with relevance beyond aerospace medicine. Furthermore, we advance basic research on neurodegenerative diseases such as synucleinopathies, collaborating with leading partners in the field, to develop early detection methods and potential interventions for neurodegeneration in aerospace and in terrestrial medicine.

Study Team

Unique selling points of the department

Study design & planning (design study protocol, obtain ethical approval, participant recruitment & screening, medical supervision, study coordination, subject care, nutrition, staff management, biological samples, data collection & sample handling, followup & monitoring, statistical analysis & interpretation, manuscript preparation & dissemination)

Ensuring highly standardized study conditions for complex human studies

Biomarker and molecular analysis (investigate α-synuclein aggregation and its role in neurodegeneration; analyze blood, brain and cellular models for α-synuclein pathology)

Study dietary impact on microbiome composition

The Study Team plays a central cross-sectional role within the Institute of Aerospace Medicine, managing biomedical and clinical studies, supporting both internal and external research groups. We contribute expertise across all stages of study execution, from concept development and planning to on-site management. Our focus is on complex, highly standardized inpatient and outpatient studies, with extensive experience in long-duration head-down tilt bed rest studies (Figure 1), isolation studies, and drug trials. Additionally, we coordinate ambulatory studies, particularly those utilizing the Short Arm Human Centrifuge (SAHC) to simulate artificial gravity. In this field, we support internal projects, ESA Ground-Based Facility studies, and the National Centrifuge Program of DLR Space Administration.
As part of our responsibilities, we oversee all procedural aspects of research, including applications for ethical approval, subject insurance, and study registration. We manage recruitment, project administration, and the preparation of study documents (protocols, case report forms, informed consent documents), and develop highly standardized nutrition protocols. Our Good Clinical Practice (GCP)-trained staff, ensures on-site study execution, supports internal reporting and communication, and coordinates scheduling and resource allocation at :envihab.
Since 2014, we have hosted ESA astronauts at :envihab directly after their return from ISS. These post-mission recovery phases, lasting at least two weeks, are organized in close collaboration with ESA and space medicine experts. Our operational experience also supported the DLR COVID-19 vaccination campaign in 2021. Moreover, we contributed to connecting :envihab with the new LUNA habitat for flexible multiple-day missions, the ESA astronaut selection campaign in 2022, and novel basic research on aggregation-resistant protein conformations in synucleinopathies.

Figure 1: Study coordination and nutrition team members during regular visits to M3 at :envihab (SMC study).

Staff members of the Study Team:
1 Head (MD and Scientist)
4 Project Managers (one of them Deputy Leader and Scientist)
2 Study Nurses
3 Nutritionists
1 Dietary Assistant
1 Project Assistant

Main projects 2021-2025

Space analogs: Head-down tilt bed rest studies:

1. NASA Spaceflight Associated Neuro-ocular Syndrome Countermeasure (SANS-CM) bed rest studies (2021 – 2023)

We played a key role in the NASA SANS_CM bed rest studies, investigating the pathophysiology of Spaceflight Associated Neuro-ocular Syndrome. Using a strict 6-degree head-down tilt bed rest (HDTBR) model at :envihab, the study simulated fluid shifts in microgravity in four campaigns. Participants underwent a 30-day HDTBR period, with pre- and post-study phases. Countermeasures tested included lower body negative pressure (LBNP), exercise combined with venous-occlusive thigh cuffs, and upright sitting as positive control. Our team handled participant recruitment, medical care, study coordination, nutrition, staff oversight, and experimental procedures, ensuring the highest scientific standards. The results will inform countermeasures to protect astronaut ocular health during long-duration spaceflight.

2. NASA Sensorimotor Countermeasures Study (SMC) bed rest studies (2024 – ongoing)

The NASA SMC bed rest study investigates sensorimotor impairments caused by prolonged inactivity in microgravity. The four campaigns each involve a 60-day HDTBR period as well as countermeasures like electrical muscle stimulation (EMS), proprioceptive training (PT), and exercise-based interventions. We oversee recruitment, coordination, medical and subject care, nutrition, staff management and data collection. Results will aid countermeasure development to maintain neuromuscular coordination and postural stability for future Moon and Mars missions.

TAhRget – Diet-Induced AhR-Dependent Immune Responses (2022 – 2023)

The TAhRget study, funded by the Federal Ministry of Education and Research, investigated how diet influences Aryl Hydrocarbon Receptor (AhR) activation and immune modulation (Figure 2). Participants followed either a plant-based diet or a Western diet. The study revealed that the plant-based diet reduced AhR activation, while the Western diet was linked to metabolic dysregulation and shifts in immune cell abundancies through AhR activation.We managed funding acquisition, participant recruitment, study coordination, medical care, and sample processing. Collaboration with the Max Delbrück Center, Charité, and the University of Regensburg enabled in-depth data analysis, with implications for clinical and space medicine. These insights contribute to dietary recommendations for immune system modulation in astronauts and terrestrial populations.

Figure 2: Representative image of Bioelectrical Impedance Analysis (BIA) measurements taken for the TAhRget study.

Biomarker development for neurodegeneration (2022 – ongoing)

Our research has provided significant insights into structural dynamics of α-synuclein, a protein expressed by the *SNCA gene*, involved in neurodegenerative diseases such as Parkinson's disease and Dementia with Lewy bodies. Our results indicate that α-synuclein tetramer levels could serve as an early biomarker for disease progression. Beyond neurodegenerative disease research, this study has implications for astronaut neurological health and performance, as spaceflight-related stressors could accelerate protein misfolding and aggregation. We have already conducted an initial study on biomarkers of neural health in the microgravity analogue head-down tilt bed rest. Identifying biomarkers for synuclein stability and aggregation could facilitate preventive measures in, both, space and terrestrial medicine.

ICAROS-PH – Individual Cardiopulmonary Adaptation to Hypobaric Hypoxia during long-distance flight simulation in patients with Pulmonary Hypertension (2023 – 2024)

The ICAROS study investigated physiological responses to long-distance flight under hypobaric hypoxia in patients with pulmonary hypertension, conducted in the :envihab barochamber in collaboration between our Department of Cardiovascular Aerospace Medicine and the University Hospital Cologne (Departments of Anaesthesiology and Cardiology). We oversaw project management, recruitment, and study execution, ensuring standardized data collection.

RIDGE – Retinal circulation during gravitation changes in a human centrifuge (2024 – ongoing)

RIDGE, conducted in collaboration with the Cardiology Department at University Hospital Düsseldorf and funded by the German Space Agency at DLR in the frame of the 3rd national centrifuge program (NZP3), takes place at :envihab (Figure 3). Participants are rotated in a supine position on the short arm human centrifuge to induce controlled fluid shifts toward either the head or the legs. RIDGE investigates cardiovascular and ocular adaptation to altered gravity, focusing on retinal blood flow. We conducted medical risk assessment and supervised external partners, ensuring study safety and compliance. Together with the DLR Centrifugation Team, we implemented scientific experiments and contributed expertise from prior studies to enhance study execution.

Figure 3: Digital Vessel Analysis (DVA) Measurements Conducted for the RIDGE Study.

ESA isolation studies and M5 platform development (2024 – ongoing)

We support ESA-funded isolation studies, ensuring standardized methodologies, and countermeasure validation. To this end, we developed a standardization plan that will guide future 100-day isolation campaigns. The upcoming 100-day ESA isolation study will investigate psychological, physiological, and operational challenges of spaceflight. A pilot study, SOLIS8, conducted in 2025, validated infrastructure and procedures. We oversaw project execution, crew recruitment, participant coordination, medical supervision, mission control, nutrition, and biological sample processing, ensuring high scientific rigor. Standardized isolation research supports preparation for future long-duration missions to the Moon and Mars and enhances knowledge on psychological and physiological resilience in extreme environments.

