

:envihab: Facing intriguing challenges of human spaceflight and inspiring future challenges of medicine on earth – the brand-new research facility of the DLR¹ Institute of Aerospace Medicine of the German Aerospace Center in Cologne, Germany

EnviHab: Enfrentando os intrigantes desafios do voo espacial tripulado e inspirando os futuros desafios da medicina na terra – o mais novo laboratório de pesquisa do Instituto de Medicina Aeroespacial do Centro Aeroespacial Alemão (DLR) em Colônia (Alemanha)

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ABSTRACT: *As a new modularly designed research facility for medical research, :envihab's purpose is to study under strictly standardized conditions the complex problems presented by a closed life-support system (:envihab = environmental habitat) and the interactions between humans and the environment and possible countermeasures. The main goal of :envihab is to contribute through hypothesis-driven research, to scientific insight and technological progress so as to provide solutions to the most important key issues for life on Earth. It will deliver industry-relevant results of scientific progress together with its economic advantages, and will encourage public debate about important future-oriented questions regarding human life. The collected data can then be used as a starting point for future modeling tasks that will be required in all areas of medicine in the future.*

KEYWORDS: *space medicine; ground based research facility; human centrifuge, :envihab.*

RESUMO: *Como um novo centro de projeto modular para experimentação médica, o propósito de :envihab é estudar em condições rigorosamente padronizadas os complexos problemas apresentados por um sistema de suporte de vida fechado (:envihab = habitat ambiental) e as interações entre os seres humanos e o meio ambiente e possíveis contramedidas. O objetivo principal do :envihab é contribuir, através da investigação orientada por hipótese, a percepção científica e do progresso tecnológico, de modo a fornecer soluções para as principais questões mais importantes para a vida na Terra. O :envihab vai entregar resultados relevantes para a indústria do progresso científico,*

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juntamente com suas vantagens econômicas, e incentivar o debate público sobre importantes questões orientadas para o futuro em relação a vida humana. Os dados coletados poderão ser utilizados como um ponto de partida para as futuras tarefas de modelação que serão necessárias em todas as áreas da medicina.

PALAVRAS-CHAVE: *medicina espacial; laboratório de pesquisa terrestre; centrífuga humana; envihab.*

1 Introduction: About DLR – the German Aerospace Center in Cologne, Germany

The German Aerospace Center (DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V., Köln) is the national aeronautics and space research center of the Federal Republic of Germany.

DLR's extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space program. DLR is also the umbrella organization for the nation's largest project execution organization (DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V. Köln 2013).

DLR has approximately 7,700 employees at 16 different locations in Germany with its headquarters in Cologne. DLR comprises 32 institutes and test- and operational facilities. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C. (Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) 2013).

DLR's mission comprises the exploration of Earth and the Solar System and research for protecting the environment. This includes the development of environment-friendly technologies for energy supply and future mobility, as well as for communications and security. DLR's research portfolio ranges from fundamental research to the development of products for tomorrow. In this way, DLR contributes the scientific and technical expertise that it has acquired to the enhancement of Germany as a location for industry and technology. DLR operates major research facilities for its own projects and as a service for clients and partners. It also fosters the development of the next generation of researchers, provides expert advisory services to government and is a driving force in the regions where its facilities are located (DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V. Köln 2013).

2 The DLR Institute of Aerospace Medicine

Within DLR the Institute of Aerospace Medicine is the only research institute that deals with life science questions concerning space flight, aviation and traffic. Our mission is to provide for health

and performance of healthy humans in the mobile society (Institut für Luft- und Raumfahrtmedizin des DLR 2013).

In the future, people will be even more mobile in a highly technological environment: This is true both on Earth and in space. People should and must remain equally healthy and effective, no matter where they find themselves. Thus, at the DLR Institute of Aerospace Medicine we focus on the maintenance of health and performance in healthy people. We think in terms of prevention, with the objective of rendering people capable of facing society's challenges – both today and tomorrow.

Our institute's core tasks are found in the areas of aviation and space medicine and psychology. In these fields we study the selection of suitable individuals for special tasks, but also the response of individuals to conditions which are potentially hazardous to health and job effectiveness. This helps us to draw conclusions about the prevention of general medical disease patterns, on the one hand, and, on the other, to transfer the results to many areas of modern life.

