ABSTRACT BOOK

28th European Low Gravity Research Association Biennial Symposium & General Assembly

3rd - 6th September 2024
Liverpool

Conference Partner

SPAN
SPACE ACADEMIC NETWORK

Conference Sponsors

UK SPACE AGENCY · esa · UKRI Science and Technology Facilities Council

Contents

A Canadian roadmap towards a Lunar Agricultural Module

Dr Jared Stoochnoff[1], Dr Conrad Zeidler[1], Mr Mathieu Tremblay[1], Ms Béatrice Poitevien[1], Dr Matthew Bamsey[1], Dr Christian Lange[1]
[1]Canadian Space Agency (CSA)
ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture, Space Seven & Eight, September 6, 2024, 9:00 AM - 10:25 AM

Biography:
As a project manager in CSA's Food Production Initiative, Jared coordinates international planning efforts for advanced controlled environment plant production systems to support sustainable exploration of the lunar surface. He joined the Canadian Space Agency in 2023 shortly after completing his PhD from the University of Guelph's Controlled Environment Systems Research Facility.

Following the 2019 Canadian Space Strategy, the Canadian Space Agency established a Food Production Initiative tasked with advancing the state of controlled environment agriculture and advanced life support systems able to provide food and life-support services for lunar exploration missions. Early consultations with Canadian industry and academia, as well as international partners, provided initial recommendations to guide investments needed to address the objectives of the Food Production Initiative; to position Canada as a leader in lunar food production and to provide one or more critical systems to an international lunar surface food system partnership. Following these recommendations, Canada, along with several international partners, is actively studying concepts for infrastructure intended to support and ensure a sustainable human presence, while also supporting meaningful lunar science. In this context, the Lunar Agricultural Module (LAM), which would significantly support international efforts to expand human presence beyond low-Earth orbit and help secure the future of the Canadian astronaut program, has been proposed. On route towards a full-scale LAM, several critical mid-term milestones that would contribute towards this proposed flagship level contribution are being actively investigated. These mid-term milestones include a small lunar plant growth payload and a high-fidelity bioregenerative life support LAM-Ground-Test Demonstrator. All proposed activities leading towards the LAM are poised to create tangible socio-economic benefits, including advancing food security in Canada's northern and remote communities. This presentation will outline some of the work to date that has led to the ensuing vision statement, approach and related infrastructure/ hardware roadmap from Canadian Space Agency consultation and analysis.

A Citizen Science Approach to Crowdsource Decision Making for Systematic reviews in Space Medicine

Ms Alexandra Waldherr[1], Ms Linda Hemmann[2], Ms Fanny Roessler[3], Mr Giorgio Lorini[2], Ms Illay Oeztuerk[4], Dr. Ria Borromeo[5], Dr Alexandra Bannach-Brown[5], Dr. Anna Fogtman[2], Prof Mona Nasser[1], N/A Systematic Threat Analysis of Radiation from Space (STARS) project STARS[2]

[1]University Of Plymouth, [2]European Space Agency (European Astronaut Centre), [3]Technical University of Munich, [4]Heinrich Heine University Dusseldorf, [5]University of the Philippines Open University, [6]CAMARADES Berlin, QUEST Centre, Berlin Institute of Health

1.3 - Life Sciences: Human Physiology and Performance, Space Nine, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Mona Nasser is a Professor in Clinical Epidemiology and Oral Health Research and Director of Plymouth Institute of Health and Care Research. She is a visiting fellow at the Quest Centre/ Berlin Institute of Health. She is trained in dentistry, clinical epidemiology, public health and astrophysics. She works with scientists in the Space Medicine team at European Astronaut Centre on impact of ionising radiation on human biology. She currently leads a research group on impact of space flight environment on craniofacial structure (https://www.plymouth.ac.uk/research/isecs).

Background: Crowdsourcing has been used in supporting the conduct of systematic reviews for the last few years. However, these approaches mainly encapsule reviews which include one single type of study design. This project specifically focuses on engaging the public in screening of a dataset that combines three study designs: human, animal and in-vitro studies.

Objectives: i) To pilot the feasibility of assembling a crowdsourcing project to engage citizens of the general public in a highly specialized screening task. ii) To validate the training and screening outcomes of this approach. Two research questions were proposed,
i) the effects of ionizing radiation on the central nervous system (CNS) and ii) sex differences in exposure to ionizing radiation (SD).

Methods: Inclusion and exclusion criteria were formatted as decision tree, mimicking the workflow of a field expert. Volunteers were trained to follow the decision tree. Five training calls were opened, access to the full screening dataset was granted to participants reaching recall > 0.8 and specificity > 0.4 on a training set of 25 prelabelled abstracts. Spanning the whole project, we built an active community with strong peer support and individualized feedback. The full screening phase is currently ongoing, the two groups are moderated in parallel (SD, CNS).

Results: 1.300 citizens expressed their interest for contributing to the project. 120 participants passed the training stage and actively contribute to the project. There was a lot more interest in the review on sex differences. From the active trainers, the most common error during the training stage was too low recall (= to harsh exclusion) as we aim at overinclusion at this stage. Intra-rater decision making agreed at >75% showing a stable approach, inter-rater decision making varied between 50-100%. We adapted a new majority vote scheme with a minimum of 5 people agreeing at ≥75%.

Conclusion: The major lessons learned are that i) long project timescales lead to loss of engagement by citizens and ii) scaling towards three study types and 51 countries requires a good data conduct combining trainings, stable platform access and standardized data formats. We showed that a trained general crowd can make decisions comparable to domain experts and hope our community-focused approach is taken up for future systematic reviews.

A toolkit for the design of orbital experiments and their corresponding twin comparative experiments on Earth

Mr Charlie Young, Dr. Mona Nasser[1], Alan Webb
[1]University of Plymouth

1.3 - Life Sciences: Human Physiology and Performance, Space Nine, September 4, 2024, 11:00 AM - 1:00 PM

Biographies:

Charlie Young: A mechanical engineer with a background in spacecraft propulsion (BAe), launch system engineering and launch campaign management (ESA/French Space Agency). He has 20 years' experience in commercial multi-channel service design, with a focus on healthcare; he played a leading role designing early online health services for the NHS. He set up Plastron with the ambition of ensuring NewSpace is a successful sector by focusing on safety, quality and productivity improvement.

Dr Mona Nasser: Professor of Clinical Epidemiology and Oral Health Research at University of Plymouth and Director of Plymouth Institute of Health and Care Research. She is a visiting fellow at the QUEST Centre/ Berlin Institute of Health (BIH). Her research focuses on dental health services research, space medicine/bioastronautics and interdisciplinary methodologies. She co-leads the Systematic Threat Analysis of Radiation from Space (STARS) project with space medicine team at European Astronaut Centre and QUEST Centre/BIH.

Currently, the UK lacks the capacity to launch and recover life science experiments in Low Earth Orbit for comparative studies. Furthermore, there are limitations in designing these experiments and their terrestrial counterparts, which can yield less reliable results. The space sector is rapidly growing in the UK, and there is a clear ambition to expand the life science dimension of this sector. This is evidenced by the recent investment of the UK government in an all-British space flight with Axiom Space. The British government announced up to £15 million in commercial funding that would become available when the Axiom space mission proceeds.

Our ongoing research addresses five fundamental areas for assuring high-quality orbital life science research programmes can succeed:

(a) Development of the End-to-End Life Cycle for orbital life sciences research, determining the critical requirements to assure experimental provenance and quarantine, regulatory mission alignment and Mission Safety Assurance.

(b) Establishing research standards and developing a best practice toolkit for the design of orbital experiments and their corresponding twin comparative experiments on Earth.

(c) Generating the critical regulatory framework to support the Civil Aviation Authority develop the necessary regulatory guidance for these types of space missions launching from, and returning to, the UK.

(d) Determining the environmental and dynamic mission management requirements for experimental provenance and quarantine throughout the mission life cycle.

(e) Defining the requirements for appropriate processes and hardware/equipment development required to ensure maritime recovery and repatriation does not compromise mission success.

The presentation will provide an update on the current findings along with standards and guidelines that we have developed.

The benefit of this activity, whilst of immediate interest to support UK Launch and related academic activities is of international value. Thus, the scientific process and methods derived from our research is ultimately an Open Source resource we feel should be made available to any country looking to initiate space-base research of this nature. Associating and verifying our work in collaboration with space agencies as well as COSPAR, ESA BSGN etc is a definitive outcome from this project.

Abnormal Mitral Valve-Related Parameters Following Long-Duration Spaceflight.