Collaboration partners within the Institute
- Dept. of Aerospace Psychology
- Dept. of Applied Aerospace Biology
- Dept. of Cardiovascular Aerospace Medicine
- Dept. of Clinical Aerospace Medicine
- Dept. of Metabolism and Human Performance
- Dept. of Radiation Biology
- Dept. of Sleep and Human Factors Research

Collaboration partners within the DLR
- Health Management
- Space Administration

Collaboration partners in Germany
- Charité-Universitätsmedizin Berlin, Dpt. of Nephrology and Intensive Care Medicine, Berlin
- European Astronaut Center (EAC) (Direct Return)
- German Sports University Cologne
- Hochschule Bonn-Rhein-Sieg – University of Applied Sciences
- Institute for Experimental Biomedicine, Universitsklinikum Würzburg
- Institute of Functional Genomics, Universität Regensburg
- Max Delbrück Center for Molecular Medicine in the Helmholtz Association (MDC)
- Universitklinikum Aachen
- Universitätsklinikum Bonn
- Universitätsklinikum Köln
- Universitätsklinikum Düsseldorf

Collaboration partners worldwide
- Ann Romney Center for Neurological Diseases, Harvard University, USA
- Dementia Research Institute, University College London, United Kingdom
- European Space Agency (ESA), European Astronaut Center (EAC)

Publications

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III. Outlook: Future challenges and strategic measures

The Institute of Aerospace Medicine actively adapts to the rapidly evolving landscape of space and aeronautics. As human space programs transition from research on the International Space Station (ISS) to deeper space exploration missions targeting the Moon, Mars, and beyond, we will continue to address biomedical and psychological challenges of long-duration spaceflight. The commercialization of low Earth orbit (LEO), including new space stations and private-sector involvement, will create new opportunities for scientific research and technology development with direct health benefits. Recreational suborbital flights will bring fresh challenges in safety, health, and performance requiring innovative solutions.

In aeronautics, demographic change challenges the sector, with an aging pilot workforce and rising air travel demand. The move toward single-pilot cockpits raises concerns about workload, decision-making, and emergency response. Integrating artificial intelligence (AI) in cockpits offers benefits but also increases complexities in human-AI interactions. Pilots must work effectively with AI while maintaining oversight, which will be essential for safety. Additionally, the COVID-19 pandemic has highlighted the need for stronger airborne health safety measures, making preventive technologies a priority.

The Institute also leads in applying advanced technologies such as artificial intelligence, health data analytics, and bioengineering to address emerging challenges in human health and performance in extreme environments. AI-based systems, wearable technologies, and real-time health data processing will serve as critical tools to safeguard personnel operating in space and aviation, while advancing medical care and personalized treatments on Earth.

To meet these challenges, the Institute will build on its scientific expertise and research infrastructure, fostering an interdisciplinary approach and ensuring seamless translation between aerospace and terrestrial applications. We will expand our national and international collaborations with academia, agencies, and industry, positioning the Institute as a global leader in space and aeronautical medicine. The DLR-University of Texas Southwestern Alliance illustrates this strategy by promoting joint research and international knowledge exchange.

Attracting and retaining top junior scientists will remain a key priority, as the Institute works to ensure a steady pipeline of talent capable of addressing the biomedical and psychological challenges of tomorrow's space and aeronautical missions. By offering structured career programs, mentorship, and expanding international collaborations, the Institute will cultivate the next generation of experts in aerospace medicine.

IV. Major research facilities

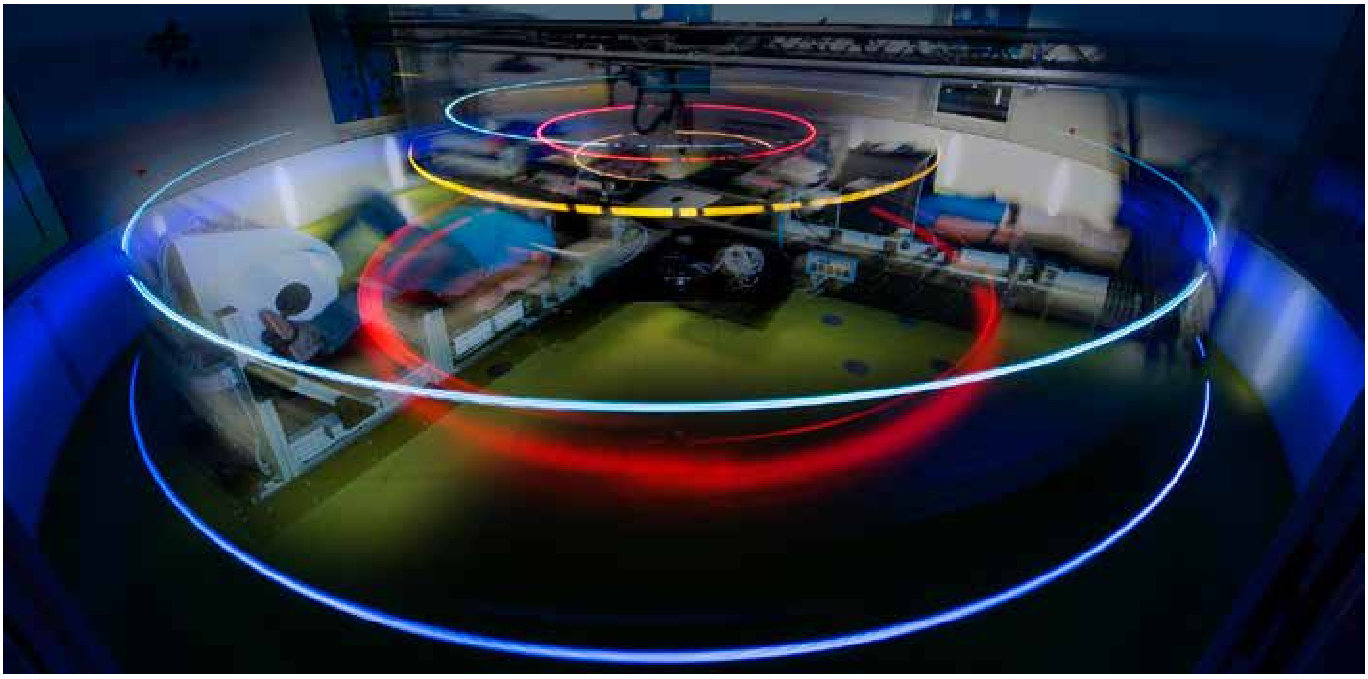
:envihab – Modules and laboratories

M1
DLR Short-Arm Human Centrifuge

The DLR Short-Arm Human Centrifuge at the :envihab research facility is a special unit offering enhanced possibilities for researching the effects of altered gravity, especially as a countermeasure to the health risks that occur in microgravity conditions. This Short-Arm Human Centrifuge is used by DLR internal and external partners (e.g. ESA) to study the effects of artificial gravity solely or combined with physical training and its impact on the human body, as well as investigating gravity effects upon biological systems. This results in a variety of applications in terms of measures to counteract both health problems during long-term missions or on Earth, such as the consequences of prolonged bed-rest, ageing, or a sedentary lifestyle. The facility is a world leader, as we offer unrivalled possibilities in terms of equipment, training options, and use in biological investigations, which we are constantly expanding and improving.

