Project Documentation
December 6, 2007

Current ISS related Experiments

German Aerospace Center (DLR)

Institute of Aerospace Medicine
Cologne

DLR
Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Today, the Space Shuttle Atlantis will launch and transport the European Columbus Module to the International Space Station. This research Module will go into operation on December 12, 2007.

The DLR Institute of Aerospace Medicine is deeply involved in operational aspects of the Columbus module as well as in research performed aboard the ISS.

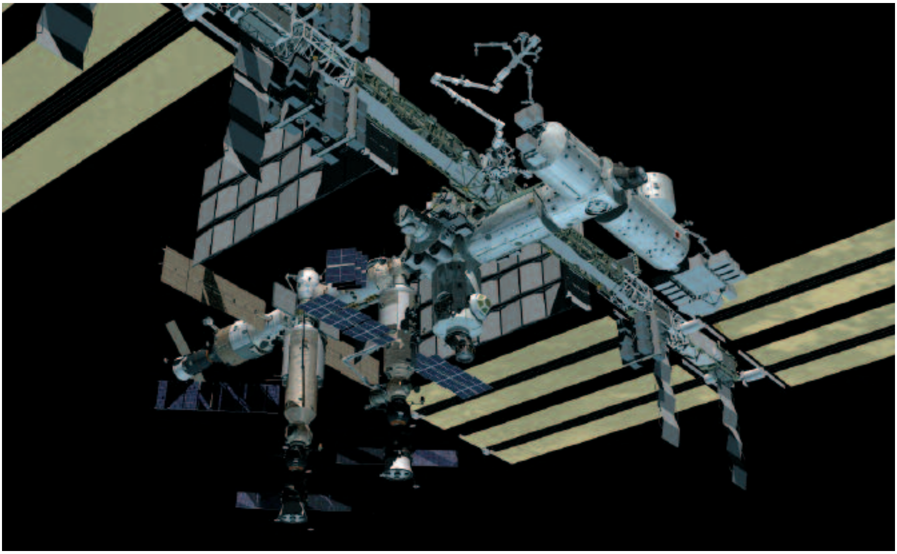
Thus, the Institute has been commissioned by ESA to care for the health of European Astronauts flying into space within the joint integrated support team for European Astronauts. The Institute also is taking care of operational aspects of the scientific use of the Space Station, especially supporting the ESA BIOLAB Facility of the Columbus Module and serving as the Facility Responsible Center (FRC) for BIOLAB. With our remote operations capabilities it will be possible to support the Astronauts from our control Rooms in the User Support Center in Cologne through teleoperations and telerobotics of the BIOLAB facility.

Presently, the Institute is preparing for 19 experiments aboard the Space Station during the next years including 8 experiments involving astronauts as test subjects and 11 experiments from cell and molecular biology, astrobiology and radiation biology. In addition, 5 ground based bed rest study campaigns funded by ESA are under preparation that lay the basis for future additional experiments in space and countermeasure developments for astronauts.

In 14 of the ISS experiments, scientists from the Institute serve as Principal Investigators (PI), and in five as Co-investigators (Co-I). Most of these experiments are done in consortia of scientists from different institutions from different countries and continents, which are coordinated by the respective principle investigators.

Thus, the Institute of Aerospace Medicine will play an important part in the life sciences experiments aboard the International Space Station in the coming years and is embedded in a worldwide scientific network.

To be even more successful in further research possibilities aboard the International Space Station and beyond and to optimize the scientific return from the investments in human space flight, the Institute is currently preparing to build a new research facility termed :envihab. This facility will aim at optimizing the possibilities to do life sciences research in space, and especially to link research topics in space with applications on earth. In addition, the facility will focus on outreach activities to motivate the young generation for challenges of the future in general.



ISS after Completion 2010 (© NASA)

The present booklet is intended to give an overview over the different scientific activities of the Institute of Aerospace Medicine aboard the International Space Station within the next years and describes the different experiments that are presently under preparation by scientists from the Institute.

Cologne, Dec. 6, 2007

Prof. Dr. med. Rupert Gerzer
Director of the Institute

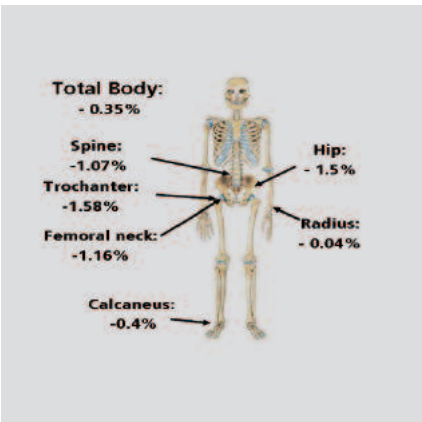
1. ISS-Experiments Space Physiology

1.1 'Salt retention in Space (SOLO)' to be first flown during increment 17

PI: **Martina Heer (DLR)**

Co-Is: **Petra Frings-Meuthen (DLR), Natalie Bäcker (DLR)**, Peter Norsk (University Copenhagen, Dk), Scott M. Smith (NASA, JSC, Houston, USA)

In 2008, SOLO will be one of the first experiments to be performed in the EPM/Cardiolab facility. Within SOLO, the interplay of nutrition, salt and fluid homeostasis with muscle and bone metabolism in humans is in the focus of the scientific interest. Basis for this research is the fact that astronauts are suffering from similar health problems as ageing humans on Earth: Due to the lack in gravity as well as in movement and mechanical load cardiovascular problems, impairment of the vestibular and the immune systems, as well as muscle and bone degradation are experienced by astronauts. Based on earlier investigations on the Russian space station MIR a completely unknown mechanism of salt storage in the human skin could be detected in so called metabolic ward studies on ground, in which the nutrition is highly controlled with varying salt concentrations. Due to the results of these investigations, textbook knowledge on the strong relation between salt and water homeostasis had to be revised. The newly detected mechanism obviously also influences the bone metabolism: High salt concentration in the food stimulates bone degradation. Therefore, the main goal of the SOLO experiment is to test if high salt concentration in the food of astronauts would stimulate bone loss in space, over and above the bone degradation caused already by microgravity. Due to the interrelation of salt, nutrition and mechanical loading with muscle and bone degradation as well as with high blood pressure the expected results are not only of importance for the astronauts. Also for the therapy of such diseases in people on Earth they promise new insights. Within the SOLO experiment, nutrition and salt intake will be strictly controlled, mechanical loading, training and excretion of the astronauts followed. A variety of physiological parameters will be measured in order to arrive at a complete picture of the physiology of astronauts.



Bone loss in astronauts per month in space. Data derived from Leblanc et al. 1999 and Lang et al. 2004.

1.2. 'Nutritional Status Assessment'

PI: Scott M. Smith (NASA, JSC, Houston, USA)

Co-Is: Sara R. Zwart (USRA, Houston, USA), Jeff A. Jones (NASA, JSC, Houston, USA), **Martina Heer (DLR, Köln)**, Joanne Lupton (Texas A&M, College Station, USA), Stephen P. Coburn (Indiana University - Purdue University, Fort Wayne, USA)

The altered nutritional status findings for several nutrients post flight are of concern, and we require the ability to monitor the status of these nutrients during flight to determine if there is a specific impetus or timeframe for these decrements. In addition to monitoring crew nutritional status during flight, in-flight sample collection would allow for better assessment of countermeasure effectiveness. This protocol is also designed to include additional normative markers for assessing crew health and countermeasure effectiveness.