Mr Cyril Tordeur[1], Dr Elza Abdessater[1], Dr Amin Hossein[1], Prof. Valentin Sinitsyn[2], Dr. Elena Mershina[2], Dr. Elena Luchitskaya[3], Prof. Jeanette Schulz-Menger[4], Prof. Vitalie Faoro[1], Prof. Jens Tank[5], Prof. Philippe van de Borne[1], Dr. Jérémy Rabineau[1]
[1]Université Libre de Bruxelles, [2]Lomonosov Moscow State University, [3]Institute of Biomedical Problems (IBMP), Russian Academy of Sciences (RAS), [4]Charité Universitätsmedizin Berlin, [5]German Aerospace Center
2.1 - Life Sciences: Cardiovascular Physiology, Space One, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Tordeur Cyril is a Ph.D. Candidate in space physiology and gravitational biology at the Université libre de Bruxelles. With a Master in Physiotherapy and a Master of Research in motor skill sciences focused on the cardio-pulmonary and vascular system, Cyril is an ESA-Academy alumni trained in gravitational research. His doctoral project revolves around assessing cardiovascular deconditioning in astronauts through real microgravity exposure, simulation of microgravity by head-down bed-rest in humans, and hindlimb unloading in mice. Passionate about advancing space health, Cyril's research contributes to our understanding of the effects of space conditions on cardiovascular function.

Introduction:
Pathology-induced left ventricular shape alterations, with increased left ventricular sphericity index, are determinants of mitral valve dysfunction [1, 2]. Long-term exposure to microgravity can lead to cardiac muscle atrophy and alter cardiac function [3, 4]. Furthermore, long-term exposure to microgravity has been shown to increase the left ventricular sphericity index [5, 6]. This research project investigates the impact of long-term spaceflight on mitral valve-related parameters.

Method:
We conducted a before-after study on nine male cosmonauts, aged 44 ± 6 years, with a BMI of 26.28 ± 1.83 kg/m², spending an average of 247 days on the International Space Station (ISS) between 2020 and 2023. A cardiac MRI, without contrast agents, was performed at the Medical Educational and Scientific Center University Hospital in Moscow. Cosmonauts were scanned in the supine position using retrospective electrocardiography-gated multi-breath-hold balanced steady-state free precession cine sequences, including two-chamber (2CV) and four-chamber (4CV) views. Each slice comprised 25 cardiac phases. The procedure was repeated before (60 ± 30 days prior to launch) and after (6 ± 2 days after landing) ISS missions. CAAS MR Solutions 5.1.2. software was used for MRI data analysis. Mitral leaflet billowing (> 2 mm systolic protrusion [7]) was assessed in the 2CV view, and a quantification was done if the billowing was present. Mitral annulus diameter was assessed in end-systole and end-diastole in the two cine views. Statistical analysis employed paired t-tests ($p < 0.05$). Compliance with test conditions was ensured before analysis.

Result:
Post-flight, billowing was present for five cosmonauts (see Table 1), without prolapse and without thickening of the leaflet. The mitral annulus diameter was larger post-flight than pre-flight. This dilation was observed in end-systole and end-diastole, both in 2CV and 4CV (see Table 1 and Figure 1).

Conclusion:
This study shows alterations of the mitral valve after long-term exposure to microgravity. Moreover, billowing was present on five out of nine cosmonauts. This highlights additional alteration of the valve, however not systematically present on this cohort of cosmonauts. Subsequent investigations need to assess if those mitral modifications could lead to mitral valve regurgitation and if an even prolonged exposure to microgravity could worsen those alterations.

Acoustic Levitation of Cyanobacteria in Weightlessness

Bérénice Dupont[1], Sébastien Vincent-Bonnieu Sébastien Vincent-Bonnieu[3], Maxime Ardré Maxime Ardre[2], Jean-Luc Aider Jean-Luc Aider[1]
[1]Laboratoire de Physique et Mécanique des Milieux Hétérogènes (PMMH), UMR CNRS ESPCI 7636, PSL University, [2]Laboratoire de Biophysique et Evolution (LBE), UMR CNRS ESPCI 8231 Chimie Biologie Innovation, PSL University, [3]European Space Research and Technology Centre (ESTEC), European Space Agency (ESA)
1.1 - Life Sciences: Cell Biology, Genetics and omics, Space One, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
2year PhD student at LBE and PMMH laboratories from the ESPCI. Study area: biophysics and microbiology

Introduction:
Cyanobacteria, also referred to as blue-green algae, are phototrophic bacteria able to perform photosynthesis and use carbon dioxide to create organic matter. These bacteria are great O2 producers and CO2 consumers, which makes them very good candidates to recycle CO2 and produce O2 in closed and highly constrained environments such as the ISS (International Space Station) or long-term space journeys. Our objective is to evaluate a cultivation technique for cyanobacteria using acoustic levitation to optimize light penetration and possibly stimulate the cyanobacteria to enhance their O2 production, which is closely associated with light exposure. Acoustic levitation is a technique that allows the manipulation of small objects and cells (from 1 µm to a few hundreds µm depending on the acoustic parameters) using ultrasounds (Jeger-madiot et al., 2022). It allows easy manipulation of micro-algae without any direct physical contact, making it particularly suitable for micro-gravity environments.

Methods:
Experiments were conducted during the CNES parabolic flights campaign in spring 2024 to determine optimal acoustic levitation parameters for cyanobacteria during 0g-phases. Our approach involves growing cyanobacteria in thin layers and subjecting them to an acoustic field. We present findings on the dynamics of acoustic trapping in micro-gravity, aiming for a comprehensive understanding of cyanobacteria manipulation in a weightless environment and for a minimization of energy consumption, which is also critical in space.
Cyanobacteria were cultivated in multi-node PDMS (polydimethylsiloxane) chips at room temperature and exposed to an ultrasonic standing wave generated by a piezoelectric transducer. Side view visualizations were used to measure oscillation velocities at various amplitude of the acoustic force.

Results:
The study identified a minimum voltage required to allow the acoustic manipulation of cyanobacteria in weightless conditions. A minimum voltage of 0.4 V was needed to move the cyanobacteria using the acoustic force. This has been compared to the minimum amplitude of 2 to 3 V needed to move the cyanobacteria on earth. It confirms that acoustic manipulation will need much less energy in space than on earth.
Furthermore, a relationship between cyanobacteria layer thickness and the amplitude of the acoustic force was established. These findings contribute to optimizing cyanobacteria cultivation techniques for space applications, particularly within the MELiSSA (Micro-Ecological Life Support System Alternative) program (Farges et al., 2008). By leveraging acoustic levitation in microgravity, we aim to enhance cyanobacteria's oxygen production capacity, facilitating sustainable life support systems for future space exploration missions.

Advancements in Microscopic Observation Technology for Space Bio-Experiments

Mr. Kohei Yoshioka[1]
[1]IDDK Co., Ltd.
1.1 - Life Sciences: Cell Biology, Genetics and omics, Space One, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Mr. Yoshioka is Co-CEO and CFO of IDDK Co., Ltd., a Japanese company with its cutting-edge microscopic observation technology, Micro Imaging Device. As Co-CEO and CFO, he is mainly responsible for financial management as well as the business strategy and the development of space bio experiment business. He also has been involved extensively in customer development and international marketing as well as establishing the company's internal management, including finance and accounting, human resources, and general affairs.

The International Space Station (ISS) has long been a hub for bio-experiments in microgravity, but challenges such as human error, labor costs, and experiment restrictions have prompted a shift towards artificial satellite-based missions. Researchers are exploring bio-experimental missions to be conducted via satellites, aiming to automate procedures and reduce human intervention. This shift becomes more crucial with the retirement of the ISS, expecting an increase in satellite-based bio-experiments.

To facilitate this transition, IDDK is collaborating with satellite manufacturers to streamline the development of bio-experimental equipment and artificial satellites. Their focus lies in microscopic observation, a vital aspect of bio-experiments, and they introduce the micro imaging device (MID) technology to address challenges related to weight, vibration, and space availability.

The MID technology revolutionizes traditional microscopy by utilizing semiconductor-based systems. Unlike conventional microscopes, MID requires no optical magnification, eliminating the need for individual adjustments of the optical lens system. This ensures a resolution dependent on the size of the semiconductor mesh, providing a lightweight and ultra-compact solution for microscopic observation.

In a microscopic observation method using MID, the specimen is placed on the surface (or placement unit set as necessary) of an MID imaging area (imaging device array) and is illuminated. The light information from the specimen is then directly collected in the MID. In MID, multiple pixels, including an optical element that collects light and a light receiving unit (photodiode) that receives the light collected by the optical element, are arranged at predetermined intervals. This method requires no optical magnification, and hence images can be acquired with a resolution dependent on the size of the semiconductor mesh without loss of light information due to the optical path. Therefore, unlike conventional microscopes, no individual adjustment is required for the optical lens system to form an image of light from the object of interest at the desired position and magnification.