Thus, with regard to providing support for healthy, able-bodied people in today's mobile society, our research focuses on three areas, each of which represents a fundamental task for the future of medicine. To be able to provide appropriate support for astronauts and pilots, it is imperative that we excel in these three areas (Institut für Luft- und Raumfahrtmedizin 2012):

1. Prevention

It is essential to ensure that, even under extreme environmental conditions, healthy top performers remain healthy and able-bodied.

2. Individualization

It is essential to be familiar with the individual characteristics of healthy top performers in order to provide them with optimal care.

3. Remote medical care

It is essential to be able to provide top performers with optimal care even if medical expertise is not present at the location where the problem exists, e. g., on the way to Mars.

The solution of such problems, however, does not require a detour via astronautics since *prevention, individualization* and *remote medical care* also constitute fundamental challenges for the future of medicine here on Earth.

With the commissioning of the new large-scale life science research facility :envihab in early 2014 we will be able to significantly broaden our range of work. The content, but also the overall modular architectural concept of :envihab allows for further research areas to be added in the future, areas which will go far beyond medical research tasks. We can therefore strategically address these research problems whose applications are urgently needed on Earth already today. Their results will be made available as concrete solutions to the field of aviation and to human space flight.

Our institute has tirelessly faced new challenges and continues to excel thanks to its life science research and development of practical solutions to pressing problems of life both on Earth and in

aviation and space flight. Its research has served as a means to develop performance standards for aircraft crews and the qualification of aviation and space flight personnel. Moreover, the institute contributes to maintaining the performance and health of people in different environments: it researches, for instance, the effects of radiation exposure upon crews and passengers, and then develops effective countermeasures. Amongst other things, our institute also examines the effects of air traffic on people through large-scale air traffic noise studies (Institut für Luft- und Raumfahrtmedizin des DLR 2013).

Our institute, the DLR Institute of Aerospace Medicine in Cologne, can look back on a 60-year history and makes it is one of the world's leading centers for aviation and space medicine (Institut für Luft- und Raumfahrtmedizin 2012).

3 :envihab – a complex research facility and networking platform – open to the public

The first concrete concepts of :envihab were presented to the public as early as 2003 (Gerzer, 2004; Gerzer, 2003). The Ground breaking ceremony took place in September 2009 and construction of :envihab began in October 2010.



Figure 1: Location of :envihab in front of the DLR Institute of Aerospace Medicine (top right of :envihab) on DLR premises in Cologne, Germany, with six atria (blue stripes on the roof) to allow for the influx of daylight

On 5 July 2013, the institute's brand-new life sciences research facility :envihab was officially and publically inaugurated. As a new modularly designed research facility for medical research, :envihab's purpose is to study under strictly standardized conditions the complex problems presented by a closed life-support system (:envihab = environmental habitat) and the interactions between humans and the environment and possible countermeasures. At the same time, :envihab is a highly sophisticated technological research platform for international and interdisciplinary cooperations of

scientists of a wide field of research disciplines. It is expected that :envihab will significantly contribute to the solution of increasingly pertinent environmental problems on Earth. It will deliver industry-relevant results of scientific progress together with its economic advantages, and will encourage public debate about important future-oriented questions regarding human life (KOCH, 2013; Institut für Luft- und Raumfahrtmedizin 2012). At the same time :envihab will demonstrate a unique new concept of displaying to the public the fascinating world of science in an authentic environment. It is our hope that :envihab will provide lasting inspiration for young researchers in industry and science.

Therefore, key to :envihab is taking a combined approach of bringing together scientific research as well as industrial and educational communities under the topic of :envihab.

4 :envihab – facility lay-out and technical features

A completely innovative research facility, :envihab meets the highest international level of DLR's research expertise while at the same time attracting worldwide interest of the top international research institutions and universities and increasingly industrial partners. Instead of a "behind the fence" research policy, innovative and future-oriented projects will be presented and explained to the public. Here, groups of interested visitors and school children will have the opportunity to experience authentic research (Institut für Luft- und Raumfahrtmedizin 2012).

An essential and unique equipment and performance feature of :envihab is the ability to combine different research modules within one facility. Special features include a newly designed human centrifuge at the center of :envihab as well as oxygen reduction areas. Additionally, there is a pressure area in which altitudes equivalent to the absolute pressure of 300 mbar can be simulated as well as a whole-body 3T MRI machine with position emission tomography capability (PET) in very close proximity to a highly technological, controllable sleep laboratory (including light diagnostics). The research modules are interconnected through the medical core area. This is where test persons will be isolated, immobilized and exposed to targeted stress situations. In addition, physical and psychological methods of recuperation will be examined as countermeasures against, for example, immobilization, isolation and weightlessness (Institut für Luft- und Raumfahrtmedizin 2012).