Additional markers of bone metabolism will be measured to better monitor bone health and countermeasure efficiency. This assessment would allow for better health monitoring, and allow for more accurate recommendations to be made for crew rehabilitation.

ESA astronaut Kuipers and his NASA colleague Foale eat Dutch cheese for breakfast on board the International Space Station. © ESA

1.3 'Bicarbonate as a potential countermeasure to bone resorption in microgravity induced by osmotically inactive sodium storage'

PI: **Martina Heer (DLR)**

Co-Is: **Petra Frings-Meuthen (DLR), Natalie Bäcker (DLR), Francisca May (DLR)**, Scott M. Smith (NASA, JSC, Houston, USA)

Results from the MIR 97 mission show that in space about 50 mEq sodium may be retained in an osmotically inactive form during normal (180 mEq sodium/d) daily salt consumption. This amount of osmotically inactive sodium storage is comparable to results from our metabolic ward studies in healthy subjects who consumed an extremely high sodium intake of 550 mEq sodium/d. Results from animal experiments show that osmotically inactive sodium storage is accompanied by increased mRNA-expression of glykosaminoglykans suggesting that they function as cation exchanger, exchanging hydrogen by sodium. If this holds true, systemic pH should be decreased because of increased hydrogen concentration. In our metabolic ward experiments, we indeed found a significant decrease in serum pH during high salt intake. Together with that, bone resorption markers increased significantly with osmotically inactive sodium storage very likely due to acidosis. It is well known that metabolic acidosis induces negative calcium balances resulting in a metabolic bone disease that exhibits both features osteoporosis and osteomalazia. On the other hand, alkali administration inhibits bone resorption. Objective: To substantiate the data that average salt intake in astronauts leads to sodium retention with concomitant increase in bone resorption activity. To investigate the effect of bicarbonate as a countermeasure to salt induced bone resorption.

1.4 'Vitamin K1 supplementation as a countermeasure for space flight induced bone loss'

PI: **Natalie Bäcker (DLR)**

Co-Is: **Martina Heer (DLR), Francisca May (DLR)**, Cees Vermeer (University Maastricht, NL)

It is well known that unloading of weight-bearing bones in microgravity induces bone resorption and reduces bone formation leading to a reduction in bone mass. A number of clinical trials have shown that increased vitamin K intake leads to an increase in circulating bone formation markers. Since bone formation markers are decreased and bone resorption markers are elevated in astronauts in space, vitamin K might have a profound effect on bone turnover in microgravity. Ground based studies on postmenopausal women showed that a supplementation of 1 mg of vitamin K1 is sufficient to reduce bone loss.

Supplementation of 1 mg/d of vitamin K1 for two weeks resulted in a decrease of under-carboxylated osteocalcin levels in postmenopausal women, as well as increases in biochemical markers of bone formation. The aim of this investigation therefore is to study if 1 mg vitamin K intake to 1 mg (more than 10 times the AI for vitamin K) is able to also prevent microgravity-induced bone loss.

1.5 The contribution of changes in free, non macromolecular bound water and in lipid content to the kinetics of muscle volume decrease during bed rest and its consequences for muscle function

PI: **Jochen Zange (DLR)**

Co-I: **Klaus Müller (DLR)**, Vladimir Shushakov (Medizinische Hochschule Hannover, D), Norbert Maassen (Medizinische Hochschule Hannover, D)

Leg muscle volume decreases more rapidly in the first week of bed rest or space flight than in the following period of unloading by simulated or real microgravity conditions. During the first days after return to normal load and activity on earth, muscle volume increases more rapidly to normal levels than in the later period of recovery. In the first hours at the beginning of and after a period of bed rest or space flight leg muscle volume predominantly decreases or increases because of changes in blood volume and interstitial water content. We test the hypothesis that in the following period of about 1 week the further rapid volume changes of about 5% are predominantly caused by changes in intracellular water content of muscle fibres rather than by changes in protein content. We will measure total muscle volume, free versus macromolecular bound water content, and relative lipid content of lean leg muscles using special MRI techniques. Functional consequences and potential underlying mechanisms of the transient shrinking and swelling processes of muscle fibres will be studied in parallel using electrophysiological techniques. These experiments will be performed in the scope of short term and medium term ESA bed rest studies that will take place at DLR in Cologne or MEDES in Toulouse.

1.6 CARD (Cardiovascular regulation in microgravity)

PI: Peter Norsk, University Copenhagen, Dk

Co-Is: N.J. Christensen (University Copenhagen, Dk), M. Damgaard (University Copenhagen, Dk), A. Gabrielsen (Karlinska Institute, Stockholm, S) M. Tangø (University Copenhagen, Dk), N. Gadsbøll (University Copenhagen, Dk), **M. Heer (DLR)**

By measuring and monitoring various cardiovascular functions in the absence of gravity insights can be gained into the mechanisms behind cardiovascular problems experienced by people on Earth. The experiment will use the ESA/NASA-developed Pulmonary Function System and the European developed MELFI freezer.

1.7 EDOS: Early Detection of Osteoporosis in Space

PI: Christian ALEXANDRE, St Etienne Cedex 2, F

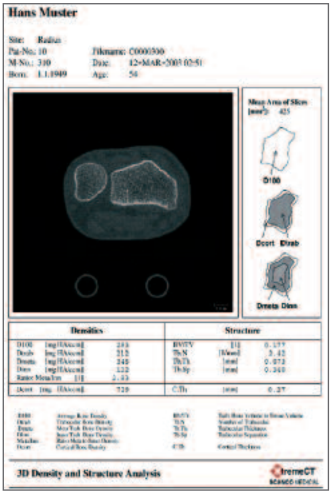
Co-Is: Laurence Vico (St Etienne Cedex 2, F), Mohamed Zouch (St Etienne Cedex 2, F), Peter Ruegsegger (ETH Zuerich, Ch); Bruno Koller (SCANCO, Bassesdorf, Ch); **Martina Heer (DLR)**

The objective of the proposed experiments is to demonstrate the efficiency of the 3DpQCT technique (XtremeCT developed by SCANCO) for an early detection of bone remodeling impairment and of the related bone microarchitecture changes and to provide information on the kinetics of bone loss. Ultimately the objective is to show if this device could provide an accurate measure to evaluate the efficiency of bone countermeasures.

The related technique was initially developed and validated for measurements on in vitro samples (microCT) and then on animals (vivaCT) within the ERISTO project. This technique namely demonstrated its capability to accurately measure bone alterations in immobilized animals (resolution of about 20 µm). Since 2003, the ADOQ project has been dedicated to the development and validation of the clinical version of this technique called XtremeCT. The XtremeCT was developed in 2003 and has been fully CE certified in 2004. It allows 3D imaging of bone microarchitecture with a resolution of 100 µm at the level of the radius and of the tibia. Five European clinical centres are right now evaluating the technique on various subjects. The device is also tested in the current long term bed rest study, 'WISE', performed in MEDES in Toulouse.