Technical facts

- Max. radial acceleration of +6 Gz at outer perimeter
- Radius: 380 cm
- Max. loading capacity: 800 kg
- Max. onset rate: 0.2 g/s
- Number and type of nacelles: 4 multifunctional gondolas
- Radius of nacelles adaptable within 200 cm (also during centrifugation)
- Centrifugation and examination of up to 4 test participants simultaneously
- Subject height 150 cm to max. 210 cm
- Monitoring and recording of various parameter, such as ECG, blood pressure, heart rate, arterial oxygenation, spirometry, electromyography
- Physical training, such as: squats, rowing, vibration training, cycling or plyometric exercises
- Dynamics of movement can be monitored by a motion capture system and two triaxial power measuring platforms
- Ultrasound examination while spinning either manually or remotely controlled via a robot-guided system to study the effects on heart and vessels
- Virtual Reality platform
- Swing-out platforms for microscopes and hardware (life sciences, material physics)
- Hyperscope – Centrifuge microscope – for live cell imaging under hyper-g



M1 DLR Short-Arm Centrifuge at :envihab

M2
Baro Laboratory/preventative and rehabilitation laboratory (Module 2 at :envihab)

At the Baro Laboratory we conduct research into the health and performance of people who live and work in difficult conditions. We carry out experiments under a range of atmospheric conditions, allowing the simulation of aviation, aerospace and mountaineering scenarios. With a total area of 110 m^2, variable space layout, pressure-reduced sanitary facilities, and a personnel air lock, Module 2 offers the opportunity to carry out long-term medical studies on test subjects under reduced pressure (to a minimum of 300 mbar, or 9,000 m altitude). In addition, it allows the deployment of large experimental setups and aircraft subsystems. The aim of the research is to examine how people are affected by specific environmental influences in aviation and aerospace scenarios to develop suitable countermeasures.

Technical facts

- Size: 110 m^2
- Ambient pressure can be reduced to min. 300 mbar (9,100 m)
- Reduction of oxygen fraction at normal pressure to min. 8 % (equivalent to 7,500 m); enrichment with carbon dioxide up to 3 %
- Individual control of temperature and humidity
- Man-rated pressure lock
- 7 labs can be freely configured, total area 200 m^2
- Decrease of oxygen down to 8 % in 5 h (25,000 ft)
- Enrichment with carbon dioxide up to 3 %, change per hour 1 %
- Temperature and humidity independently adjustable

M3
Living and simulation facility/residential research facility (Module 3 at :envihab)

The living and simulation area of the research facility :envihab is a highly complex and completely unique residential research facility. It offers optimal conditions for researching various aspects of aerospace medicine with up to 12 participants in individual rooms. Across a total area of 364 m^2, this large-scale research facility can be used to research aspects of human physiology over long periods of time under strictly controlled environmental conditions. Factors such as ambient light, temperature, atmosphere etc. can be varied to suit study requirements. The module is suitable for conducting bed-rest and clinical studies, as well as investigating reactions to a laltered atmospheres, or the effect of ambient light.

Technical facts

- 12 individual rooms and a living room, total area 364 m^2
- Reduction of oxygen to min. 8 % in 5 h (25,000 ft)
- Enrichment with carbon dioxide up to 3 %
- Control of light intensity in each room in the range of 3 and 1,000 lux
- Blood sampling during sleep
- Temperature and humidity independently adjustable
- Kitchen for metabolic nutrition
- Blood and Urin Lab
- Foot distance to PET-MRI, pressure chamber and Short-Arm Human Centrifuge – easily connected to all :envihab research facilities

M3 Dining and living area with access to the metabolic kitchen (right)

M4
3T Positron emission and magnetic resonance tomograph (PET-MRI) (Module 4 at :envihab)

The PET-MRI at :envihab helps elucidate physiological changes during head-down tilt bed rest, altered atmosphere, sleep deprivation, or space missions. Observed effects range from changes in brain connectivity to advanced cardiovascular and metabolic imaging findings. A key advantage is its integration into the :envihab research laboratory, with immediate proximity to the research ward (M3), Baro Module (M2), and Psychology Module (M5). We recently expanded our capabilities with a dedicated 3T MRI (see below). These imaging resources and our expertise are crucial for our interdisciplinary research program and attract collaboration partners from academia and industry. Third-party funding comes from space agencies and industrial partnerships (e.g., pharmaceutical companies, contract research organizations).

Technical facts

- Siemens Biograph mMR; whole body 3 Tesla MRI with integrated PET
- Combination of PET (positron emission tomography) and MRI (magnetic resonance imaging), both systems can be used simultaneously
- Muscular fat and water content quantification
- Liver fat content quantification
- MR-compatible thigh- and calf ergometer
- Special MRI procedures: sodium imaging (^{13}N), phosphorus spectroscopy (^{31}P), carbon (^{13}C) spectroscopy, perfusion and diffusion measurement and functional imaging (fMRI)
- PET nuclide: ^{18}F fluoride tracer
- Wedges for head-down tilt brain acquisitions
- Possibility of breathing gas mixing via a reservoir and a breathing mask
- Lower body negative pressure for brain and cardiac scans

M5
Psychology laboratory (Module 5 at :envihab)

In the Psychology Laboratory, we investigate how extreme working conditions (for example isolation and stress) can affect human health and performance, and develop countermeasures with applications on Earth. During "the Direct Return" of European astronauts from the ISS, the astronauts and mission crew stay in this module. With its equipment and location, this offers both a living area and control centre with excellent conditions for scientific and medical examinations.

Technical facts

- Two separated areas, connected by a passage, total area 258 m^2
- One area specially soundproofed (130 m^2)
- Isolation and privacy conditions for up to 6 test subjects in parallel
- Temperature and humidity independently adjustable
- Surveillance system with up to 45 Cameras and additional audiomonitoring
- Intercomsystem with additional mobile Beltpack-Units
- Atmospheric conditioning: temperature 17 °C to 30 °C; humidity 40 % to 70 %; Oxygenlevel ~21 % to 7,5 % (normobar); CO_2 level ~0,04 to 3 %

M6
Biology Laboratory (Module 6 at :envihab)

The molecular and microbiology laboratories are part of the core medical area at :envihab and allow direct investigation of microbial diversity within the inhabited, closed parts of the research unit. Modern molecular methods can be completed in the laboratories; the facility also provides gene laboratories and clean rooms. Microbiological and molecular biological analysis is carried out with a strong focus on the human microbiome. Furthermore, microbial space experiments are prepared and evaluated, and space hardware is examined according to planetary protection regulations.

Technical facts

- Five laboratory rooms
- Experiment preparation room
- ISO class 8 clean room
- Genetic laboratory safety level 1
- Professional microbiological lab equipment (e.g. microscopes, real-time thermocycler for quantitative polymerase chain reaction (qPCR), automated electrophoresis unit (Tape Station), MiSeq Sequencing System, Nanopore Sequencing)

Further research facilities and laboratories

Space Simulation facilities

At the Space Simulation facilities, we perform hardware tests for space experiments, mission preparation as well as ground-based simulation and we support for decision-making on Planetary Protection. We exposure (micro)biological samples and organisms and simulate space and environmental parameters such as vacuum, defined pressures, defined gases, temperature, temperature curves, X-rays, ultraviolet (UV) radiation, and also extraterrestrial (LEO) UV radiation with wavelength s longer 200 nm. The facility is used by DLR Applied Aerospace Biology and Radiation Biology, DLR MUSC, universities, research institutions, ESA as well as in collaboration with NASA and JAXA. There is a wide range of applications due to various vacuum recipients of different sizes. Very low pressures are possible at this facility.