The MID technology's versatility is demonstrated through sample images, showcasing the ease of capturing microscopic images without the need for focusing. The images include zooplankton and lysozyme crystals, highlighting the technology's capabilities in observing dynamic samples.

Moving forward, IDDK is developing a Micro Bio Space Lab, a compact system for real-time microscopic observation of cultured cells or microorganisms in space. This lab aims to provide an integrated solution, incorporating environmental sensors and a solution tank for various applications, including cell culture.

Advances in soft matter characterization capabilities for lunar exploration: ddm to spectroscopy to computer vision

Dr. Suman Sinha Ray[1,2], Dr Amine Missaoui[1,2], Ms Emily Johnson[2], Ms Sathyashri Muruganandam[2], Mr. Jack Qiao[2], Mr Prakash Chaudhary[3], Mr Iksha Gurung[4], Mr Muthukumaran Ramasubramanian[4], Dr. Manil Maskey[5]

[1]Nasa Glenn Research Center (USRA), [2]NASA Glenn Research Center, [3]Department of Computer Science, University of Alabama, [4]Earth System Science Center, University of Alabama, [5]Marshall Space Flight Center

1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Dr. Suman Sinha Ray has PhD in Mechanical Engineering from University of Illinois at Chicago (UIC) followed by two years of postdoc in Mechanical Engineering (UIC). Currently he is working as the Lead Discipline Scientist of Soft Matter at NASA Glenn Research Center (USRA). His responsibility ranges from developing a soft matter research program for NASA for the next decade to performing fundamental research of soft matter physics. He is also an Adjunct Associate Professor at UIC. Till date, he has published 69 peer reviewed journal publications, 4 invited book chapters and 15 patents.

In 1991, famous French scientist Pierre-Gilles de Genes was awarded Nobel prize for his impactful research in soft matter, more specifically polymers. He is defined as the founding father of soft matter. In his Nobel lecture [1] he described soft matter aka complex fluids as materials with two primary features – (a) complexity and (b) flexibility. The sub-categories of soft matter (e.g.- granular materials, polymers, foams, colloids etc.) are defined on the basis of Pierre-Gilles de Gennes' definition. At NASA GRC, we are pushing the boundaries for fundamental study of soft matter on Lunar Surface. With regard to Lunar surface science, we are focusing on developing capabilities pertaining to granular materials and bio-soft/active matter to facilitate future efforts in ISRU and bio-ISRU capabilities. In order to achieve fundamental goals of soft matter research within the limitations of Lunar environment, the scientific capabilities need to be small, flexible, modular, off the shelf and the focus needs to be more on developing an interdisciplinary capability that leverages the recent growth in AI/ML and Computer Vision to augment our understanding of fundamental science. This strategy would allow us to reduce our resource requirement during launch, installation, and occupied real estate footprint on Lunar surface

In this talk, we will go over 3 different capabilities that we have developed in house and in close collaboration – (a) Differential Dynamic Microscopy (DDM), (b) Portable In-situ Chemical Spectroscopy (PICS) and (c) Computer Vision Enabled Observation. At very high level, Differential Dynamic Microscopy (DDM) allows us to study the structure-property-process relation (microrheology) of bio-soft/active matter using optical microscope and improved image analysis capabilities. PICS uses AI/ML-based advanced signal deconvolution and analysis technique that can work with existing portable spectroscopy tools to perform materials analysis (e.g.- granular materials and bio-soft/active matter) inspection on the go. Finally, computer vision enabled analysis allows us to use simple camera images for 3D reconstruction of experimental process and tracking of objects of interest in an experiment.

We expect that this detailed process will allow us reach a thorough understanding of soft matter in Lunar environment. The capabilities developed by us will help to validate and establish fundamental understanding in Lunar environment. This will, in turn, allow us to guide future space exploration missions and expand the knowledge base of the scientific and engineering communities.

Analysis of the mass transport properties of polymeric mixtures under microgravity conditions: DCMIX4 campaign

Antton Sanjuan[1], Prof. Dr. Werner Köhler[2], Prof. Dr. Valentina Shevtsova[1,3], Prof. Dr. M. Mounir Bou-Ali[1]

[1]Fluid Mechanics Group, Mondragon Unibertsitatea, [2]Physikalisches Institut, Universität Bayreuth, [3]Ikerbasque, Basque Foundation for Science

1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Antton Sanjuan Esnaola, PhD student in the Fluid Mechanics group of Mondragon University, with experience in experimental fluid analysis and numerical simulations (CFD). In 2018 he joined the Fluid Mechanics group, where he began his laboratory training, acquiring over the years experience in the numerical-experimental field to carry out both his final degree and master's degree projects, collaborating also in several publications. At present, after obtaining the grant from the Basque Government for the pre-doctoral research programme, he is analysing and determining the mass transport properties of binary and multicomponent macromolecular mixtures under both terrestrial and microgravity conditions.

In recent years, and due to its applicability in different sectors, the study and interest of mass transport properties based on concentration (molecular diffusion) and temperature gradients (thermodiffusion) has grown considerably [1]. In 1999, the first joint investigations dealt with the analysis of binary subsystems considering different ground conditions techniques. In 2003, the first collaborative results were published and today this database is used for the validation of new experimental techniques [2]. Nevertheless, most of the systems present in natural processes comprise more than two components and therefore, the interest of the scientific community focused on the study of multicomponent systems, for which a ternary mixture is the simplest representation. At the start, the determined transport coefficients were not in good agreement by considering the different experimental techniques. The complexity of the analysis of ternary mixtures increases and any convective flow generated by the effect of the gravity force can disturb the experiments. In this context, the Diffusion and thermodiffusion Coefficients in ternary MIXtures (DCMIX) project was founded to generate a reference database of different binary and ternary systems by studying them both in terrestrial and microgravity conditions [3]. Throughout the four missions of the DCMIX project, a total of five ternary systems were examined. In this context, one of the mixtures of interest during the fourth campaign (DCMIX4) was a polymeric system and its transport coefficients have not yet been published. Thus, the motivation of this work was to analyse the thermodiffusion experiments conducted under microgravity conditions with the focus on the polymer solution of DCMIX4. The investigated mixtures were the binary reference subsystem polystyrene toluene at a mass fraction of 2% (polystyrene) and the ternary mixture composed of polystyrene, toluene and cyclohexane at a mass fraction of 2% (polystyrene) and equimass fraction of the remaining solvents. The experiments were carried out via the selectable optical instrument technique. Additionally, four different working temperatures were considered starting from 20ºC up to 35ºC (increment of 5ºC). Regarding the followed methodology and obtained preliminary results, first, the quality of the captured interference patterns, the contrast, saturation, as well as the phase-shifting technique were evaluated. Additionally, the temperature recorded during the thermodiffusion experiments was examined to assess the potential presence of thermal instabilities. It was concluded that experiments were carried out successfully and data processing is currently underway to determine the mass transport coefficients of the binary and ternary polymeric mixtures.

Assessment of Spaceflight Associated Neuro-Ocular Syndrome Countermeasures in a Spaceflight Analog

Director Brandon Macias[1]
[1]Nasa
6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Brandon R. Macias, PhD., is the Director of the Cardiovascular and Vision Laboratory, at NASA-Johnson Space Center. Dr. Macias is principal investigator of three International Space Station Studies focused on characterizing and developing countermeasure for Spaceflight Associated Neuro-ocular Syndrome (SANS) and supports several other studies to address the SANS and Cardiovascular Adaptations spaceflight risks.

Introduction: Crewmembers flying ~6-month missions to the International Space Station show signs of optic disc edema (ODE), chorioretinal folds, globe flattening, and/or hyperopic shifts in refractive error; these findings are known as spaceflight associated neuro-ocular syndrome (SANS). The chronic headward fluid shift is believed to be the primary cause, and use of the spaceflight analog strict 6˚ head-down tilt bed rest (HDTBR) has replicated key SANS findings. The purpose of this study was to test the ability for two candidate countermeasures to reverse the headward fluid shift during strict HDTBR.

Methods: Using a cross-section study design, participants were exposed to 30 days of strict HDTBR and randomly assigned to 1 of 4 groups: Control (n=12, 6 female); Seated (n=11, 5 female); Lower Body Negative Pressure (LBNP, n=12, 6 female); Thigh Cuff (n=12, 4 female). Participants of the LBNP (50 mmHg) and Seated group were exposed to 6 hours of daily fluid shift reversal. Thigh cuffs were worn for 6 hours on 6 out of 7 days. Various ultrasound targets and intraocular pressure were used to assess the headward fluid shift before and during use of countermeasures throughout HDTBR. Optical coherence tomography images were analysed for the development of ODE.