:envihab modules

M1 DLR Short Arm Centrifuge	M5 Psychology Lab
M2 Prevention & Rehabilitation Lab	M6 Biology Lab
M3 Sleep & Physiology Lab	M7 Infrastructure
M4 MRI/ PET	M8 Auditorium

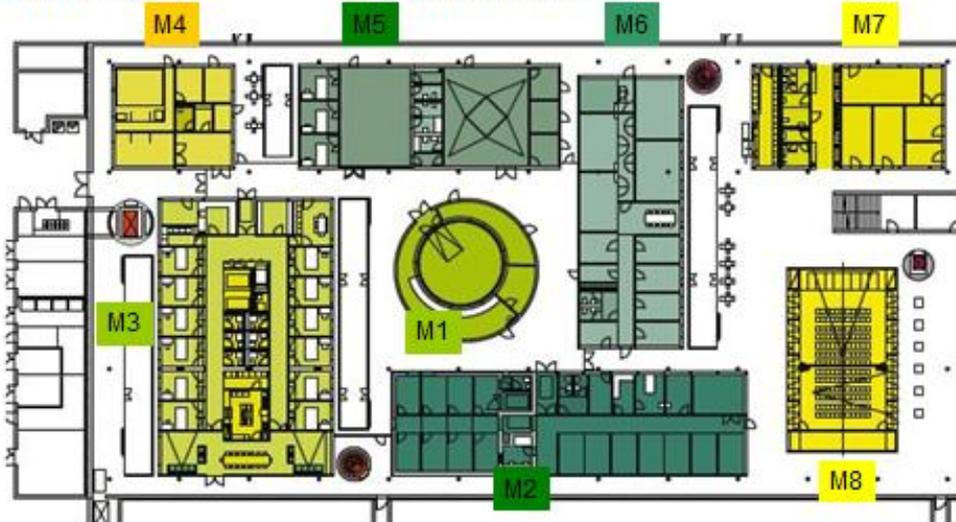


Figure 2: Lay-out of :envihab and location of the different modules and laboratories: eight separate modules, six laboratories – overall size: approx. 5,400m² (~101m x 53m); floor: approx. 4,300m² (~90m x 47m); height: approx. 9.25m; air-conditioning in core area: 17-30°C, ± 1°C, adjustable; 2.5°C/h temperature adaptable; 40–60% relative humidity adjustable, oxygen (21 to 12% and carbon dioxide (up to 3%) levels adjustable.

On the main floor, :envihab’s modules are arranged in the main building hall according to a “house in house” principle. The medical core area of :envihab encompasses five specialized modules that can be hermetically closed to the outside environment with respect to noise, light, vibration, atmosphere and, if needed, any possibility of test subjects to contact the outside. Special features of :envihab include

- a newly designed human centrifuge in the center of :envihab (M1),
- oxygen reduction areas in the Prevention and Rehabilitation Lab (M2) and Sleep and Physiology Lab (M3) and
- additionally a pressure reduced area in which altitudes equivalent to the absolute pressure of 300 mbar can be created for up to six persons for longer test durations, in the Prevention and Rehabilitation Lab (M2),
- a whole-body 3T MRI machine with a Na²³ coil and with a position emission tomography capability (PET) in the MRI/ PET Lab (M4), and this

- in very close proximity to the highly technological and controllable Sleep and Physiology Lab (M3) with
- special illuminated sleeping and living quarters for light diagnostics. Up to twelve test subjects for studies can live here and be investigated under identical environmental parameters. And together with the
- Psychology Lab (M5) featuring a noise isolated lab,
- these five research modules are interconnectable in individual combinations through the medical core area
- while at the same time closed to the remaining :envihab and outside environment.

Depending on the study design, test persons will be isolated, immobilized and/or exposed to defined, individual or combined targeted stress situations. In addition, physical and psychological methods of recuperation will be examined under highly controlled and repeatable environmental conditions as countermeasures against the applied parameters, as for example immobilization, isolation and weightlessness in this area.

The remaining 3 modules of the total eight modules of :envihab are a safety level 2 biological laboratory with a class 8 clean room in the Biology Lab (M6), a housekeeping, building infrastructure and maintenance in Infrastructure module (M7) including the main IT center to keep :envihab running, and a catering area for the Forum (M8). Up to 150 people can be accommodated for lectures or the main auditorium can be divided into two separate presentation rooms, one featuring a podium (KOCH, 2013). The modules and some additional special features are shown in Table 1.