Technical facts

- 93 m^2 technical simulation and exposure lab, genetic laboratory S1, biohazard laboratory S2
- 7 vacuum recipients, 5 with temperature controlled cold plates/shrouds, 5 with rotary vane pumps, 3 with additional ion getter pumps
- Pirani cold cathode pressure measurement systems
- 4 solar simulators, Deuterium, Mercury, Xenon lamps
- Double monochromator UV spectroradiometer with calibrated calibration UV lamp
- X-ray facility with CO_2 and N_2 supply
- 3 cryostats, thermistors, feed-back control systems
- Crane, red light
- Biosafety cabinets, cell culture and fluorescence microscope, and CO_2 incubator
- Anaerobic workbench in adjacent microbiology laboratories
- Hypoxia workstation in nearby cell culture laboratories
- Minus 80 °C freezer

Baromedical Laboratory II

The facility consists of a pressure chamber complex and a separate low-pressure chamber for simulating altered pressure and atmospheric conditions, as well as closed atmospheric cycles.

The facility is used to research the effects of extreme pressure conditions and altered atmospheric composition on human health; this has applications in space and air travel, as well as mountaineering. It is possible to simulate working conditions in aircraft and spacecraft realistically in order to study the resulting stresses to which pilots, passengers and astronauts are subjected.

Technical facts

- Ambient pressure range between min. 0.01 bar (absolute pressure) and 1 bar
- Variable gas composition, e.g. substitution of inert-gas components or enrichment of O_2 or CO_2 fraction
- Rapid pressure changes of up to 0.5 bar/s
- Seats for 6 test subjects
- Chamber: length 2.80 m, diameter 2 m
- airlock: length of 0.8 m, diameter of 1.50 m
- Seats for 6 test subjects Temperature range 15 – 35 °C
- 20 – 80 % relative humidity (adjustable)

Aviation and Space Psychology Test Center

Within the Institute of Aerospace Medicine, the Department of Aviation and Space Psychology runs a test center for aerospace personnel selection in Hamburg. Up to 10,000 applicants are tested each year to check their suitability for aerospace professions such as pilots, air traffic controllers (ATCOs), and astronauts. To this end, applicants' cognitive abilities are assessed at the test center as part of an extensive selection process. Applicants who successfully pass the entire selection process are recommended to the respective clients to start their pilot or ATCO training. Clients of the DLR are German Air Navigation Service Provider, international airlines, European Space Agency, German Federal Police and state police forces, for example. The DLR test procedures are valued for their high scientific standards and the test preparation that DLR provides for all applicants. The DLR selection process, including the computer-based testing phase at the test center, makes a decisive contribution to increasing flight and air traffic safety across the aviation industry.

Technical facts

- 110 test stations in three test rooms

Microgravity research laboratory: Micro-G Lab

In the Micro-G Lab, we cultivate and examine cell cultures, organoids, spheroids, and organisms under altered gravity conditions. This large-scale facility allows a fundamental analysis of how biosystems, at the cellular level, perceive and adapt to (altered) gravity. By altering the effective force of gravity, weightlessness is simulated on ground using 2D clinostats. In specialized centrifuges, we expose biological systems to increased gravity.

Data obtained on the ground are validated by experiments under real microgravity conditions, e.g. in drop tower experiments, in parabolic flights, with sounding rockets, on board the ISS (in the Biolab or FLUMIAS-ISS), commercial free-flyers or on-board satellites.

The microgravity research laboratory provides a unique and extensive toolset for ground-based altered gravity research. It is used by DLR-internal groups, cooperation partners and, as part of the ESA Ground-Based Facilities program, by scientists all over Europe.

Technical facts

2D clinostats – simulation of weightlessness

- 2D Pipette-Clinostat – exposure of e.g. cell suspensions
- 2D Slide Flask Clinostat – exposure of e.g. adherent cells
- 2D Ibidi Channel Slide Clinostat – exposure of e.g. adherent cells
- 2D 3.5 cm Dish Clinostat – exposure of e.g. adherent cells
- 2D Fluorescent Clinostat Microscope – live-cell imaging
- 2D Submersed Clinostat – exposure of aquatic biosystems
- 2D Photomultiplier Clinostat – measurement of online kinetics of cellular activities
- 2D Organoid Clinostat – irradiation with X-rays or heavy ions during clinorotation

Random Positioning Machine to randomize the influence of gravity and for analyzing the effect of shear forces acting on cells (different modes of operation and speed rates)

Centrifuges: 1–50 *g; controlled environmental conditions; hardware for cultivation and video observation of biosamples

- MuSIC – Multi-Sample Incubator Centrifuge – long-term exposure to physiological levels of hypergravity, parabolic flight hypergravity control, sounding rocket hypergravity control, ISS upload hypergravity control
- Hyperscope – Centrifuge microscope – for long-term live cell imaging under hyper-gravity
- Fully equipped cell biology labs – cultivation/preparation of cell culture samples, spheroids, organoids, primary cells
- FLUMIAS Science Reference Model – Live-cell high-resolution fluorescence microscope for experiment preparation and validation of live-cell imaging campaigns on the ISS

3T Magnetic resonance tomograph

The 3T Magnetic resonance tomograph is a state-of-the-art scanner equipped with a high-performance gradient system that allows the application of the newest applications in neuro and cardiac MRI as well as in MRI of the musculature, metabolism and nuclear magnetic resonance (NMR) spectroscopy.

The main task of the MRI is the detection of changes in different organ systems caused by various environmental influences like bed rest, head-down tilt, hypoxia, hypercapnia and sleep deprivation, such as those caused by space missions and accelerations (artificial gravity, centrifuge).

The translation of experience gained in space medicine into clinics is a focus of our research and initial studies have been carried out in close cooperation with university partners.

A special feature is the real-time MRI, with which the beating heart can be recorded while breathing freely.

As pure research scanner, the users are internal and external researchers, which can be cooperation partners from the clinics or universities. Third-party funding can come via the space agencies or can be cooperative pharmaceutical research.

Technical facts

- Siemens VIDA whole body 3 Tesla MRI
- State-of-the-art neuro and cardiac imaging
- Subcortical functional MRI of the autonomic nervous system
- Special MRI procedures:
    - Real-time MRI capable of acquisition up to 20 ms per image
    - ^{13}C spectroscopy