Results: All participants completed 6 hours of daily exposure to each countermeasure without incident. LBNP led to a small increase in HR, but this did not change throughout the 3-hour exposure, or throughout 30 days of HDTBR. Cardiac output was reduced during use of each countermeasure. Use of LBNP or thigh cuff led to ~50% reduction in internal jugular vein cross-sectional area, while the upright group demonstrated complete reduction. LBNP reduced IOP by ~1.5 mm Hg, while use of thigh cuff led to a modest ~0.5 mm Hg reduction. ODE developed in all 4 groups.

Discussion: We rapidly tested 2 countermeasures by studying 47 volunteer participants exposed to 30 days of strict HDTBR. Both countermeasures were successfully implemented for 6 hours per day and resulted in an ~50% reversal of the headward fluid shift. However, SANS findings still emerged in all groups, suggesting that longer countermeasures exposures may be necessary.

Biopsychosocial health considerations for astronauts in long duration spaceflight and interplanetary exploration: A Narrative Review

Dr Payam Ghoddousi[1]
[1]King's College London / Civil Aviation Authority
1.3 - Life Sciences: Human Physiology and Performance, Space Nine, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Dr Payam Ghoddousi is an Aviation and Space Medicine Speciality Registrar since August 2022. Prior to this, he worked in acute medicine and emergency medicine and developed an interest in pre-hospital emergency care. He later completed training in General Practice with an extended role in Lifestyle Medicine and long term disease prevention. He has just this year completed the diploma in Aerospace Medicine at King's College London and the RAF and will progress to the Masters course as part of his specialty training with the Civil Aviation Authority.

Introduction: Long-duration spaceflight beyond low Earth orbit, including missions to the Moon and Mars, pose several health risks. The biopsychosocial model provides a holistic approach to healthcare and has been shown to optimise health outcomes in terrestrial settings.

Methods: a narrative review of the health risks to long-duration spaceflight and interplanetary exploration was conducted within the context of a BPS framework. A conceptual model was developed to highlight the multifactorial BPS effects of spaceflight, with respect to NASA's main hazards of spaceflight.

Challenges: Long-duration space missions pose many psychological stressors, ranging from confinement and isolation to the demands of living and working in highly controlled environments. It is also recognised that multiple biological factors can affect behavioural health and performance in space missions. The physiological function and psychological resilience of crew members becomes critical in the face of prolonged separation from Earth, compounded by the inherent risks and uncertainties associated with deep space exploration. Additionally, crucial to mission safety and success, are the interpersonal dynamics between crew. Differences in personality, communication styles, and cultural backgrounds among crew members can result in cohesive teamworking and contribute to a successful operation or may lead to conflicts and compromise safety. Issues related to mixed-gender dynamics may also arise, emphasising the importance of maintaining positive interpersonal relations and effective communication to foster a cohesive and productive team environment.

Countermeasures: In-flight countermeasures should aim to reduce the dependency on ground-based support, a crucial element for deep space explorations, where traditional reliance on Earth's resources is impractical due to significant communication delays and logistical constraints. Strategies may include ergonomic design improvements, structured work-rest schedules, continuous well-being monitoring using innovative tools such as AI-based voice stress analysis, and personalised in-flight interventions using virtual reality and digital self-help resources. Biomarkers relating to CNS effects of radiation exposure, stress response and sleep disturbance are being evaluated as possible tools for early detection of adverse cognitive effects. Real-time monitoring systems to aid in identification of early signs of stress are being studies to enable timely intervention. Post-mission, comprehensive debriefing and continued psychological support may be needed to facilitate re-adaptation to Earth's environment and address any long-lasting effects on behavioural health.

Conclusion: Based on existing literature and practices, a biopsychosocial approach to NASA's five main hazards was proposed, as a conceptual model to health in long-duration spaceflight and interplanetary exploration.

C.R.O.P. ® - Combined Regenerative Organic-food Production - Biofilter to close the nitrogen cycle

Dr. Jens Hauslage[1], Ilse Holbeck[1], Dr. Gerhild Bornemann[1]
[1]German Aerospace Center

ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space, Space Seven & Eight, September 5, 2024, 9:00 AM - 10:40 AM

Biography:
As a gravitational biologist, I study the perception as well as impacts of gravity (weightlessness) on life and its development. I am a plant physiologist by training with a minor in physics. Other areas of my research include the development of bioregenerative life support systems for space and earth applications and the design and construction of sensor systems and space experiments for microgravity platforms, e.g. sounding rockets (DLR Mapheus), drop towers and satellites. To transfer my gained knowledge to the following generations, I teach at several nat./int. universities and as trainer for esa astronauts.

The complete closing of material cycles is the ultimate goal in closed life-support systems. The integration of plants and humans in such a system provides both groups with the necessary substances to sustain life. The obvious cycles here are those of air and water, but the nutrition of plants in particular is also an important cycle that can only ensure long-term survival if it is closed. The DLR C.R.O.P biofilter is a trickle filter that brings the functionality of nitrification into a closed technical system and is able to convert urine into a nitrate-containing solution within a short time. In addition to nitrification, xenobiotics can also be degraded. This has been demonstrated with ibuprofen and diclofenac. The filter is also characterized by a long service life and low maintenance. The filter has a natural bacterial consortium, which has been analyzed several times in independent filters. The method is now being commercialized as a technology developed for space travel in a DLR spin off in the agricultural sector for liquid manure. Converting manure in a better fertilizer for agricultural use.

Cell biological experiments in sustainable and multi-usable hardware for studies under altered gravity conditions

Dr. Ruth Hemmersbach[1], Dr. Jens Hauslage, Ilse Holbeck, Sebastian Feles, Maximilian Sturm, Laura Kalinski, Dr. Yannick Lichterfeld, Dr. Robert Prior, Sarah Schunk, Dr. Christian Liemersdorf
[1]DLR, Institute of Aerospace Medicine, Gravitational Biology
1.1 - Life Sciences: Cell Biology, Genetics and omics, Space One, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
As a gravitational biologist, I study the perception as well as impacts of gravity (weightlessness) on life and its development. I am a plant physiologist by training with a minor in physics. Other areas of my research include the development of bioregenerative life support systems for space and earth applications and the design and construction of sensor systems and space experiments for microgravity platforms, e.g. sounding rockets (DLR Mapheus), drop towers and satellites. To transfer my gained knowledge to the following generations, I teach at several nat./int. universities and as trainer for esa astronauts.

Introduction / Background:
Single cells to complex organisms demonstrate changes in physiology and signaling pathways when being exposed to altered gravity conditions. However, open questions concerning the underlying mechanisms of gravi-perception/ signaling still exist. We focus to understand how neuronal cells respond to altered gravitational conditions, since neuronal activity is modulator of behavior, human cognition, learning, memory and motor skills. Changes are highly important for crew performance.
Method:
We developed experiment modules for cell cultivation (temperature, etc.), online electrophysiological measurements and chemical fixation of adherent or suspension cellular or organoid samples. Reusable modules/hardware were designed employing conventional and more sophisticated modelling as well as bio-compatible 3D printing. Development of experiment modules that can be utilized in common gravity research platforms (ZARM Drop Tower in Bremen, Germany; DLR Short-Arm Human Centrifuge in Cologne, Germany; parabolic flights from Bordeaux, France and sounding rockets from ESRANGE, Kiruna, Sweden) plays an increasingly role in data comparability and statistical analysis. In the recently launched DLR rocket campaign MAPHEUS-14, several biological experiments were performed in parallel. Online electrophysiological measurements on a multi-electrode array (MEA) system were recorded (“Mind-G”). In-flight chemical fixation of biological samples (human IPSC-derived motoneurons, primary murine astrocytes) during various acceleration phases was conducted for subsequent proteomic profiling (LIFT). In-flight fixation was performed on mature human IPSC-derived brain organoids for transcriptomic analyses (ROMS). Microgravity studies should always be well prepared and accompanied by studies in ground-based facilities (GBFs). A broad portfolio of facilities for studies in simulated microgravity (which need final verification in real microgravity) as well as hypergravity are used in our studies and are provided to external scientists e.g. by the ESA GBF program.
Results:
All experiment modules functioned flawlessly and environmental data revealed the desired stable conditions throughout the rocket flight. The flight scenario of MAPHEUS-14 equipped with a new motor system provided microgravity time of approximately 6.5 min with optimal conditions for the cell cultures, as revealed by post-flight cellular and organoid morphology as well as by persisting live neuronal activity even after several days after return to Earth.
Conclusion:
The increasingly specialized development of printable materials and the availability of electronic components is opening up a new world of experiment development for space experiments, here demonstrated for sounding rockets. This trend in the growing new space sector also enables the simple and application-based training of young scientists.