EDOS consists in evaluating the XtremeCT with pre and post-flight measurements in a series of flights of at least 3 months. Measurements will include XtremeCT, DEXA and analysis of bone markers (blood samples).

XtremeCT should allow an earlier detection of bone architecture changes and a better evaluation of the kinetics of bone loss recovery post flights. In addition, the results should enable further investigations on the different behaviours of weight vs. non-weight bearing bones.



Example of a printout of the XtremeCT.
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1.8 Neurolab psychophysiological performance Monitoring

PI: **Bernd Johannes (DLR)**

Co-I: V. Salnitzki (IBMP, Moscow, Russia)

The autonomic nervous system reacts differently to mental stress in different people. While blood pressure goes up in many people, others react with sweating or with feeling pressure at the pit of the stomach. This is called the ‘reaction pattern of the autonomic nervous system’.

In the space experiment, cosmonauts will be exposed to a realistic stress situation on ground and aboard the Space Station by simulating docking to the Space Station under manual control. Mental and physiological reaction patterns will be continuously measured. Data will be recorded by Healthlab, a medical measuring system developed by DLR.

The data will help to improve individual docking training and will contribute to the development of a modelling system that allows to predict individual reaction patterns and to improve individual performance prediction and support.

2. 'Head-down bed rest'-Experiments (ESA-funded ground-based studies to prepare for countermeasures in space)

2.1 MAP-Project 'Nutritional countermeasures during immobilization'

PI: **Martina Heer (DLR)**

Co-Is: **Natalie Baecker (DLR)**, Gianni Biolo, University Trieste, Italy, Jesper Kelsen, University Arhus, Denmark

Astronauts in microgravity and people subject to bed rest suffer simultaneously from a) a deficiency of gravity, b) a mild acidosis and c) weakening of immune functions. Deficiency of gravity leads to severe loss of bone and muscle that begins immediately on exposure to microgravity. Moreover, astronauts also experience disturbances in acidbase balance. It is well known that this metabolic acidosis induces negative calcium balances resulting in an additional loss of muscle and bone. Recently, clinical research studies have demonstrated that bone resorption observed in conditions such as aging and osteoporosis which are associated with aciduria, can be prevented with oral potassium bicarbonate (KHCO3). Another critical medical problem during space flight is that human immune system is weakened during spaceflight. The glycoprotein osteopontin may exert anti-inflammatory actions and inhibits cell apoptosis. Objective: We hypothesize that supplementing the diet of astronauts or subjects in a simulation model of microgravity, i.e. Head down bedrest, with alkali, like KHCO3, will protect their musculoskeletal systems from the degradation currently experienced during their time in μG conditions. In addition, adding osteopontin may have an additional immune stimulating effect.

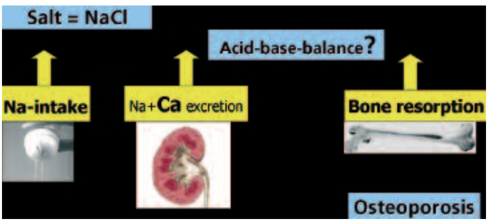
Test subjects enjoying meals in head-down tilt position

2.2 ESA bed rest 'Changes in acid-base balance and its effect on bone metabolism during HDT bed rest', ESA-Bed rest Studies 2008 – 2010

PI: **Martina Heer (DLR)**

Co-Is: **Petra Frings-Meuthen (DLR)**, Scott Smith, NASA JSC, Tx, Michael Boschmann, Charite Berlin

Immobilization like in bed rest or in microgravity causes bone loss because of reduced mechanical loading. On the other hand it is well known that metabolic acidosis induces negative calcium balances resulting in a metabolic bone disease that exhibits features of both osteoporosis and osteomalacia. Nutrient composition (protein, sodium, potassium etc.) has a significant effect on acid-base balance. Our hypothesis is that nutrient intake during bed rest can profoundly affect countermeasure success via changes in acid-base balance which might be positive, i.e. an increase in bone formation by nutrients leading to low-grade metabolic alkalosis or negative, i.e. an exacerbated bone resorption by nutrients leading to a low grade metabolic acidosis. Heavy exercise regimes also affect acid-base balance. When anaerobic processes are activated to provide energy because of insufficient oxygen delivery, lactate is produced which also decreases pH in blood. So, exercise regimes may be more effective if less acid precursors from the diet are consumed. At least the effect of exercise on muscle mass, force and bone mass and strength should be evaluated in light of the respective acid-base status. Objectives: To calculate the potential renal acid load (PRAL) from the diet, analyze blood and urine parameters regarding changes in acid base balance and evaluate the effects on calcium and bone turnover markers and bone mineral density (BMD) during bed rest and bed rest plus countermeasures. Our long term objective is, to understand the impact of nutritional and exercise countermeasures and the combination of both on acid-base balance and bone turnover.



Scheme of interaction between sodium and bone metabolism

2.3 ESA bed rest 'Monitoring of Vitamin K status and its relation to bone metabolism in HDT bed rest studies', ESA-Bed rest Studies 2008 – 2010

PI: **Natalie Baecker (DLR)**

Co-Is: Cees Vermeer, Maastricht University, **Francesca May (DLR), Petra Frings-Meuthen (DLR), Martina Heer (DLR)**

Little is known about the relationship of bone loss and vitamin K status in immobilization, like bed rest or space flight. However the scarce data obtained during spaceflights indicate that some of the changes in bone turnover markers may not only be related to mechanical unloading but to a lack of vitamin K. Measurements of undercarboxylated osteocalcin in two cosmonauts showed that undercarboxylated osteocalcin increased significantly from preflight levels of 12-15% to 25% within the first five days inflight. Caillot Augusseau et al concluded, that this impairment of vitamin K metabolism could be a consequence of either a decrease in vitamin K intake or an increase in daily vitamin K needs or degradation. Also Smith et al showed that weightlessness during space flight (3 months) results in increased serum undercarboxylated osteocalcin. Moreover, Vermeer et al. analyzed the Gla-content of plasma-osteocalcin from 4 astronauts before, during and after the D-1 mission. The results show that microgravity conditions may affect the Gla-content of newly formed osteocalcin and also its plasma level.

Broad objectives: 1. To monitor Vitamin K intake during bed rest. 2. To monitor vitamin K status in immobilization and how the used countermeasures (especially nutritional countermeasures) influence vitamin K metabolism. 3. To investigate the relation between concentration of undercarboxylated osteocalcin levels and markers of bone metabolism in different time regimes (STBR, MTBR and LTBR) of HDT bed rest.

Long term objective: To better understand the role of Vitamin K on bone metabolism in immobilisation, like bed rest or space flight.