V. Scientific activities

V.1 Teaching activities

2024		
Name	**University**	**Subject**
Aeschbach, Daniel	Universität Bonn	Cognitive Neuroscience
Anken, Ralf	Universität Hohenheim	Weltraumbiologie
Bartels, Susanne	RWTH Aachen	Effects of (air) traffic noise on humans (Gastvorlesung)
Beblo-Vranesevic,Kristina	University of Applied Sciences Bonn-Rhein-Sieg	Mikrobiologie
Berger, Thomas	FH Aachen, Luft- und Raumfahrttechnik	Space Radiation
Berger, Thomas	Universität Stuttgart	Space Radiation
de Boni, Laura	Universitätklinikum Bonn	Neurologie
Elmenhorst, Eva-Maria	RWTH Aachen	Aviation and Travel Medicine
Elmenhorst, Eva-Maria	RWTH Aachen	Space Medicine
Frett, Timo	University of Applied Sciences Bonn-Rhein-Sieg	Elective Planning and implementation of human physiological studies
Gerlach, Darius	Universität Köln	Physiologie
Goerke, Panja	University of Applied Sciences Wedel	Communication skills
Hauslage, Jens	Tierärztliche Hochschule Hannover	Gravitationsbiologie
Hauslage, Jens	La Trobe University Melbourne, Australia	Gravitationsbiologie
Hellweg, Christine	Universität Bonn	Radiopharmacy
Hellweg, Christine	Universität Bonn	Strahlenschutzkurs
Hellweg, Christine	Universität Mainz	Masterstudiengang Epidemiologie
Hellweg, Christine	Freie Universität Berlin	Immunologie
Hellweg, Christine	Freie Universität Berlin	Pathologie
Heußer, Karsten	Universität zu Köln	Physiologie
Liemersdorf, Christian	Universität Bonn	Molekulargenetik
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Advanced Methods in Health
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Business Systems in Health Care
Melcher, Wiebke	Hochschule der Bundesagentur für Arbeit	Berufliche Eignungsdiagnostik
Pesta, Dominik	Universität zu Köln	Medizin
Pustowalow, Willi	University of Applied Sciences Bonn-Rhein-Sieg	Informatik
Schudlik, Kevin	International School of Management	Statistische Analysen / Medienpsychologie
Stelling, Dirk	Hochschule Fresenius	Differenzielle Psychologie / Testen und Entscheiden
Stern, Claudia	TU Braunschweig	Luft- und Raumfahrtmedizin
Stern, Claudia	International Space University, France	Human Vision System
Stern, Claudia	Universität der Bundeswehr München	Raumfahrtmedizin
Stern, Claudia	ESAM Academy	Aerospace Medicine
Stern, Claudia	European School of Aviation Medicine, Frankfurt	Aviation Ophthalmology
Tank, Jens	Medizinische Hochschule Hannover	Propädeutik
Utesch, Katharina	Universität Münster Professional School	Führung und Personalmanagement
Zange, Jochen	Universität zu Köln	Medizin
Zinn, Frank	Universität Hamburg	Diagnostik

2023		
Name	**University**	**Subject**
Aeschbach, Daniel	Universität Bonn	Cognitive Neuroscience
Anken, Ralf	Universität Hohenheim	Space Biology
Belser, Nadine	Universität Hamburg	Psychology
Berger, Thomas	International Space University, France	Master of Space Studies
Clemen, Christoph	Universität zu Köln	Biochemistry and Molecular Biology
de Boni, Laura	Universitätsklinikum Bonn	Neurology
Elmenhorst, Eva-Maria	RWTH Aachen	Aviation and Travel Medicine
Elmenhorst, Eva-Maria	RWTH Aachen	Space Medicine
Frings-Meuthen, Petra	International Space University, France	Nutrition in Space
Frings-Meuthen, Petra	Universität Kiel	Nutrition in Space
Gerlach, Darius	Universität zu Köln	Physiology
Goerke, Panja	University of Applied Sciences Wedel	Communication skills
Hauslage, Jens	Medizinische Hochschule Hannover	Propaedeutics
Hauslage, Jens	Tierärztliche Hochschule Hannover	Gravitational Biology
Hauslage, Jens	La Trobe University, Australia	Gravitational Biology
Hellweg, Christine	Universität Bonn	Radiation Protection
Hellweg, Christine	Freie Universität Berlin	Immunology
Hellweg, Christine	Freie Universität Berlin	Pathology
Hellweg, Christine	Universität Bonn	Radiopharmacy
Hemmersbach, Ruth	Universität Bonn	Gravitational Biology
Heußer, Karsten	Universität zu Köln	Physiology
Liemersdorf, Christian	Universität Bonn	Molecular Genetics
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Health Telematics
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Literaturseminar Digital Health
Mittelstädt, Justin Maximilian	Universität Hamburg	Psychological assessment
Möller, Ralf	University of Applied Sciences Bonn-Rhein-Sieg	Microbiology
Möller, Ralf	University of Applied Sciences Bonn-Rhein-Sieg	Bachelor program: Space Microbiology
Möller, Ralf	University of Applied Sciences Bonn-Rhein-Sieg	Master program: Space Biotechnology / Medicine
Oubaid, Viktor	Universita San Raffaele, Italy	Advanced course in Aviation Psychology
Pesta, Dominik	Universität zu Köln	Research Track: Critical Reading
Pesta, Dominik	Universität zu Köln	Physiology Practical Course
Pfander, Boris	Universität zu Köln	Medicine
Pfander, Boris	Universität zu Köln	Research Seminar at the Institute of Genome Stability
Pfander, Boris	Universität zu Köln	Journal Club at the Institute of Genome Stability
Pfander, Boris	Universität zu Köln	Biology / Molecular Mechanisms of Human Disease
Pfander, Boris	Universität zu Köln	Medicine / Research Track / DNA breaks
Pustowalow, Willi	University of Applied Sciences Bonn-Rhein-Sieg	Computer Science
Stelling, Dirk	Hochschule Fresenius	Psychology
Stelling, Dirk	Hochschule Fresenius	Psychology
Stelling, Dirk	Hochschule Fresenius	Psychology
Stern, Claudia	Technische Universität Braunschweig	Aerospace Medicine
Stern, Claudia	International Space University, France	Human Visual System
Stern, Claudia	European School of Aviation Medicine	Ophthalmology
Zinn, Frank	Universität Hamburg	Psychology

2022		
Name	**University**	**Subject**
Aeschbach, Daniel	Harvard Medical School	Sleep Medicine
Berger, Thomas	International Space University, France	Radiation Physics
Berger, Thomas	University of Applied Sciences Wedel	Radiation Physics
Berger, Thomas	Universität Stuttgart	Radiation Physics
Berger, Thomas	University of Applied Sciences Bonn-Rhein-Sieg	Radiation Physics
de Boni, Laura	Universitätklinikum Bonn	Neurologie
Elmenhorst, Eva-Maria	RWTH Aachen	Flug-/Reisemedizin
Elmenhorst, Eva-Maria	RWTH Aachen	Raumfahrtmedizin
Gerlach, Darius	Universität zu Köln	Cardiovascular physiology for midwife bachelor students
Gerlach, Darius	Universität zu Köln	Physiology practical training for medical students
Goerke, Panja	University of Applied Sciences Wedel	Soft Skills
Hellweg, Christine	Universität Bonn	Radiation Protection Course: Radiation Biology
Hellweg, Christine	Freie Universität Berlin	Immunology
Hellweg, Christine	Freie Universität Berlin	Pathology
Hellweg, Christine	Universität Bonn	Radiopharmacy: Radiation Biology
Herzog, Merle	Universität Hamburg	Psychology
Heusser, Karsten	Universität zu Köln	Physiology
Kölzer, Ana	University of Applied Sciences Wedel	Soft Skills
Liemersdorf, Christian	Universität Bonn	Molekulargenetik
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Health Telematics
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Literaturseminar Digital Health
Mittelstädt, Justin	Universität Hamburg	Psychology
Möller, Ralf	University of Applied Sciences Bonn-Rhein-Sieg	Microbiology
Rittweger, Jörn	Universität zu Köln	Blockseminar Pädiatrie
Schudlik, Kevin	International School of Management (ISM), Hamburg	Psychology & Management
Schulze Kissing, Dirk	Hochschule Fresenius	Psychology
Stelling, Dirk	Hochschule Fresenius	Psychology
Stern, Claudia	TU Braunschweig	Aerospace Medicine
Stern, Claudia	ISU Strasbourg	Human Visual System
Stern, Claudia	Universität der Bundeswehr München	Aerospace Medicine
Stern, Claudia	School of Aviation Medicine	Ophthalmology
Tank, Jens	Medizinische Hochschule Hannover	Propaedeutics
Zinn, Frank	Universität Hamburg	Psychology