CFD Predictions of Boiling Regime Transitions during Line Chilldown validated against a 1G LN2 Experiment

Dr Mohammad Kassemi[1], Ms. Sonya Hylton[1]
[1]Case Western Reserve University
5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Dr. Mohammad Kassemi is a Professor & Director of the National Center for Space Exploration Research at Case Western Reserve University and NASA Glenn Research Center in Cleveland, Ohio. He is the Principal Investigator of the Zero-Boil-Off Tank (ZBOT) experiment series performed aboard the ISS. He is a member of the National Academy of Sciences Committee on Biological and Physical Sciences in Space. He is an AIAA Associate Fellow and a member of the AIAA Liquid Propulsion Technical Committee. He is also the recipient of the 2015 NASA Exceptional Public Achievement Award and the 2019 NASA Silver Snoopy Award.

Introduction:
Before filling a propellant tank on the ground or in Space, the transfer line between the donor and receiver tanks must be cooled down preferably by sacrificing a minimum amount of the cryogenic fluid. The cryogenic line chill-down process involves a transition between different flow boiling regimes, namely, film boiling, transition film boiling, and nucleate boiling which are complex and may be quite gravity-dependent [1]. Capturing these boiling phenomena and predicting the transition between them in a CFD framework is new and challenging both for 1g and microgravity applications.
Materials & Methods:
The present work addresses this challenge by employing a two-phase Eulerian approach for a homogeneous mixture together with the Lee phase change model to capture the film boiling regimes of the chill-down process using ANSYS Fluent®. The nucleate boiling regime is predicted by incorporating an in-house developed sub-grid model that accounts for bubble nucleation, bubble growth, bubble departure diameter, and their shedding frequency. The sub-grid model is implemented into Fluent via a user-defined function for the wall-fluid heat flux calculations. The mathematical formulation and numerical implementation of the CFD model are described in detail. The coupled CFD-Subgrid model is validated against published experimental data for liquid nitrogen chill-down of a heated stainless-steel pipe in 1g [2].
Results:
Numerical simulation results show good agreements between the CFD predictions of the wall temperature evolution, rewetting temperature, and transition between film and nucleate boiling, with the experimental measurements published by Darr et al [2] for several different LN2 flowrates in the vertical pipe orientation. The CFD predictions for the wall temperature distribution indicate rapid quenching of the wall at two upstream and downstream temperature sensor locations with excellent agreement with the experimental measurement as shown in Fig 1. The only tuning parameter in the CFD model is the Lee mass transfer coefficient. The CFD Model predicts the Liedenfrost rewetting temperature also in close agreement with the experiment. This marks a transition from the stable to the transitionary film boiling regimes. The CFD-predicted boiling curve for the downstream sensor location is also compared against its experimental counterpart in Fig. 2 and indicates that the model is able to predict all the key temperature and heat flux parameters during the transitions from stable film boiling to nucleate boiling regimes in close agreement with the experiment. A sequence of predicted volume fraction and temperature contours depicting these transitions is shown in Fig 3.

Changes in endocannabinoid signalling under Space conditions

Miss Noemi De Dominicis[1,2], Dr. Veronica Carnicelli[2], Dr. Sara Standoli[3], Dr. Marina Fava[4,5], Prof. Cinzia Rapino[6], Dr. Alessandro Leuti[4,5], Prof. Mauro Maccarrone[2,5]

[1]Department of Physics, University Of Trento, [2]Department of Applied Clinical Sciences and Biotechnologies, University of L'Aquila, [3]Department of Bioscience and Technology for Food Agriculture and Environment, University of Teramo, [4]Department of Medicine, Campus Bio-Medico University of Rome, [5]European Center for Brain Research/IRCCS Santa Lucia Foundation, Rome, [6]Department of Veterinary Medicine, University of Teramo

4.1 - Life Sciences: Bone, Muscle and Immune responses, Space One, September 5, 2024, 11:00 AM - 1:00 PM

Biography:

PhD Student in Space Science and Technology for Astrobiology and Space Life Sciences. The aim of my project is to investigate the role of bioactive lipids in intestinal cells subjected to simulated microgravity.

Background. Microgravity, a Space stressor, is associated with cellular and molecular alterations of the immunological profile that impact on the human body homeostasis, gastro-intestinal (GI) tract included[1]. Noteworthy, the onset, progression, and outcome of inflammatory processes are regulated by specific endogenous bioactive lipids, that can be synthesized by specific fatty acid precursors like arachidonic acid (ARA) and docosahexaenoic acid (DHA). Experiments performed in recent years on primary human immune cells onboard the International Space Station (ISS) – like ROALD [2], RESLEM [3] and SERiSM [4] – and under simulated microgravity conditions [5], demonstrated that metabolism of bioactive lipids and signal transduction thereof are dysregulated in microgravity. Hence, we sought to interrogate whether bioactive lipids may influence human intestinal cells' response to authentic or simulated microgravity, thus contributing to maintain GI homeostasis. Among the bioactive lipids, endocannabinoids (eCBs) represent strong pro-homeostatic signals [6]. Accordingly, nutraceutical or pharmacological modulators of the receptors that bind such lipids, as well as of their metabolic enzymes, were employed. The goal was to develop potential countermeasures against Space-related human diseases. Methods. Human Caco-2 cells were chosen as a model of intestinal epithelial cells. During ground control studies (1xg) Caco-2 cells were treated with ARA, DHA, and the short chain fatty acids (SCFAs) butyrate (But) and propionate (Pro) [7,8]. In addition, Caco-2 cells were subjected to simulated microgravity (10-5xg) by means of the Rotary Cell Culture System (RCCS) developed by NASA. Western blotting and qPCR were performed to interrogate possible effects on the eCB system (ECS) at a protein and genic level. Results. In the 1xg experiments, the 50% critical micelle concentration (½CMC) of ARA and DHA (30 µM), as well as of But and Pro (2.5 mM) was chosen to treat Caco-2 cells. Briefly, ARA induced a decrease in the expression of the eCB-binding cannabinoid (CB1 and CB2) receptors, whereas DHA downregulated the expression of CB2 only. The SCFAs did not modulate any component of the ECS. Regarding the microgravity studies, Cytodex3 microcarriers were necessary for Caco-2 survival [9,10]. Of note, simulated microgravity downregulated PPARγ gene expression and increased MAGL gene expression. At the protein level, CB1 and CB2 were downregulated. Conclusions. Most of the treatments induced downregulation of eCB-binding receptors at the protein level, with CB1 and CB2 being involved in intestinal motility [11]. These effects, along with the gene and protein expression of the main eCBs metabolic enzymes, will be better elucidated in ongoing experiments.

Circadian Disruption in Arabidopsis Under Simulated Microgravity: Towards Understanding Plant Timekeeping in Space.

Dr. Colleen Doherty[1], Blake Horton, Joseph Tolsma, Imara Perera, Kanjana Laosuntisuk, Jeff Richards, Jacob Torres
[1]North Carolina State University
ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics Continued..., Space Seven & Eight, September 5, 2024, 2:15 PM - 4:10 PM

Biography:

Colleen Doherty is an Associate Professor of Biochemistry at North Carolina State University. Her research interests include understanding how timing (time of day or season) affects plants' environmental responses and stress tolerance and developing synthetic plant systems tailored to unique goals and environments.

Dr. Doherty received her Biochemistry Ph.D. from Michigan State University, studying the signaling pathways that enable plants to perceive, respond, and adapt to low temperatures. Dr. Doherty completed her postdoc with Steve Kay and Trey Ideker at UC San Diego, investigating the networks that control how plants measure time and use temporal cues to modulate environmental responses.

Long-duration space missions require a deep understanding of how plants respond to the altered gravity environment. In microgravity, fluid flow and diffusion-dependent biochemical processes, like the circadian clock, might be disrupted.
The circadian clock is an internal timekeeping system in plants that coordinates their internal processes with the external day-night cycle. This anticipation allows plants to optimize their performance and survival. It relies heavily on precise movement and interactions within cells, making it a sensitive model for studying microgravity's effects. Moreover, understanding the impacts of microgravity on the circadian clock will be essential for astronaut and plant health on long-duration space flights. Therefore, we addressed the question: Does reduced gravity affect the plant's circadian clock?
We used a Random Positioning Machine (RPM) to simulate microgravity and studied the response of the Arabidopsis plant's circadian clock genes. We collected root and shoot samples every 2 hours over 48 hours, allowing us to track changes in gene expression. RNA analysis revealed disruptions in the rhythmic expression patterns of core circadian clock genes like CCA1 and LHY. This disruption cascaded to affect downstream clock-controlled genes as well. Overall, RNA sequencing showed a widespread shift in the plant's circadian rhythmicity under simulated microgravity.
In conclusion, this research highlights the potential disruption of the plant's internal timing system under microgravity conditions. Further study is needed to understand the long-term implications for plant growth and development in space.