2.4 ESA bed rest 'The contribution of changes in free, non macromolecular bound water and in lipid content to the kinetics of muscle volume decrease during bed rest and its consequences for muscle function', ESA-Bed rest studies 2008 – 2010

PI: **Jochen Zange**

Co-Is: **Klaus Müller (DLR)**, Vladimir Shushakov (Medizinische Hochschule Hannover, D), Norbert Maassen (Medizinische Hochschule Hannover, D)

Leg muscle volume decreases more rapidly in the first week of bed rest or space flight than in the following period of unloading by simulated or real microgravity conditions. During the first days after return to normal load and activity on earth, muscle volume increases more rapidly to normal levels than in the later period of recovery. In the first hours at the beginning of and after a period of bed rest or space flight leg muscle volume predominantly decreases or increases because of changes in blood volume and interstitial water content. We test the hypothesis that in the following period of about 1 week the further rapid volume changes of about 5% are predominantly caused by changes in intracellular water content of muscle fibres rather than by changes in protein content. We will measure total muscle volume, free versus macromolecular bound water content, and relative lipid content of lean leg muscles using special MRI techniques. Functional consequences and potential underlying mechanisms of the transient shrinking and swelling processes of muscle fibres will be studied in parallel using electrophysiological techniques. These experiments will be performed in the scope of short term and medium term ESA bed rest studies that will take place at DLR in Cologne or MEDES in Toulouse.

2.5 ESA bed rest 'Effects of head-down tilt bed rest on cartilage', ESA-Bed rest studies 2008 – 2010

PI: Jochen Mester, Deutsche Sporthochschule, Köln

Co-Is: Anna-Maria Liphardt, Deutsche Sporthochschule, Köln; **Martina Heer (DLR)**, Thomas P Andriacchi, Standford University, USA, Anne Muendermann, Standford University, USA

Articular cartilage in synovial joints serves a variety of functions including providing joint congruency, transferring and distributing forces, and allowing joint movement.

Healthy cartilage is the prerequisite for proper joint function and thus unconfined physical activity. The effects of immobilization on articular cartilage in humans are barely known and cartilage health of the lower limb joints has, to our knowledge, not been subject to microgravity related research yet.

Broad objectives: 1. To investigate the effect of different length of immobilisation on articular cartilage health. 2. To monitor the potential of countermeasures as for example vibration training to stimulate cartilage metabolism. 3. To monitor the correlation between biomarkers of cartilage health and imaging techniques.

To test the effect of unloading on articular cartilage thickness, magnet resonance imaging before and after bed rest periods would be performed. Additionally, blood samples would be taken throughout the studies to investigate the effect of immobilisation on biomarkers of cartilage health. The methods will be the same for the examination of the combined effect of bed rest and an applied countermeasure.

Long term objectives: 1. To understand the effects of immobilization and space flight on articular cartilage health. 2. To asses the risk of cartilage degeneration during long and mid term space missions.

3. ISS Experiments Radiation- and Astrobiology

3.1 RADIS / MATROSHKA – 2 (MTR -2) (Study of Depth Dose Distribution inside a Human Phantom Using the MATROSHKA Facility onboard the Russian Segment of the International Space Station)

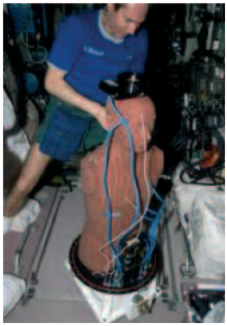
PI: **G. Reitz (DLR)**

Co-Is: V. Petrov, (IMBP, Russia), **T. Berger (DLR**), S. Burmeister, B. Heber (Kiel Univ., D), M. Luszik-Bhadra (PTB, D) N. Vana, M. Hajek (ATI,A), P. Beck (ARCS, A), L. Sihver (Chalmers Univ., S), I. Apathy, S. Deme , J. Palfalvi (KFKI, HU), D.O´Sullivan (DIAS, Ireland), M. Casolino (INFN,I), M.Durante (Univ.Naples, I), C. Lobascio (Alenia, I), L. Hager (HPA, UK) P.Bilski, P. Olko (INP, PL), N. Yasuda, Y. Uchihori (NIRS, JP), A. Nagamatsu (JAXA, JP), S. McKeever, E. Yukihara, E. Benton (OSU, USA), F. Cucinotta (NASA JSC, USA), N. Zapp (NASA SRAG, USA) J. Miller (LBL, USA)

For radiation risk assessment the knowledge of organ (or tissue equivalent) doses in critical radiosensitive organs is an important prerequisite. The main objective of the RADIS experiment is therefore to use the MATROSHKA facility in order to determine the empirical relations between measurable absorbed doses and the required tissue absorbed doses in a realistic human phantom. Hence, several passive and active sensors are exposed at the surface and at different locations inside the phantom.

MATROSHKA was exposed for the first time for measurements of the radiation distribution inside a human phantom under extra vehicular activity (EVA) conditions in the years 2004 – 2005 (MTR – 1). In the framework of the RADIS experiment measurements are performed inside the space station (MTR – 2 A: January to December 2006; MTR – 2B: October 2007 -). Sets of passive detectors, such as thermoluminescence dosimeter and nuclear track detector foils with and without converter foils are used to provide for mission integrated measurements of absorbed dose, neutron dose and flux of heavy ions and their spectral composition with respect to charge, energy and linear energy transfer (LET). In addition, a particle spectrometer (ALTEINO) will measure the radiation environment close to the MATROSHKA facility in MTR – 2B. The already installed active detectors developed by the investigators, the silicon detector telescope DOSTEL, the scintillator/silicon detectors (SSDs) and the tissue equivalent proportional counter shall be activated in December 2007 to measure the flux of neutrons and of charged particles and the corresponding dose rate and LET spectra separately for galactic cosmic particles and trapped particles as a function of time. All detector systems are calibrated using different on ground irradiation sources.

For the passive devices an on-ground reference program will be performed. The different systems allow for inflight cross-calibrations. A second objective is to investigate the effects of different shielding material by providing defined multi-layer configurations for radiation shielding optimization and validation in LEO. The flight testing of new soft materials in flight will be supported by ground testing and calculations, to assess shielding strategies for LEO and, in perspective, for interplanetary vehicles and habitat modules on planets.



05. January 2006 Detector integration for the MATROSHKA 2A experiment

07. December 2006 Detector dismounting by Thomas Reiter

3.2 DOSIS (Dose Distribution inside ISS)

PI: G. Reitz (DLR)

Co-Is: V. Petrov, (IMBP, Russia) **T. Berger (DLR)**, S. Burmeister, B.Heber (Kiel Univ., D), M. Luszik-Bhadra (PTB, D) N. Vana, M. Hajek (ATI, A), I. Apathy, S. Deme , J. Palfalvi (KFKI, HU), D.O´Sullivan (DIAS, Ireland), M. Casolino (INFN, I), L. Hager (HPA, UK) P.Bilski, P. Olko (INF, PL), N. Yasuda, Y. Uchihori (NIRS, JP), A. Nagamatsu (JAXA, JP), S. McKeever, E. Yukihara, E. Benton (OSU, USA), F. Cucinotta (NASA JSC, USA), N. Zapp (NASA SRAG, USA) J. Miller (LBL, USA)

Radiation constitutes one of the main restricting parameters for long duration space flight. The radiation surveillance for astronauts – either by applying personal dosemeters – as DLR is doing this for the European Astronaut Center (EAC) in the framework of the EuCPD programm – or by area monitoring is a moral and legal obligation of the space faring nations. With the **Columbus** module Europe will have an outstanding experiment platform. As it is know from measurements inside the Russian and the American Modul of the ISS the radiation load inside the moduls can vary up by a factor of 2. Therefore area monitoring at different positions inside the Columbus module, applying active and passive radiation detector systems is crucial for the health of the astronauts and therefore proposed in the framework of the **DOSIS** proposal.