2021		
Name	**University**	**Subject**
Aeschbach, Daniel	Harvard Medical School	Sleep Medicine
Anken, Ralf	Universität Hohenheim	Zoology
Berger, Thomas	International Space University, France	Radiation Physics
Berger, Thomas	University of Applied Sciences Aachen	Radiation Physics
Berger, Thomas	Universität Stuttgart	Radiation Physics
Berger, Thomas	University of Applied Sciences Bonn-Rhein-Sieg	Radiation Physics
Clemen, Christoph	Universität zu Köln	Biochemistry & Molecular Genetics
Clemen, Christoph	Ruhr-Universität Bochum	Translational Myology
Elmenhorst, Eva-Maria	RWTH Aachen	Aviation and Travel Medicine

Elmenhorst, Eva-Maria	RWTH Aachen	Space Medicine
Gerlach, Darius	Universität zu Köln	Cardiovascular Physiology for midwife bachelor students
Gerlach, Darius	Universität zu Köln	Physiology practical training for medical students
Goerke, Panja	University of Applied Sciences Wedel	Soft Skills
Hauslage, Jens	Tierärztliche Hochschule Hannover	Gravitational Biology
Hauslage, Jens	University of Applied Sciences Bonn-Rhein-Sieg	Gravitational Biology, Botany
Hauslage, Jens	International Space University, France	Gravitational Biology and Biological Life Support
Hauslage, Jens	IPEN Sao Paulo	Gravitational Biology and Biological Life Support
Hellweg, Christine	Universität Bonn	Radiation Protection Course: Radiation Biology
Hellweg, Christine	Freie Universität Berlin	Immunology
Hellweg, Christine	Freie Universität Berlin	Pathology
Hellweg, Christine	Universität Bonn	Radiopharmacy: Radiation Biology
Hemmersbach, Ruth	Universität Bonn	Zoology & Gravitational Biology
Herzog, Merle	Universität Hamburg	Psychology
Heusser, Karsten	Universität Köln	Physiology
Kölzer, Ana	University of Applied Sciences Wedel	Soft Skills
Liemersdorf, Christian	Universität Bonn	Molecular Genetics
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Health Telematics
Lindlar, Markus	University of Applied Sciences Bonn-Rhein-Sieg	Literature seminar Digital Health
Mittelstädt, Justin	Universität Hamburg	Psychology
Möller, Ralf	University of Applied Sciences Bonn-Rhein-Sieg	Microbiology
Rittweger, Jörn	Universität Köln	Seminar paediatrics
Schudlik, Kevin	Int. School of Management (ISM), Hamburg	Psychology & Management
Schulze Kissing, Dirk	Hochschule Fresenius	Psychology
Stelling, Dirk	Hochschule Fresenius	Psychology
Stern, Claudia	Technische Universität Braunschweig	Luft- und Raumfahrtmedizin
Stern, Claudia	International Space University, France	Human Visual System
Stern, Claudia	Universität der Bundeswehr München	Raumfahrtmedizin
Stern, Claudia	School of Aviation Medicine	Ophthalmology
Tank, Jens	Medizinische Hochschule Hannover	Propaedeutics
Zinn, Frank	Universität Hamburg	Psychology

V.2 Graduations

Supervised Doctoral Students

2024			
University	**Space**	**Aviation**	**Traffic**
Deutsche Sporthochschule	3		
Eindhoven Univ. of Technology, the Netherlands	1		
ETH Zürich	1		
University of Applied Sciences Bonn-Rhein-Sieg	1		
La Trobe University Melbourne, Australia	1		
Radboud University, the Netherlands	1		
RWTH Aachen	4	3	1
University of Applied Sciences Köln	3		
Tierärztliche Hochschule Hannover	1		
University of Applied Sciences Braunschweig	1		
University of Applied Sciences Darmstadt	1		
University of Applied Sciences Dresden		1	
Universität Bochum	1		
Universität Bonn	3		
Universität Düsseldorf		1	
Universität Duisburg-Essen	1		
Universität Gießen	1	2	
Universität Hamburg	1		
Universität Jyväskyä, Finland	1		
Universität zu Köln	6		
Universität Oldenburg	1		
University of Leiden, the Netherlands		1	

Doctorates

2024			
University	**Space**	**Aviation**	**Traffic**
Universität Bonn	1		
Universität Duisburg-Essen	1		
Universität Jena		2	
Universität zu Köln	2		
University of Applied Sciences Dresden		1	

Bachelor Degrees

2024			
University	**Space**	**Aviation**	**Traffic**
Univ. of Applied Sciences Bonn-Rhein-Sieg	7	2	3
Universität Frankfurt	2		
RWTH Aachen	1		
Universität Bonn	1	1	1

Diploma Theses/Master Degrees

2024			
University	**Space**	**Aviation**	**Traffic**
Universität Mainz	1		
University of Applied Sciences München	1		
Universität Düsseldorf	3		
Universität Bamberg		1	
Hochschule Reutlingen		1	
Univ. of Applied Sciences Bonn-Rhein-Sieg	2	2	
Universität Düsseldorf	1		
Universität Bonn	2		
Universität Bochum	2		
International Space University	1		

Supervised Doctoral Students

2023			
University	**Space**	**Aviation**	**Traffic**
Universität Giessen		1	
Radboud University, the Netherlands	1		
Universität Bochum	1		
Technische Universität Darmstadt	1		
Technische Universität Braunschweig	1		
University Bern, Switzerland	1		
Universität Bonn	5		
Universität zu Köln	11		
Universität Duisburg-Essen	2		
Universität Düsseldorf		1	
Universität Oldenburg	1		

Doctorates

2023			
University	**Space**	**Aviation**	**Traffic**
Medizinische Hochschule Hannover	1		
Manchester Metropolitan University	1		
Universität Bonn	1		
Universität zu Köln	2		
Universität Bochum	1		

Bachelor Degrees

2023			
University	**Space**	**Aviation**	**Traffic**
Universität Düsseldorf	2		
University of Applied Sciences Aachen	1		
Univ, of Applied Sciences Bonn-Rhein-Sieg		1	1

Diploma Theses/Master Degrees

2023			
University	**Space**	**Aviation**	**Traffic**
Hochschule Fresenius		1	
Hochschule Rhein-Waal Kleve	3		
Sorbonne University, France	1		
Technische Hochschule München	1		
Universidade d Coimbra, Portugal	1		
Universität Mainz	1		
Universität Bonn	1		
Universität zu Köln	1		
Universität Geisenheim	1		
University of Naples, Italy	1		
Vrije Universiteit Amsterdam, the Netherlands	1		

Supervised Doctoral Students

2022			
University	**Space**	**Aviation**	**Traffic**
Universität Bonn	2		
Medizinische Hochschule Hannover	3		
Universität Hamburg	3		
Universität Göttingen	1		
RWTH Aachen	5	3	
Universität Salzburg, Austria		1	
University of Leiden, the Netherlands		1	
Universität zu Köln	3		
Universität Düsseldorf		2	
Universität Gießen	1	2	1
Universität Bochum			
Universität Duisburg-Essen	2		
Technische Universität Braunschweig	1	1	
Universität Oldenburg	1		
Radboud University, the Netherlands	1		

Doctorates

2022			
University	**Space**	**Aviation**	**Traffic**
LMU München	1		
Medizinische Hochschule Hannover	2		
TU Darmstadt	1		
Universität zu Köln	1		