Conserved molecular responses to Spaceflight; Insights from the Advanced Plant Experiment APEX-07

Dr. Imara Perera[1], Eric Land[1], Lucas Bauer[1], Emma Canaday[2], Sarah Wyatt[2]
[1]North Carolina State University, [2]Ohio University
1.4 - Life Sciences: Plant Biology adaption and response to space, Space Seven & Eight, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Dr. Imara Perera is a Research Professor at North Carolina State University (NCSU) in the Department of Plant and Microbial Biology. Her primary research interest is on understanding the molecular mechanisms plants utilize to sense and respond to environmental stresses. She has over 20 years of research experience in plant gravitational biology and has conducted spaceflight experiments to study plant adaptations to microgravity and the space environment.

Long duration spaceflight missions will require the development of plants adapted to the space environment. Transcriptional profiling of mRNA is a robust method for querying plant molecular responses to abiotic stresses, including spaceflight. However, changes in transcriptional abundance do not always manifest at the protein level. The Advanced Plant Experiment APEX-07 was designed to query both total mRNA (transcriptome) as well as polysome associated mRNA species (translatome). Comparison of these two populations from Arabidopsis plants grown on the International Space Stations (ISS), and ground controls provides valuable insight into post transcriptional regulation associated with adaptation to the space environment.

APEX-07 consisted of two flight experiments carried out sequentially, which were initially analyzed independently. In order to increase statistical power and identify conserved trends among the two experiments, both RNA-Seq datasets were combined and reanalyzed. We found that, in root tissues, ~32% of genes were similarly upregulated in total and polysomal mRNA, while ~ 47% were similarly upregulated in shoot tissue. Response to stress and defense responses were among the enriched categories for genes commonly upregulated in root total and polysomal fractions, while photosynthesis related genes were commonly upregulated in both fractions of the shoot tissue.

Misregulation of photosynthesis (PS) related genes has been widely reported from several different plant spaceflight experiments. These findings are not limited to light-grown shoot tissues, and have been observed in dark-grown roots as well. Interestingly, we noted that PS related genes were highly enriched in the root total mRNA yet only ~17% of these were shared with the polysome. Conversely, both total and polysomal fractions showed enrichment of PS related genes in the shoot tissue. These results suggest that the majority of PS transcripts upregulated in roots are not actively recruited to the polysome.

Another aspect of the APEX study involves utilizing image analysis software (SOAPP – simple online automated plant phenomics) to analyze phenotypic differences between ground control and spaceflight plants. In particular, we are focused on rosette characteristics such as color, size and density. We anticipate that this approach will provide a quantitative measurement of observed qualitative differences between spaceflight and control plants.

Controlling plant root electrotropism to optimise root growth in microgravity

Ms Maddalena Salvalaio[1], Dr Giovanni Sena[1]
[1]Imperial College London

ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics Continued..., Space Seven & Eight, September 5, 2024, 2:15 PM - 4:10 PM

Biography:

My background is in theoretical physics and developmental biology.

- Senior Lecturer (2020 – present), Imperial College London, London, U.K.
- Senior Lecture (2020 - now), Imperial College London, UK
- Lecturer (2012 – 2020), Imperial College London, UK
- Post-doctoral Research Associate (2005 - 2011), New York University, US
- Visiting Fellow (2005 - 2011), The Rockefeller University, New York, USA
- Post-doctoral Fellow (2003 - 2005), The Rockefeller University, New York, USA
- Ph.D., Biology (2003). Developmental Genetics. Prof. P. Benfey lab, New York University, USA
- B.Sc. / M.Phys., Physics (1995, Laurea), University of Milan, Italy.

Prolonged human missions in space, whether in orbit or interplanetary travel, will require access to a sustainable food supply. During multi-year missions, key nutrients like vitamins C and B1 will degrade in packaged food, but the integration of plants into advanced Bioregenerative Life Support Systems could represent a sustainable and economically attractive way to provide a balanced diet during long-duration missions.

Although a variety of small plant species have been grown on the International Space Station (ISS), the cultivation of larger crop plants in µg still needs to be fully developed. One of the practical issues that requires attention is the control of root growth in the absence of gravity. A mature plant develops a complex root system made of tens to hundreds of single root tips, whose growth rate and orientation are regulated by environmental signals such as gravity, light, water potential, chemical gradients and electric charges. In fact, the ability to change growth direction in response to an external cue (tropism) is a key characteristic of plant development. Crucially, the biological response to gravity (gravitropism) is one of the dominant forces shaping complex root systems on Earth.

In microgravity environments, plant roots cannot use gravitropism to establish and maintain their optimal spatial distribution. To directly address this challenge, we are proposing to adopt the natural tendency of roots to reorient towards negative charges (electrotropism) and use artificial electric fields to mimic the effect of gravitropism on roots.

In this talk, I will present a quantitative characterization of the tropic response exhibited by roots of the plant model system Arabidopsis thaliana exposed to external electric fields in laboratory conditions on Earth. Our study elucidates the dose-response kinetics of early electrotropism stages, exhibiting a power law reminiscent of physiological reactions in animals. I will also discuss long-term electrotropism traits, such as overshoot, habituation, and the role of past exposures in the response to electric fields (hysteresis), offering quantitative insights into the intricate nature of root behaviour in these conditions.

Overall, this study represents a first step towards the possible adoption of electrotropism as a replacement for gravitropism when growing plants in microgravity environments.

Convective regimes of planetary atmospheres in the AtmoFlow spherical shell experiment: Solid-body and differential rotation

Yann Gaillard[1], Peter Haun[1], Dr. Peter Szabo[1], Prof. Dr-Ing Christoph Egbers[1]
[1]Department of Aerodynamics and Fluid Mechanics, Brandenburg University of Technology Cottbus-Senftenberg, Siemens-Halske-Ring 15a, 03046 Cottbus, Germany
2.2 - Physical Sciences: Material Science, Space Two, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
I am an aerospace engineering graduate from the Technical University of Munich. Throughout my academic journey, I showcased leadership as the team leader in the Scientific Student Rocketry Group (WARR) and conducted research as a dedicated assistant in fluid mechanics of rocket engines. In 2021, I began my PhD at the Brandenburg University of Technology (BTU), delving into the field of thermoelectric hydrodynamics in spherical Taylor-Couette systems.

Convection in a planetary atmosphere is of particular interest when discussing climate change. The fundamental understanding of large-scale convection in atmospheres relies commonly on observations of planets such as Earth and Jupiter and celestial bodies or numerical models. Laboratory experiments of such large-scale flows are mostly limited to experiments in cylindrical or spherical shell configurations that retain the overall physical meaning. AtmoFlow is one of those experiments composed of two concentric shells mimicking a planetary atmosphere by equatorial heating and pole-ward cooling. Planetary rotation is given by spherical shell rotation, and terrestrial gravity is given by an artificial central force field induced by an electric field between both shells. The working fluid is confined between the spherical shells. However, this configuration is sensitive to buoyancy caused by natural convection. Therefore, the system will be placed on the International Space Station (ISS), presumably in 2026. The AmoFlow experiment will replace the former GeoFlow experiment, a spherical shell experiment used to study mantle convection, served on the ISS from 2008 to 2017. Here, we present a three-dimensional (3D) Direct Numerical Simulation (DNS) of the AtmoFlow spherical shell experiment and its expected flow patterns for the parameter space in solid body and differential rotation configurations. The numerical simulation shows distinct regimes for the solid body case, illustrating transitions between convective states. The convective pattern formation for the differential rotating configuration is classified into distinct regimes concerning the forcing strength. The classification can be made into time-periodic Taylor vortex flow and irregular convective flow with plume structures for large rotational and buoyant forcing. Smaller buoyant forcing exhibits distinct time-invariant plume structures reminiscent of classical Rayleigh-Bénard convection, while intermediate equivalent forcing strength for rotational and buoyant forcing reveal time periodic fish-bone structures. The numerical study used a finite volume technique based on OpenFoam and was performed on the HLRN cluster.

CRYSALIS – Acoustic technologies for a European Cryogenic Storage and Refuelling In-orbit Demonstration

Dr. Ricard González-Cinca[1], Sara Cecilia Abecia Hernanz[1]
[1]Universitat Politècnica de Catalunya - BarcelonaTech
6.2 - Physical Sciences: Multiphase Flows, Space Two, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
RGC is Head of the UPC Space Exploration Lab. He has worked in microgravity research projects funded by Spanish Ministry of Science, ESA, NASA and CNES for the last 17 years. His current research is focused on the management of multiphase flows in space and on ISRU-based power systems for the Moon. He was the ELGRA President 2017-2021.