The proposed experiment will provide measurements at different locations with different shielding distributions in the European **Columbus** Module - using several passive and active detector systems. The passive dosimetry packages consist of nuclear track detectors with and without converter foils and thermoluminescence dosimeters (TLDs). Mounting of the stacks in different orientations inside the packages allow to measure angular distributions of heavy ions and target fragments. Mission integrated dose, neutron dose, particle flux and energy –and energy transfer spectra will be received. The active devices comprise silicon detector telescopes (DOSTEL) – already applied in previous ISS missions, a TLD Reader, the **ALTEINO** and a new developed neutron dosimeter. These instruments provide time resolved information on dose and fluence rate and LET spectra.

Dosimetric data of the proposed experiment will constitute essential information for the application of radiation protection standards for manned spaceflight and for any radiation susceptible experiment in space. In addition, the measurements will contribute to the understanding of radiation transport through matter and for the understanding of the radiation field characteristics e.g. composition and anisotropy. The different systems allow for inflight cross-calibration of measurements at different shielding configurations in which the measurements of the onboard Tissue Equivalent Proportional Counter (TEPC) of NASA shall be included. On-ground cross-calibration of the equipment with well known sources is an indispensable part of the work.

Distribution of passive and active detector systems inside Columbus

3.3 DOSIS on EuTEF

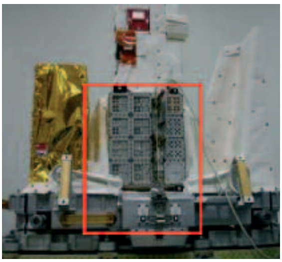
PI: **G. Reitz (DLR)**

Co-Is: **T. Berger (DLR, D)**, P. Olko, P. Bilski (INF, PL), M. Hajek (ATI, A) P. Vanhavere (SCK-CEN, B), F. Spurny (NPI, Cz), D. O'Sullivan (DIAS, Ireland), E. Yukihara (OSU, USA)

Despite the fact, that the **DOSIS** project has not started yet, part of the DOSIS community together with the investigators of the **DOBIES** project (ILSRA-2004-248 'Dosimetry for Biological Experiments in Space' PI: Dr. F. Vanhavere) were selected to perform passive dosimetry measurements for the EXPOSE Facility mounted on the EuTEF platform outside of COLUMBUS. The aim of these measurements is the exact determination of the radiation exposure at the site of the chemical and biological samples exposed inside the EXPOSE facility.

A total number of 64 measurement positions are allocated to the **DOSIS / DOBIES** cooperation. These positions were divided in 32 'depth dose measurement' positions – enabling the determination of the radiation load after very low shielding thickness directly near the biological samples – and 32 'dark control' positions for the measurement of the radiation load for the 'dark control' samples of the experiment.

All the work for the EXPOSE radiation detectors – including construction and building of the hardware, experiment integration etc. has been performed by DLR.



The picture shows the EXPOSE facility (red) mounted on the EuTEF plattform

'Depth dose measurement' positions at the top of the experimental container of EXPOSE (red circle)

'Dark control measurement' positions at the bottom of the experimental container of EXPOSE

3.4 DOSTEL (Advanced DOSTEL on EuTEF)

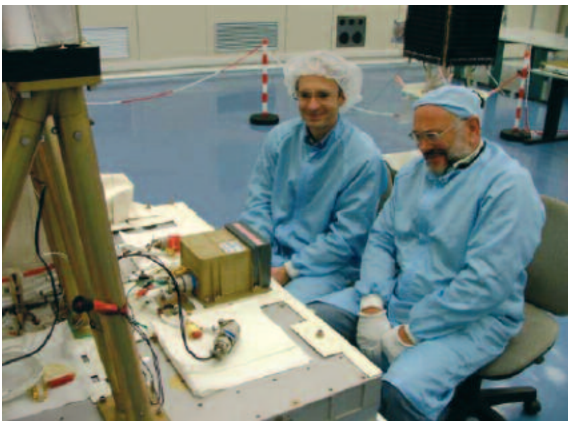
PI: G. Reitz (DLR)

Co-Is: T. Berger (DLR), S. Burmeister (Kiel Univ., D), I. Apathy (KFKI, Hu)

The Advanced DOSTEL experiment is designed to measure time dependent fluence rates of charged particles and their corresponding dose rates. The experiment uses as two sensor types planar Silicon detectors (PIPS) and PIN diodes.

The instrument will continuously monitor temporal variation of the charged particle count rate, the dose rate, charged particle and LET spectra. Three modes of operation will be performed: a) single detector mode for dose measurements in the individual detectors, b) coincidence mode for the measurement of particle and linear energy transfer (LET) spectra c) single event mode. While modes a) and b) integrate over software defined time periods resulting in a reasonable data reduction, the mode c) measurement will store the conversion results of the four detectors for each individual particle. This mode produces large amount of data and will only be activated during limited time periods.

LET spectra will be deduced from the energy deposit of coincident events in the PIPS detectors. Since the incidence angle of the particles is not measured, the energy deposit is converted into linear energy transfer (LET) in silicon, as energy deposit divided by the mean path length in the detector.



Final test of the instrument before integration in the EuTEF Facility

3.5 EuCPD (European Crew Personal Dosemeter)

ESA Officer: **U. Straube (EAC, D)**

DLR PI: **G. Reitz**

Radiation constitutes one of the main restricting parameters for long duration space flight. The EuCPD is designed to measure the individual radiation exposure of the European Astronauts and is therefore a essential part of the medical surveillance activities. In 2006 DLR – Institute of Aerospace Medicine – Radiation Biology started, on a contract for **EAC/ESA**, with the allocation of the **European Crew Personal Dosemeter**. This dosemeter system is built up of passive thermoluminescence detectors (TLDs) and nuclear track etch detectors (CR-39). For each European Astronaut a set of five EuCPDs is provided – 2 for the measurement of their radiation load inside the space station (to be worn on the waist and on the ankle), 2 for the measurement of their radiation load outside the space station (to be worn on the waist and on the ankle) and 1 reference detector package. Up to now five European astronauts have been equipped with the detectors (Christer Fuglesang, STS-116, Thomas Reiter – Astrolab mission, Paolo Nespoli, STS-120, Hans Schlegel STS-122 and Leopold Eyharts STS-122/ISS).