Bachelor Degrees

2022			
University	**Space**	**Aviation**	**Traffic**
Hochschule Albstadt-Sigmaringen	1	1	1
Universität Bonn	1		
Univ. of Applied Sciences Bonn-Rhein-Sieg	2	1	1
Universität Düsseldorf	1		

Diploma Theses/Master Degrees

2022			
University	**Space**	**Aviation**	**Traffic**
Universität Frankfurt	1		
University of Applied Sciences Aachen	1		
Technische Hochschule Regensburg	1		
Universität Bonn	2	1	1
University of Zagreb, Croatia	1		
Universität Bonn	1		
Radboud University, the Netherlands	1		

Supervised Doctoral Students

2021			
University	**Space**	**Aviation**	**Traffic**
Universität Bern, Switzerland	1		
Universität Bonn	3		
Medizinische Hochschule Hannover	3		
Universität Hamburg	3		
Universität Göttingen	1		
RWTH Aachen	5	3	
Universität Salzburg, Austria		1	
University of Leiden, the Netherlands		1	
Universität zu Köln	5		
Universität Düsseldorf		2	
Universität Gießen	1	2	1

Universität Bochum	1		
Universität Duisburg-Essen	2		
Technische Universität Braunschweig	1	1	
Universität Oldenburg	1		
Radboud University, the Netherlands	1		

Doctorates

2021			
University	**Space**	**Aviation**	**Traffic**
Medizinische Hochschule Hannover	2		
Darmstadt	1		
Georg-August-Universität Göttingen	1		

Bachelor Degrees

2021			
University	**Space**	**Aviation**	**Traffic**
Hochschule Albstadt-Sigmaringen	1	1	1
Universität Bonn	5		
Univ. of Applied Sciences Bonn-Rhein-Sieg	2	1	1
Universität Düsseldorf		1	
FH Aachen	1		
Universität Bochum	1		

Diploma Theses/Master Degrees

2021			
University	**Space**	**Aviation**	**Traffic**
Goethe Universität Frankfurt	1		
FH Aachen	1		
OTH Regensburg	1		
Universität Bonn	2	1	1
University of Zagreb, Croatia	1		
Universität Bonn	1		
Radboud University, the Netherlands	1		

V.3 Scientific exchange

2024	14 guest scientists (Czech Republic, India, USA)
2023	14 guest scientists (Italy, France, Portugal)
2022	11 guest scientists (Brazil, Italy, UK)
2021	14 guest scientists (Canada, Italy, France, Spain, UK)

V.4 Awards

2024

- Franca Arndt: EANA Space Factor Student Contest 1st Place
- Darius Gerlach: Travel Award American Autonomic Society conference in Santa Barbara, USA, by AGANS (Arbeitsgemeinschaft Autonomes Nervensystem)
- Noah Klett: 32. Jahrestagung der Deutschen Gesellschaft für Schlafforschung und Schlafmedizin e.V.
- Yannick Lichterfeld: ELGRA Best Presenter Award, Liverpool
- Yannick Lichterfeld: ELGRA Best Poster Award, Liverpool
- Jorge Manuel: Streeten Travel Fellowship Award
- Jorge Manuel: Travel Award American Autonomic Society conference in Santa Barbara, USA, by AGANS (Arbeitsgemeinschaft Autonomes Nervensystem)
- Stefan Möstl: Poster Award American Autonomic Society conference in Santa Barbara, USA
- Dominik Pesta: TEB Distinguished Editorial Support Award, Editorial Board Meeting Congress Center Hamburg
- Johanna Piepjohn: Budde-Preis
- Mona Plettenberg: 48th European Radiation Research Society Meeting (ERRS)
- Alessa Schiele: EANA Space Factor Student Contest 2nd Place
- Anna Seemüller: The EAAP35 Best Paper Award European Association for Aviation Psychology, (Athens, Greece
- Claudia Stern: Goldene Ehrennadel 62. Jahrestagung der Deutschen Gesellschaft für Luft- und Raumfahrtmedizin
- Sarah Weidenfeld: 32. Jahrestagung der Deutschen Gesellschaft für Schlafforschung und Schlafmedizin e.V.
- Tommaso Zaccaria: Albrecht-Ludwig-Berlinger-Award

2023

- Ines Figueiredo: EANA 2023 Space factor Student Contest 2nd Place (MSx Awardees)
- Carolin Krämer: EANA 2023 Space factor Student Contest 2nd Place (PhD Awardees)
- Afonso Mota: EANA 2023 Space factor Student Contest 2nd Place (MSx Awardees)
- Team NUNOS (Tim Paulke; Fabian Mierbach; H. Sommerlad; Johannes Stock):
  - Innovationspreis Startup-Days der Andreas Hermes Akademie (AHA), Internationale Grüne Woche
  - Start-up-Preis Growth Alliance Networking Summit (GANS), Landwirtschaftliche Rentenbank
  - 3. Platz Bio-Gründer Wettbewerb, Bio-Security Management GmbH
  - Gründungspreis Gründungswettbewerb – Digitale Innovationen, Bundesministerium für Wirtschaft und Energie (BMWK)
- Bruno Pavletic: Best Poster Award at 8th European Congress of Virology, Gdansk
- Bruno Pavletic: Poland 3rd Poster Award at the DGLRM Conference, Cologne "Phages as tools in spaceflight virology research"
- Johanna Piepjohn: 1st Poster Award at VAAM special group "Space Microbiology" Workshop BigBang…Microbes! Workshop on Cultivation of the Uncultivationables!, Cologne; "Horizontal gene transfer in space – preparation of the ISS experiment Bacterial Conjugation"
- Petra Rettberg: 2nd Poster Award at the DGLRM Conference, Cologne; "Is the repair kinetics of radiation induced DNA damages influenced by microgravity? Preparation of the space experiment LUX-in-Space"
- Dorothee Steven: Rainer-Kowoll-Nachwuchspreis
- Alena Warkentin: 2nd Poster Award at VAAM special group "Space Microbiology" Workshop BigBang…Microbes! Workshop on Cultivation of the Uncultivationables!, Cologne; "Beyond Gravity: Using gut microbiome insights in simulated weightlessness via SANS Studies as a first step to improve health in Astronauts"

2022

- Hinnerk Eißfeldt: EAAP Honorary member
- ESA astronaut selection team: ESA Teamwork Excellence Award Psychology Department: European Association for Aviation Psychology (EAAP) Award
- Yannick Lichterfeld: ELGRA Best Presenter Award, Granada, Spain
- Theresa Schmakeit: ELGRA Best Poster Award, Granada, Spain
- Laura Weber; Tim Paulke; Johannes Stock: 3rd place business plan competition KUER.NRW

2021

- Kristina Beblo-Vranesevic: Best Presentation Award, European Astrobiology Network Association (EANA) Virtual Conference
- Marta Cortesao: Add-on Fellowship for Interdisciplinary Life Science 2021 der Joachim Herz-Stiftung
- Darius A. Gerlach; Jorge Manuel; Alex Hoff; Karsten Heusser; Jens Jordan;Jens Tank: High Impact Paper for Summer 2021 in the category of basic science of the journal "Hypertension": "Medullary And Hypothalamic Functional Magnetic Imaging during Acute Hypoxia in Tracing Human Peripheral Chemoreflex Responses"
- Maria Magliulo: Three Minute Thesis competition, University of Essex
- Hector Hugo Palomeque Dominguez: 4th place of the Space Factor Contest, EANA 2021
- Petra Rettberg: International Astronautical Federation (IAF) Distinguished Service Award
- Laura Weber; Tim Paulke; Johannes Stock: 3rd place business plan competition KUER.NRW