The long-term storage and in-orbit transfer of cryogenic propellants will be key technologies for enabling a European in-space transportation ecosystem. An in-space logistics system consisting of a range of depots and refuellable orbital vehicles will enable sustainable, long term manned missions to Mars and the moon. One of the main challenges to achieve this vision is the low saturation temperatures of cryogenic propellants which introduce additional challenges in their management. At present, neither long-term storage nor refuelling with cryogenic propellants has been demonstrated in-orbit, and the technologies and processes necessary lack maturity in Europe.

CRYSALIS (CRYogenic Storage And refueLling In-Space) is a collaborative EU funded project (101135431) between Absolut System, The Exploration Company, the Universitat Politècnica de Catalunya - BarcelonaTech, and the Université de Liège, to mature the technologies necessary for the storage and transfer of cryogenic propellants, in particular liquid oxygen and liquid methane. The project aims to perform a small-scale in-obit demonstration with liquid nitrogen on-board the Nyx Earth capsule in 2028, to permit the maturation of technologies that cannot be matured on earth and to improve the knowledge of cryogenic fluid behaviour in a microgravity environment.

The UPC-BarcelonaTech will develop three techniques based on acoustics in the framework of the CRYSALIS Project. These techniques aim at the control of boil-off in the tank [1], the measurement of propellant mass [2], and the management of bubble dynamics.

A preliminary feasibility study and design for the demonstration will be presented, including the main objectives, with a focus on the technologies to be matured by UPC-BarcelonaTech.

Data-driven thermodynamic modeling of microgravity sloshing: outcomes from the 83rd ESA parabolic flight campaign

Pedro Afonso Marques[1,2], Eng. Francisco Monteiro[1], Dr. Alessia Simonini[1], Eng. Louis Carbonnelle[1], Assoc. Prof. Miguel Alfonso Mendez[1]
[1]von Karman Institute For Fluid Dynamics, [2]Transferts, Interfaces Et Procédés (TIPs), Université Libre de Bruxelles
6.2 - Physical Sciences: Multiphase Flows, Space Two, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Pedro graduated as an aerospace engineer from Instituto Superior Técnico in 2020. In 2021, he graduated with honors from the von Karman Institute's "Research Master" program. He won the "Theodore von Karman Award" for his work on his project entitled "Experimental characterization and modeling of non-isothermal sloshing." As of September 2021, Pedro is a PhD candidate with the TIPs laboratory in the Université Libre de Bruxelles, working on the data-driven characterization of heat and mass transfer in cryogenic storage tanks.

Advances in modern space propulsion systems heavily rely on understanding and managing the complex thermodynamic phenomena within their cryogenic propellant tanks. These fluids demand chilling storage temperatures, making the tanks susceptible to heat ingress and propellant boil-off. The challenges in thermal control are aggravated by sloshing, which disrupts the dynamic stability of the spacecraft and produces violent pressure fluctuations, potentially hindering the smooth fuel supply to the engine. Consequently, controlling the tank's operating conditions requires advanced control strategies tailored to each stage of the spacecraft's mission profile. However, this requires robust modeling of the underlying heat and mass transfer to accurately predict the system's thermodynamic evolution.
As a part of a broader research effort characterizing sloshing for space propulsion, this work focuses on the propellant's thermo-hydraulics during the ballistic flight phase. In this context, the presented work combines experimental methods and data-driven modeling techniques to characterize the tank's thermodynamic evolution in microgravity conditions. The experiments were conducted in the 83rd ESA parabolic flight campaign within the NT-SPARGE (Non-isoThermal Sloshing PARabolic FliGht Experiment) project. The setup consists of four major components: a 'donor' tank carrying superheated HFE-7000 vapor, a 'receiver' tank partially filled with liquid HFE-7000, a pressurizing line connecting these two, and an acquisition system collecting all sensor information. The setup is instrumented with pressure transducers and racks of thermocouples measuring the spatial distribution of temperature inside and outside both tanks and along the pressure line. The experiment comprises two stages: (1) pressurization and thermal stratification and (2) disruption of the 'receiver' through sloshing.
The system is modeled via a 0D thermodynamic model derived from conservation balances applied to the gas, liquid, and solid regions. This implementation expresses heat and mass exchanges between each control volume through flux terms, depending on some heat transfer coefficients. We write these terms through parametric functions depending on the model's thermodynamic state and a set of (unknown) weights. We employ the acquired data to derive and update these functions using an adjoint-based non-linear optimization that identifies the weights by minimizing the discrepancies between model prediction and system evolution. Enriched by the data-driven thermodynamic closure, the identified model tracks the thermodynamic history of the 'receiver' tank during microgravity sloshing. Given the model's negligible computational cost, it can be integrated into broader system models, enabling real-time predictions and opening the path toward model-predictive control and anomaly detection in cryogenic thermal management systems.

Design, performance, and preliminary ground results of the MarPCM experiment

Úrsula Martínez[1], José Miguel Ezquerro[1], Dan Gligor[1], Ignacio Tinao[1], José Fernández[1], Pablo Salgado[1], Karl Olfe[1], Jeff Porter[1]
[1]Universidad Politécnica de Madrid
4.3 - Physical Sciences: Marangoni convection, Space Nine, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Jeff Porter received his Ph.D. from the University of California at Berkeley in 2001 and has held a position of Profesor Contratado Doctor (I3) at the UPM since 2006. His research applies ideas from nonlinear dynamical systems, like bifurcation theory and pattern formation, to the study of fluid instabilities, particularly under microgravity conditions. He is interested in Faraday waves, cross-waves, frozen waves, vibroequilibria and, most recently, the effect of thermocapillary convection on Phase Change Materials.

Introduction:
MarPCM will investigate the efficacy of thermocapillary convection for augmenting the heat transfer rate of passive phase change materials (PCMs) in microgravity that incorporate a free surface; so-called thermocapillary-enhanced PCMs (TePCMs). Compared to conduction, thermocapillary flows can increase heat transport by a factor of two or more. The experiment seeks to understand heat and mass transport mechanisms during melting and solidification and assess the practicality of using TePCMs as passive control devices for space missions.
Here, we briefly revise the design, performance, and ground results of the cuboidal MarPCM cell. For further details, the reader is referred to Porter et al. (2023) and Martinez et al. (2024).

Experiment:
The experiment consists of two units: the Electronics and Computer Unit (ECU) and the Experiment Cells and Diagnosis Unit (ECDU). The ECU contains the computer and other electronic components for power conditioning. The ECDU is an exchangeable module that includes two experiment cells (ECs) and elements for diagnosis and data acquisition. Three different ECDUs, holding a total of six different ECs, will be launched to the ISS in 2026 (subject to the final operations schedule).
The cuboidal EC has interior dimensions (in mm) of 22.5 (length) x 15 (height) x 25 (depth). Two types of cuboidal cells are designed. The Marangoni cell has a 5 mm layer of air above the PCM to allow thermocapillary convection during the phase change while the Reference cell is completely filled with PCM so that melting dynamics is driven solely by conduction.
To ensure precise temperature measurements, we select fast-response NTC temperature sensors, which are coupled with high-performance thermoelectric modules and a precision temperature controller for the thermal control of the ECs. The optical setup includes two cameras equipped with both telecentric and fixed focal length objective lenses, and an LED panel for illumination; see the left panel of the figure.

Results:
Ground tests on the cuboidal Marangoni setup confirm its satisfactory operation; see the right panel of the figure. Results indicate sufficient image quality for processing, precise and stable temperature measurements, accurate thermal control, coherent melting times with the applied thermal gradients, and repeatability in design, manufacturing, and integration of the experiment units.

Conclusions:
The developed hardware provides acceptable performance while the ground results obtained are coherent and compliant with the experiment requirements; the feasibility of the proposed design is thus demonstrated. Furthermore, the design illustrates a comprehensive approach towards developing space experiments.

Developing plant cultivation technologies for space at DLR - from Antarctica to the Moon

Michel Fabien Franke, Prof. Daniel Schubert, Ms. Jess Marie Bunchek, Mr. Vincent Vrakking, Ms. Claudia Philpot, Dr. Volker Maiwald, Mr. Markus Dorn
[1]German Aerospace Center (DLR)
2.4 - Life Sciences: Life Support systems, Agriculture and Life Support Systems, Space Seven & Eight, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Michel Fabien Franke is a young engineer with longstanding experience in the automotive and space sector. He received a B.Eng. in Automotive Engineering (work-study degree programme) and a M.Sc. in Space Engineering from the University of Bremen. Additionally, he completed an apprenticeship with Volkswagen (Construction Mechanic), did an internship at Space Application Services in Brussels and completed ISU's Space Studies Program. Now, he is a full-time Systems Engineer at DLR, developing planetary infrastructures for Moon and Mars (focusing on bio-regenerative life support systems like the EDEN ISS, EDEN LUNA and EDEN NEXT GEN greenhouses).