Christer Fuglesang and Thomas Reiter onboard the ISS – the EuCPD´s are worn on blue belts around their waists

3.6 ALTCRISS (Alteino Long Term Monitoring of CosmicRays on the International Space Station)

PI: M. Casolino, INFN and University of Rome Tor Vergata, Italy

Co-Is: F. Altamura, M. Minori, P. Piccozza (INFN, I), C. Fuglesang (EAC, D),A. Galper, A. Popov (MSEP, Russia), V. Benghin, V.M. Petrov (IMBP, Russia), A. Nagamatsu (JAXA, JP), **T. Berger (DLR), G. Reitz (DLR)**, M. Durante, M. Pugliese, V. Roca (Univ. Naples, I), L. Sihver (Chalmers Univ., S), F. Cucinotta, E. Semones (NASA JSC, USA), M. Shavers Wyle Labs, USA),V. Guarnieri, C. Lobascio (Alenia, I), D. Castagnolo I, R. Fortezza (Mars s.r.l. Naples, I)

DLR is a co-investigator in the Italian ALTCRISS project, and supplies passive radiation detector systems for the "study of the effectiveness of shielding materials". These passive detectors systems have been supplied since Increment 12 as part of the ALTCRISS project.

The ALTCRISS project aims to perform a long term survey of the radiation and cosmic ray environment on board the ISS. It was submitted to ESA in response to the AO in Life and Physical Science of 2004 with observations beginning at the end of 2005 (increment 12) and expected to continue for 3 years. This experiment follows previous ones on Mir where relative nuclear abundances and Light Flash perception measurements have been performed with similar silicon detector based devices (Sileye-1 and Sileye-2). Previous measurements on ISS with Sileye-3/Alteino have been performed in 2002 and 2005 in the framework of the first and second Italian-Soyuz Missions.

ALTEINO with the shielding tile experiment (passive detectors from DLR)

The main goals of this project are:

- Monitoring of long and short term solar modulation of cosmic rays. The active nature of the device allows to identify particles of galactic, trapped and solar origin according to their position and temporal profile. Observations are currently being carried at solar minimum, going toward solar maximum.
- Observations of solar particle events. We expect in 3 years about 10 events with an energy and fluence high enough to reach the interior of the station and trigger our detector. For these events we plan to observe the temporal profile and the nuclear abundances.
- Survey of different locations of the ISS modules. By relocating and rotating the instrument it is possible to study the differences in flux and nature of cosmic rays due to the different shielding of the station material (hull, racks, instruments, etc.). Flux is also dependent on station attitude and orientation: currently several locations in the Pirs (Russian docking) and in the Service Module (Central area, crew cabins) have been studied. In the future it is planned to make measurements in the **COLUMBUS** module and in the US section of the station.
- Study of the effectiveness of shielding materials. Different materials are being considered to reduce the dose to the astronauts: the current approach in weight effective shielding in space is to use low Z materials for their higher stopping power and fragmentation cross-section of the projectile. In this way it is possible to reduce the LET (Linear Energy Transfer) and the quality factor of the radiation, thus reducing the equivalent dose to the astronauts.

3.7 ADAPT (Molecular adaptation strategies of microorganisms to different space and planetary UV climate conditions)

PI: **Petra Rettberg (DLR)**

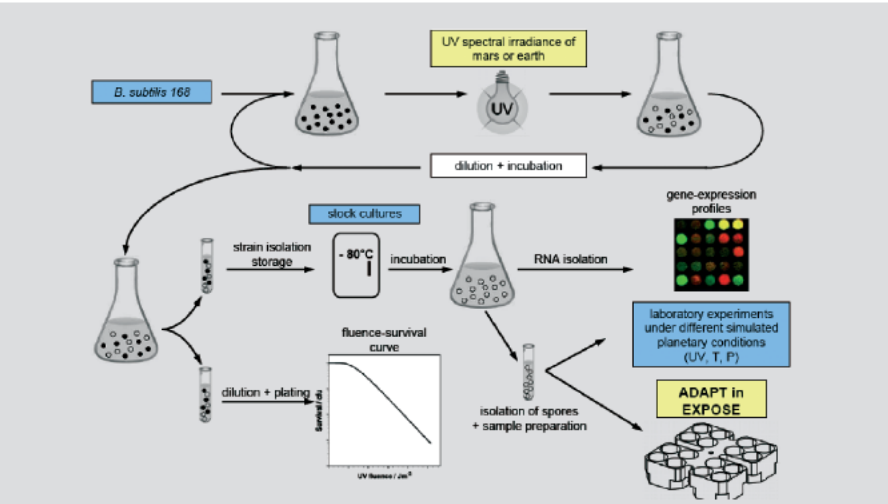
Co-Is: **Elke Rabbow (DLR), Ralf Möller (DLR), Gerda Horneck (DLR)**, Corinna Panitz (RWTH Aachen, D), Charles Cockell (OU, UK) Thierry Douki (CEA, F), Jean Cadet (CEA, F), Helga Stan-Lotter (Univ. Salzburg, A)

In the experiment, ADAPT, the capability of microorganisms to adapt themselves to qualitatively and quantitatively different UV levels like those on earth and on Mars will be investigated. Due to the different composition of the Martian atmosphere and it’s low pressure, the Martian UV radiation climate is significantly different from that of the earth. Energy-rich biologically harmful UVB and UVC radiation can penetrate to the surface of Mars. The hypothesis to be tested experimentally in the experiment ADAPT is whether longer-lasting selective pressure by UV radiation of different quality results in a higher UV resistance as well as in a higher resistance against the simultaneous action of further ‘extreme’ environmental factors that exist in space or on other planets like vacuum or cosmic radiation.

The ESA facility EXPOSE-E mounted on the Columbus platform EuTEF will be used to investigate and compare the different adaptation and survival strategies of three highly resistant microorganims from very distinct terrestrial habitats: *Gloeocapsa sp.*, an epilithic photosynthetic cyanobacterium naturally exposed to high levels of solar UV radiation, *Halococcus dombrowskii*, an Archaeal isolate from a permo-triassic Alpine salt deposit, and *Bacillus subtilis*, an ubiquitous spore-forming soil bacterium which is also able to withstand desiccation as well as high levels of solar UV radiation when in its dormant stage as spore.

The special strain of *Bacillus subtilis* was obtained by exposing a growing bacterial culture of a wildtype *Bacillus subtilis* to a repetitive selective pressure by mars-like UV radiation. The survivors of each UV inactivation cycle were used as a starter for the next one. After 69 cycles the bacterial population exhibited a 3 to 4 times higher resistance to UV radiation than the original one. On the ISS it will be tested whether these highly UV-resistant bacteria exhibit also a higher resistance against other limiting environmental parameters in space like ionizing radiation, low pressure, temperature cycles etc.

The results of this experiment will contribute to our understanding of the adaptability of life to extreme environments on earth and on other planets in general. One of the most important factors that have influenced biological evolution on earth, solar UV radiation, will be addressed and its effects as well as its interaction with other environmental parameters will be investigated at the cellular and molecular level. The direct comparison of the survival strategies of three phylogenetically different microbial species will also give new insights into the adequacy of actual planetary protection measures.