VI. Abbrevations

^{18}F-FDG-PET: Fluorine-18 Fluorodeoxyglucose Positron Emission Tomography
4D: four-dimensional

A

ADAC: Allgemeiner Deutscher Automobil-Club
AeMC: Aeromedical Centre
AGBRESA: 60 days ESA-NASA-DLR bed rest study with short arm human centrifuge (SAHC)
AhR: Aryl Hydrocarbon Receptor
AI: Artificial Intelligence
AOK: Allgemeine Ortskrankenkasse
ARS: Acute Radiation Syndrome
ATCO: Air Traffic Controller
ATHLETIC: AstronauT HeaLth EnhancemenT Integrated Countermeasure

B

BIA: Bioelectrical Impedance Analysis
BiG C.R.O.P.®: Biologische Gülleaufbereitung mit dem C.R.O.P.®-Filter
BIOFILMS: Biofilm inhibition on flight equipment and on board the ISS using microbiologically lethal metal surfaces
BMDS: Bundesministerium für Digitales und Staatsmodernisierung
BMUKN: Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit
BMV: Bundesministerium für Transport
BMVG: Bundesministerium der Verteidigung
bpm: Beats per minute

C

CAD: Crew Active Dosimeter
CAU: Christian-Albrechts-Universität zu Kiel
CECAD: Cologne Excellence Cluster on Aging-associated Diseases
CHRNA3 gene: Candidate gene for Chronic Obstructive Pulmonary Disease identified by Genome-wide association studies
CI: Confidence interval
C.R.O.P. ®: Combined Regenerative Organic food Production. Biofilter technology developed by DLR for degradation and modification of nitrogen rich wastewaters in closed systems and in the agricultural sector towards a fertilizer solution for plant nutrition. Degradation of xenobiotica and medication residuals in wastewater.
CSA: Canadian Space Agency

D

dB: Decibel
DFD: German Remote Sensing Data Center
DIN EN ISO 9001: Standard in the field of quality management
DNA: Deoxyribonucleic acid
DOSIS 3D: Dose Distribution Inside the ISS 3D
DOSTEL: Measurement of radiation environment inside the COLUMBUS module of ISS in the frame of the DOSIS/DOSIS3D experiments
DSMZ: German Collection of Microorganisms and Cell Cultures

E

EAC: European Astronaut Centre
EASA: European Aviation Safety Agency
EKC: European Knowledge Center
EMS: Electrical muscle stimulation
EMT: Epithelial-mesenchymal transition
:envihab: Environmental habitat
ESA: European Space Agency
Eu:CROPIS: Euglena: Combined Regenerative food Production in space. Spin rotated satellite with lunar and Martian gravity to investigate the impact of reduced gravity on biological life support systems in long-term experiments in space
EULe project: Elektrochemische Nachbehandlung von Recyclingdüngern aus Urin für die Lebensmittelproduktion

F

FAA: Federal Aviation Administration
FiO_2: Fraction of inspired Oxygen
FLUMIAS: DLR high-resolution fluorescence microscope for live-cell imaging
fMRI: Functional MRI

G

GANDALF: DLR Graduate School for Awareness and Fighting of Pandemic Threats
GBF: Ground-based simulations of space conditions (ground-based facilities
GCP: Good Clinical Practice
GCR: Galactic cosmic radiation
GenDG: Federal genome diagnostic act
GSI: Gesellschaft für Schwerionenforschung

H

H2AX: Phosphorylated histone variant
HCT: Hydrochlorothiazide
HDTBR: Head-down tilt bed rest
HIDA: Helmholtz Information and Data Science Academy
HNK: Hydroxynorketamine
hPa: Hectopascal
HypoFon study: Midterm moderate hypoxia and its effects on sleep, pulmonary blood flow, hemorheology, and physical performance in patients with Fontan-circulation
HypoNorm-HIF study: Study on the effects of less pronounced hypoxia combined with drugs stabilizing hypoxia-inducible factors

I

ICAROS study: Study on adaptation to hypoxia from patients with severe pulmonary hypertension
IFATCA: International Federation of Air Traffic Controllers' Associations
iPSCs: Pluripotent stem cells
ISA: Israel Space Agency
ISS: International Space Station
ISO 9000: Set of internationally recognized standards for quality management systems
ISU Strasbourg: International Space University Strasbourg
ITEM Fraunhofer: Fraunhofer Institute for Toxikology and Experimental Medicine

J

JAXA: Japan Aerospace Exploration Agency

K

KNIMS: Kompetenznetzwerk Immobilisationsbedingte Muskelstörungen

L

LAMP: Loop-mediated Isothermal Amplification
LBNP: Lower body negative pressure
LEO: Low Earth Orbit
LMU Munich: Ludwig-Maximilians-University Munich
LOKI: Collaboration of Aviation Operations and AI Systems project
LUNA facility: Simulation of the lunar surface in Cologne
LVAD: Left-ventricular assist device

M

M-42: Radiation detector system for fast and easy radiation measurements
Mapheus®: DLR sounding rocket campaigns
MARE: Matroshka AstroRad Radiation Experiment
MDC Berlin: Max Delbrück Center
MEAs: Multielectrode Arrays
MEDES: Institut de Médecine et de Physiologie Spatiales
mGy/d: Milligray per day
MIT: Massachusetts Institute of Technology
mmHg: Millimeters of mercury
MORABA: Mobile Rocket Base
MP Institute: Max Planck Institute
MRI: Magnetic Resonance Imaging
mSv/d: Millisieverts per day
MUSC: Microgravity User Support Center
MyoCardioGen: Myocardial Regeneration by Hypoxia in Humans

N

NASA: National Aeronautics and Space Administration
Nex4Ex: Novel Exercise Hardware for Exploration
NMDA: N-Methyl-D-Aspartat
NMJs: Neuromuscular junctions
NSCLC: Non-small cell lung carcinoma
NUNOS: Technology that converts human urine into plant fertilizer to grow fresh food in space
NZP: National centrifuge program

O

OCT: Optical coherence tomography

P

PBMCs: Peripheral blood mononuclear cells
PET: Positron emission tomography
PT: Proprioceptive training

R

RAMIS: Measurement of the radiation field onboard the DLR Eu:CROPIS Satellite
REMS: Rapid eye movement sleep
RFA: German Space Agency at DLR
RoSTo: Rolling Stock, long-distance train study on thermal comfort
RWTH Aachen: Rheinisch-Westfälische Technische Hochschule Aachen

S

SAHC: Short-arm human centrifuge
SANS_CM study: Spaceflight-Associated Neuro-Ocular Syndrome Countermeasures study (NASA/DLR bed rest study)
SAS: Space Applications Systems
SCK: Belgian Nuclear Research Center
SEM: Standard Error of the Mean
SMC-study: Sensorimotor countermeasures study (NASA/DLR bed rest study)
SOLIS8: 8 days isolation study (ESA pilot study)
SP: Single pilot
SPE: Sporadic solar particle events
SRM: Science reference module
SSK: Radiation Protection Commission
STED: Stimulated Emission Depletion
STED: Super-Resolution microscopy

T

TAhRget study: Diet-Induced AhR-Dependent Immune Responses
TH Cologne: Technische Hochschule Cologne
TUM: Technical University Munich

U

UAM: Urban Air Mobility
UAS: Unmanned Aircraft System
UAV: Unmanned aerial vehicle
UTSW: University of Texas Southwestern

V

VALIS: Validating ATCO (Air Traffic Controller) Selection and Training

DLR at a glance

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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