Module	Features
<p data-bbox="264 1294 724 1328">Module 1: DLR Short-Arm Centrifuge</p> 	<ul style="list-style-type: none"> • Radius 3.80m, max. radial acceleration of 6g at outer perimeter • Acceleration from 0g to 6g within 30s • 98% darkening of the centrifuge room • Lighting dimmable 0–800 Lux • Simultaneous testing of up to four test subjects • Subject height 1.50m to 2.10m

Module	Features
<p>Module 2: Prevention and Rehabilitation Lab</p> 	<ul style="list-style-type: none"> • 7 labs freely configurable, total 200m² • Decrease of oxygen down to 12% within 5h (15,000ft) • Enrichment with CO₂ up to 3%, 1% change per hour • Temperature and humidity adjustable
<p>Module 2: Baro-complex (part of Module 2)</p> 	<ul style="list-style-type: none"> • Total area 110m², dividable into 8 units • Reduction of ambient pressure to minimal 300 mbar (30,000ft) • Decrease of oxygen down to 12% within 5h (15,000ft) • Enrichment with CO₂ up to 3%, 1% change per hour • Pressure lock for staff access and supply (food etc.) • Sanitary installations available under the same conditions
<p>Module 3: Sleep and Physiology Lab</p> 	<ul style="list-style-type: none"> • 12 rooms (à 12.9m²) for test subjects and a social/ retreat room (71m²); Total area 364m² • Decrease of oxygen down to 12% within 5h (15,000ft) • Enrichment with CO₂ up to 3%, 1% change per hour • Individual lighting 0.5–1,500 Lux (related to white) • Mood of lights adjustable (RGB LED) • Blood sampling during sleep without disturbance of the test subject • Temperature and humidity adjustable • Kitchen for metabolic nutrition • Two locks for staff access
<p>Module 4: PET/ MRI (Positron Emission Tomography/ Magnetic Resonance Imaging)</p> 	<ul style="list-style-type: none"> • 3 Tesla MRI/ MRS machine • Whole body scanning • 23Ma MRI Coil • with integrated PET • with a Na²³ coil

Module	Features
<p>Module 5: Psychology Lab</p> 	<ul style="list-style-type: none"> • Two different areas, connected by lock, total area 258m² • One area (130m²) specially soundproofed • Isolation and privacy conditions for up to 6 test subjects in parallel • Temperature and Humidity adjustable
<p>Module 6: Biology Lab (and Medical Infrastructure)</p> 	<ul style="list-style-type: none"> • 4 laboratory rooms, one of them class 8 clean room • Experiment preparation room • Tabletop Electron Microscope • 4 medical examinations rooms • Seminar room for up to 10 persons
<p>Modules 7: Infrastructure</p> 	<ul style="list-style-type: none"> • :envihab's IT center • :envihab's Data management • :envihab's building services and Utilities management
<p>Modules 8: Auditorium and surrounding area</p> 	<ul style="list-style-type: none"> • Lecture hall for 150 visitors, dividable into two separate rooms, and additional • Public area approx. 1,500m² incl. catering and exhibition and convention hall area

Table 1: :envihab modules and features.

As stated above, the most part of the technical infrastructure is housed in :envihab's massive roof (Fig. 3.).



Figure 3: The massive white roof houses the technical infrastructure of :envihab. The main floor with its modules is a slightly bit dug into the ground

5 :envihab – helping to cross new boundaries

:envihab will make possible the study of human subjects under complex, standardized conditions which take into account individual characteristics (both physiological and psychological). The collected data can then be used as a starting point for future modeling tasks that will be required in all areas of medicine in the future. Space medicine is particularly suited for such tasks since for space medicine research it is typical – and unique in the world of medicine – to conduct large study campaigns on healthy test persons and with the participation of multiple groups of scientists. We are unaware of any other research facilities whose architectural design is specifically tailored to tackle this question to the same extent as :envihab. Apart from scientific insights, it will enable the development of innovative products in collaboration with partners from science, industry and business. The main goal of :envihab, however, is to contribute, through hypothesis-driven research, to scientific insight and technological progress so as to provide solutions to the most important key issues for life on Earth. It also seeks to contribute to the human endeavor of studying the unknown through space flight.

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