Scheme for the adaption of B. subtilis to UV radiation of different quality

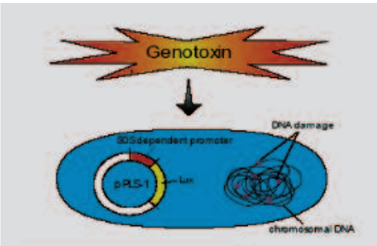
3.8 TripleLux

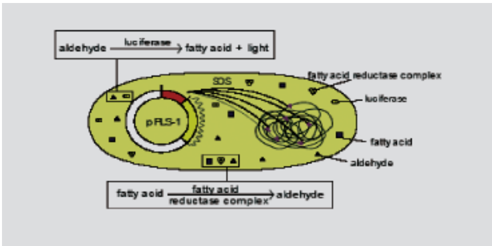
PI: B. Hock, TU Munich, D, TripleLux Part A

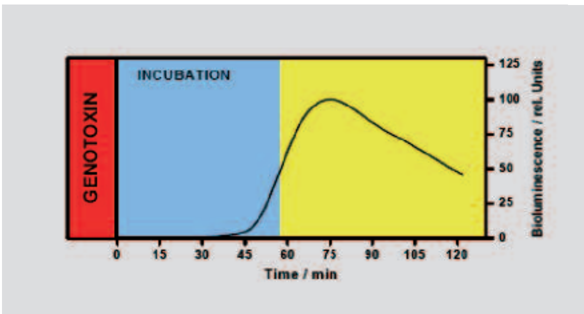
Co-Is: P.D. Hansen, TU Berlin, TripleLux Part B
P. Rettberg (DLR), E. Rabbow (DLR), C. Baumstark-Khan (DLR), G. Reitz (DLR), C. Panitz, RWTH Aachen, D, TripleLux Part C

Title Gene, immune and cellular responses to single and combined space flight conditions: TRIPLELUX assay

The aim of the experiment is to understand the mechanisms at the cellular level which underlie the following phenomena previously observed in spaceflight experiments (i) enhancement of responses to radiation in microgravity, and (ii) clear separation of the effects of microgravity from other spaceflight factors by use of an onboard 1g centrifuge and by performing a parallel ground simulation experiment with identical samples.







Kinetics of the SOS-LUX test

Specifically the following parameters will be examined in TripleLux Part C:UV irradiation will be used under microgravity to cause a defined type of DNA damage, i.e. pyrimidine dimers, in bacteria, which serve as model organisms possessing the same type of nucleotid excision repair as all other living organisms including humans. The capability of bacterial cells to counteract radiation damage by activating genes involved in DNA repair will be assessed using a bioluminescent reporter gene operon under the control of the the SOS regulon, known as the SOS lux assay. The repair kinetics of DNA damage will be followed by bioluminescence measurements under microgravity and on the onboard 1g centrifuge.

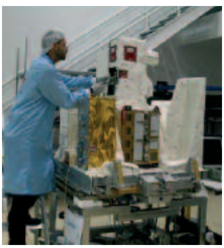
In previous spaceflight experiments in some biological systems a synergistic effect of the combined exposure to microgravity and radiation was found. With other biological systems complementary results have been obtained. Since the last space experiments investigating these phenomena (i.e. REPAIR IML-2, STS 65; KINETICS IML-2, STS 65) no further research could be performed under microgravity due to the lack of flight opportunities. In TripleLux Part C the enzymatic repair of DNA damage induced by radiation under microgravity will be investigated directly after damage induction with the SOS lux assay. This assay was originally developed for the investigation of the effects of genotoxic, i.e. DNA damaging agents in general, especially of toxic chemicals which can induce cell death, mutations and also cancer in higher organisms. The SOS lux assay was already applied for the investigation of pure chemical compounds and pharmaceutical drugs as well as for environmental samples. The SOS lux assay, in the meantime in the modified version of the SWITCH assay, was compared to other genotoxicity tests in direct intercomparisons in double blind studies with ground water, surface water and sediments. Preparatory work to adapt the SOS lux assay to the space conditions provided by the BioLab facility on the ISS and to the experiment specific hardware being under development by industry was performed.

3.9 PROTECT (Resistance of spacecraft isolates to outer space for planetary protection purposes)

PI: **Gerda Horneck (DLR)**

Co-Is: J. Cadet, T. Douki (CENG, CEA, F), R. Mancinelli (SETI Institute, USA), **P. Rettberg (DLR), E. Rabbow (DLR), R. Moeller (DLR),** W. L. Nicholson (Univ. of Florida, USA), C.Panitz (RWTH Aachen, D) ,J. M. Pillinger (Open Univ. Milton Keynes, UK), K. Venkateswaran, A. Spry (JPL, USA), E. Stackebrandt (DSMZ, D)

The project PROTECT will be performed on board of the EXPOSE-E facility of ESA, which is part of EuTEF, a European Technology Facility attached to the COLUMBUS module, to test the resistance of spacecraft isolates to outer space. It will tackle questions connected with planetary protection requirements for exploratory missions. For this purpose, bacterial endospores will be exposed to selected conditions of outer space. Spore-forming microbes are of particular concern in the context of planetary protection, because their endospores are highly resistant to a variety of environmental extremes, including certain sterilization procedures and the harsh environment of outer space or planetary surfaces. It has been found that bacterial spores recovered from spacecraft surfaces or spacecraft assembly facilities (SAF) are more resistant than spores of related laboratory strains. This leads to the hypothesis that the special conditions of ultraclean SAF and the applied spacecraft cleaning and decontamination measures cause a selection of the most resistant organisms as survivors. To test this hypothesis, spores from these environmental isolates as well as from related laboratory strains have been mounted as dry layers onto spacecraft-qualified material. They will be exposed to the following parameters of space, applied separately or in selected combinations: (i) space vacuum, (ii) solar extraterrestrial UV radiation including vacuum-UV, (iii) simulated Mars atmosphere and UV radiation climate, and (iv) galactic cosmic radiation. After recovery, the spores will be subjected to an intense analysing program, including (i) vitality; (ii) mutagenic spectrum, (iii) DNA lesions, (iv) global gene expression and (v) genomic and proteomic characterization. The data generated will be of importance for assessing both, probability and mechanisms of survival of spore contaminants during future robotic missions to Mars.



EXPOSE-E during assembly in the EuTEF platform at KSC

ExoMars of ESA, to be flown to Mars in 2013. The data gained from PROTECT will provide valuable information concerning the planetary protection requirements of such missions

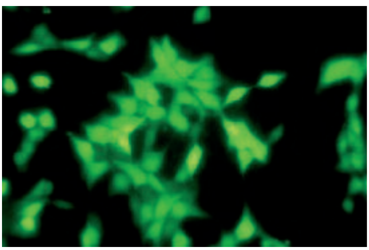
3.10 CERASP (Cellular responses to radiation in space: The effects of single and combined space flight conditions on mammalian cells)

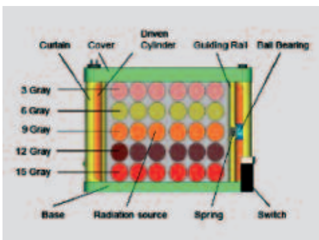
PI: **Christa Baumstark-Khan (DLR)**

Co-Is: **C.E. Hellweg (DLR), G. Reitz (DLR),** C. Johannes, Department of Genetics, University of Essen, Essen, Germany

The experiment Cellular Responses to Radiation in Space (CERASP) will supply basic information on the cellular response to radiation applied in microgravity. The aim of the experiment is to understand the mechanisms at the cellular level which underlie the following phenomena previously observed in spaceflight experiments
- Enhancement of responses to radiation in microgravity,
- Clear separation of the effects of microgravity from other spaceflight factors by use of an onboard 1 x g centrifuge and by performing a parallel ground simulation experiment with identical samples.

Specifically the following parameters will be examined in CERASP:
Ionising irradiation produced by a beta source will be used under microgravity to cause a defined type of DNA damage, i.e. single- and double-strand breaks, in various mammalian cell lines, which carry different biological markers to access especially such biochemical pathways which are related to the radiation-induced human stress response. One of the biological end-points under investigation will be survival reflected by radiation-dependent reduction of constitutive expression of the enhanced variant of green fluorescent protein (EGFP), originally isolated from the bioluminescent jellyfish *Aequorea victoria*. A second end-point will be gene activation by space flight conditions in mammalian cells, based on fluorescent promoter reporter systems using the destabilized EGFP variant (d2EGFP). The promoter element to be investigated will reflect the activity of the NF-ÍB stress response pathway as an anti-apoptotic radiation response. DNA damage will be measured by fluorescent analysis of DNA unwinding (FADU). The systems have worked properly for terrestrial applications during the first experiments. Experiments using accelerated particles produced at the French heavy ion accelerator GANIL have given insights into cellular mechanisms relevant for the exceptional radiation field in space.





Human ebryomic kidney cells expressing the reporter Enhanced Green Fluorescent Protein and sketch of the beta radiation source

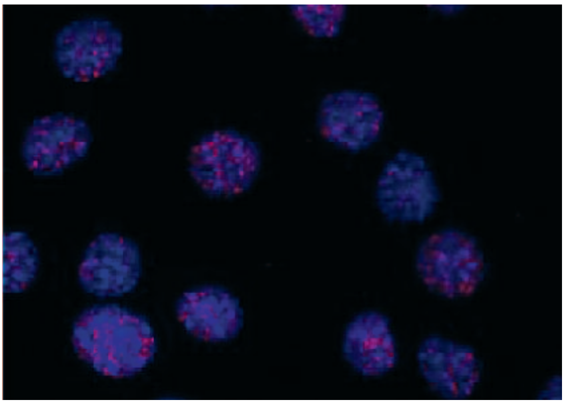
3.11 CELLPATH (Modification of Cellular Signalling Pathways and DNA Damage Processing by Radiation in Space)

PI: **C. Baumstark-Khan (DLR)**

Co-Is: **C.E. Hellweg (DLR), A. Arenz (DLR)**, M. Abend, H. Schertan, IRB, German Armed Forces, Munich, Germany, L. Sabatier, I. Testard, ROL, CEA, Fontenay aux Roses, France, D. Averbeck, DR2, CNRS, Paris, France,
M. Durante, University of Naples "Federico II", Naples, Italy

The experiment Cellular Responses to Radiation in Space (CELLPATH) will supply basic information on the cellular response to radiation applied in microgravity. The aim of the experiment is to understand the mechanisms at the cellular level which underlie the following phenomena previously observed in spaceflight experiments
- Enhancement of responses to radiation in microgravity,
- Clear separation of the effects of microgravity from other spaceflight factors by use of an onboard 1 x g centrifuge and by performing a parallel ground simulation experiment with identical samples.

Specifically the following parameters will be examined in CELLPATH:
Ionising irradiation produced by a beta source will be used under microgravity to cause a defined type of DNA damage, i.e. single- and double-strand breaks, in various mammalian cell lines, which carry different biological markers to access especially such biochemical pathways which are related to the radiation-induced human stress response.



Fluorescent stained DNA repair factories in mammalian cell nuclei.

4. User support contract from the European Space Agency (ESA)

The Institute of Aerospace Medicine has taken over operational tasks for the European Space Agency as part of a User Support and Operations Center (USOC) for ISS, for bio-science experiments.

The European User Support and Operation Centres (USOCs), in the framework of the ESA ISS Utilisation Programme, are responsible for carrying out the majority of tasks related to the preparation for and in-flight operation of multi-user facilities and experiments.

These activities are conducted by use of already existing national centres that are outfitted as necessary to interface the European ISS Ground Operations Network, and to accommodate ground models of the ESA-developed Facilities. The USOCs are instrumental for the implementation of the ISS ground segment for payload operations preparation, real-time data dissemination and provisions for instantaneous experiment command processing. The USOCs act as the link between the user community and ESA's ISS utilisation organisation. During the experiment preparatory phase, the USOCs are focused on activities such as ground model operations, facility and experiment procedure development, as well as payload and experiment operations preparation, optimisation and calibration. During the in-orbit payload operations, the USOCs receive facility and experiment data, and perform, in support of Columbus Control Centre, the operations of the payloads they are responsible for. In addition, the USOCs are be responsible for the interaction with the scientists in the User Home Bases in disseminating experiment data to them and receiving and processing requests for experiment scheduling and direct commanding.

The tasks are:

- A powerful control center environment for on-line mission support and data management and distribution
- Ground support facilities for the Columbus BIOLAB:
  - engineering model with a high fidelity from the technical point of view for procedure development, mission simulation and on-line assistance during mission
  - science reference model for ground reference experiments

  The ground infrastructure systems have been provided by the European Space Agency in the framework of the USOC implementation programme

BIOLAB mission operations infrastructure at DLR

4.1 BIOLAB Facility Responsible Center (FRC)

- Responsibility of mission preparation including BIOLAB operations planning, payload operations data file (procedures) and ground displays design.

- Responsibility of BIOLAB mission operations and support with a 24/7 presence in the control center during active BIOLAB mission phases, monitoring experiment progress, guiding the astronaut or applying BIOLAB's telerobotics capabilities by direct commanding from ground

The Columbus facility BIOLAB (here the engineering model) is dedicated for the investigation of micro-organisms, animal and plant cells, small plants, aquatic invertebrates and insects. The BIOLAB facility has an automated part which can be operated from ground, and a part which is manually operated by the astronaut on orbit, resulting in a high degree of astronaut to ground interaction and vice versa. Biological and bio-medical samples are housed in experiment-specific containers supplied with gases and defined humidity by a life support system

4.2 KUBIK Facility Support Center (FSC)

- **Support of KUBIK experiments preparation, including operations planning and procedure development**

- **Support of KUBIK experiment real time operations**

KUBIK is a mobile ESA incubator facility for cell biological research that is used during the Soyuz missions to ISS

4.3 Facilities and User Support for Artificial Gravity Research on ground

In addition to this direct involvement into the ISS/Columbus scenario, the Institute of Aerospace Medicine offers to the microgravity scientists a portfolio of facilities for microgravity simulation and research under artificial gravity conditions as well as a lab infrastructure for the support of experiment campaigns as well as parabolic flight campaigns at the Cologne Airport.

DLR at a Glance

DLR is Germany´s national research center for aeronautics and space. Its extensive research and development work in Aeronautics, Space, Transportation and Energy is integrated into national and international cooperative ventures. As Germany´s space agency, DLR has been given responsibility for the forward planning and the implementation of the German space program by the German Federal Government as well as for the international representation of German interests. Furthermore, Germany's largest project-management agency is also part of DLR.

The DLR employs approximately 5,600 people at 13 locations in Germany and operates offices in Brussels, Paris, and Washington, D.C.

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