Introduction/Background:
By signing the Artemis Accords, spacefaring nations from around the globe have expressed their willingness to return astronauts to the Moon by the end of this decade. Unlike past lunar programs, Artemis aims to establish a long-term human presence on the surface of Earth's natural satellite. A crewed outpost like the Artemis Base Camp requires a reliable supply of food and other consumables like oxygen. To address this need in a sustainable way, frequent resupply from Earth is not an option. Instead, a closed-loop bio-regenerative life-support system (BLSS) will be needed to produce fresh food and oxygen on-site, while eliminating carbon dioxide and other unwanted waste products. Thus, BLSS technologies have to be developed and field-tested in a space-analogue environment.

Method/Experiment:
To this end, DLR has founded the Planetary Infrastructures research group. The group has worked on BLSS for more than 10 years and has developed, built and operated a prototype-level greenhouse for space called EDEN (Evolution & Design of Environmentally-closed Nutrition-Sources) ISS at the German Neumayer-Station III in Antarctica. The purpose of this facility was to enable multidisciplinary research on topics related to plant cultivation for future human space exploration missions. Research on plant health monitoring, microbiology, food quality and safety, and human factors was conducted, while simultaneously validating the system.

Result:
After 5 years in Antarctica and more than 1 ton of biomass produced, the greenhouse was shipped back to Germany, bringing the project to a successful end in 2023. The follow-on project, EDEN LUNA, is currently under development. Its goal is to refurbish and upgrade the existing Controlled Environmental Agriculture (CEA) subsystems, while also introducing new technologies like a robotic arm, nutrient recovery from urine, and AI-based risk mitigation. Additionally, the group is working on a realistic version of a Lunar Agriculture Module Ground Test Demonstrator (LAM-GTD) together with the Canadian Space Agency and other international partners. Designed for the lunar environment and dimensioned to be compatible with current launch vehicles and space standards, the LAM-GTD symbolizes the last step of analogue testing, paving the way for actual space missions to Moon and Mars.

Conclusion:
This paper summarizes lessons learned from EDEN ISS, while giving a status report on the development of the EDEN LUNA project. Moreover, a system overview for the LAM-GTD will be given, showcasing the most significant advances in BLSS technology at DLR.

Elucidating the impact of spaceflight on plant immune responses

Dr. Anjali Iyer-Pascuzzi[1], Denise Caldwell
[1]Purdue University
ISLSWG Plants in Space Workshop - Theme 1: Plant Adaptation and Response to Space Environmental Stress Continued..., Space Seven & Eight, September 4, 2024, 4:30 PM - 6:15 PM

Biography:

Dr. Iyer-Pascuzzi is a Professor in the Department of Botany and Plant Pathology at Purdue University in West Lafayette, Indiana, USA. Her research is focused on plant-microbe interactions both on Earth and in Space.

Introduction/Background: Understanding how plants adapt to the unique pressures of spaceflight is critical for growing food in deep space. Microbes, including plant pathogens, were recently identified on the International Space Station (ISS) (Checinska Sielaff et al. 2016; Urbaniak et al. 2018; Khodadad et al. 2020), and disease loss threatens crop production in space (Urbaniak et al. 2018). To sustain long duration human space exploration, we need to grow and harvest edible crops and minimize crop loss from disease. This requires knowledge of plant immune responses during spaceflight, and how pathogen colonization and virulence are impacted by spaceflight conditions. However, our current knowledge of plant-microbe interactions in space is very limited (Foster et al. 2014).
Method/Experiment: The Advanced Plant Habitat (APH) is a plant growth system that provides improved growing conditions during spaceflight (Massa et al. 2016; John et al. 2021). We are investigating how the tomato immune system adapts to spaceflight when grown in the APH aboard the ISS. In early 2024, we grew both wild type and immune-deficient tomatoes in the APH and elicited defense responses with a chemical elicitor. Upon return to Earth, we will use genome-wide transcriptional profiling to compare the immune responses of space-grown tomatoes to ground controls. We are also investigating how tomato colonization by a fungal pathogen, Fusarium oxysporum, is altered by simulated microgravity on Earth using a custom-made 2D clinostat.
Results: Tomato plants grew well in the APH on the ISS and the experiment was successful. Tomato leaf samples arrived back to Earth in February 2024 and will be analyzed for gene expression in Spring 2024. Results will be shared at the conference.
Conclusion: We anticipate that our results will reveal fundamental insights into how the plant immune system responds to spaceflight conditions. Results will contribute to the development of sustainable crop production strategies in space and will enhance human exploration activities in space.

Enabling microgravity research - from LEO to the Moon

Ms Rona Stewart[1]
[1]The Exploration Company GmbH
2.3 - Gravity Related platforms and Launch Services, Space One, September 4, 2024, 4:30 PM - 6:15 PM

Biography:
Rona is the Business Development & Marketing Manager at The Exploration Company, a European start-up that builds reusable spaceships, which fly to space stations around the Earth and the Moon – with the ability to return to Earth.
Prior to joining The Exploration Company and the space community, she worked in the whisky industry on the marketing and communications team of the spirit company, Whyte & Mackay.

The Exploration Company is a French-German company with the mission to democratize space exploration for space & non space industries. To realize this mission, The Exploration Company develops, manufactures, and operates Nyx, a modular and reusable orbital vehicle which can eventually be refueled in orbit. Nyx provides various in-orbit services to Low-Earth Orbit like carrying cargo in its first version, with the potential to carry humans and cargo up to the Moon in its future version. The technical bricks of Nyx are built with open interfaces: they are available on a Space Store to enable space & non-space companies to use them and develop new applications.
Our missions to LEO and to the Moon enable researchers, institutions and companies to send their microgravity research into space for up to 6 months and then have it returned to them back in Earth.
In 2028 we will launch our mission to the Moon, giving researchers the opportunity to conduct experiments on the Lunar surface.
In our talk, we would like to highlight the upcoming missions in 2024 launched by Ariane 6 and in 2025 launched by SpaceX with scientific payloads on board.
We want to emphasise that our goal is to make space affordable and accessible for research across all industries and to prove this by showing the range of experiments that are now booked to fly on our mission in 2025 which include life science, food and beverage and cosmetic related studies.
We would like to present Nyx as a new platform to perform scientific research in LEO to the Moon and present Nyx' capabilities (pricing, implementation partners, power, communication and late access).

Energy-Efficient Oxygen and Fuel Production in (Photo-)Electrochemical Devices in Microgravity Environment

Dr. Katharina Brinkert[2]
[1]University of Warwick, [2]ZARM - Center of Applied Space Technology and Microgravity, University of Bremen
5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Completed undergraduate degree at the University of Glasgow in 2019 having carried out research projects with Prof. Justin Hargreaves and Dr. Gerardo Colon (University of Seville, Institute of Material Science Seville)

Went on to study a master's by research with Prof. Katharina Brinkert 2021-2022 studying hydrogen evolution photoelectrocatalysis and isotope separation

After completing the master's by research continued working with Prof. Katharina Brinkert starting a PhD (2022-2026) continuing the same project and exploring the fabrication of materials photoelectrochemical hydrogen evolution.

Human deep space exploration will rely on efficient and sustainable life support systems for the production of oxygen and other chemicals as well as the recycling of carbon dioxide. Photoelectrochemical (PEC) devices are investigated for the light-assisted production of hydrogen and carbon-based fuels from CO2 within the green energy transition on Earth. Similarly to natural photosynthesis, they only require water and solar energy for the process and release oxygen as a by-product. Their monolithic, compact design comprising integrated semiconductor-electrocatalyst systems for light absorption, charge separation and catalysis as well as their sole reliance on solar energy makes them attractive for applications in space, where they can directly convert solar into chemical energy without requiring additional accessories.

Here, we will highlight our recent experiments with PEC devices in microgravity environments realised for 9.3 s at the Bremen Drop Tower and links results regarding device efficiencies to gas bubble management and optoelectronic simulations. We will discuss obstacles such as the limiting solar irradiance on Mars as well as the reduced gravitation on the Martian and lunar surface for the application of PEC and other electrochemical devices in these environments and point to practical, sustainable solutions how to overcome them.

Engineering plant adaptation to spaceflight: Insights from Arabidopsis, cotton and tomatoes

Dr. Sarah Swanson[1], Dr. Arkadipta Bakshi[1], Dr. Sabrina Chin[1], Dr. Richard Barker[1,2], Dr. Simon Gilroy[1]
[1]University of Wisconsin-Madison, [2]Blue Marble Space Institute of Science
ISLSWG Plants in Space Workshop - Theme 1: Plant Adaptation and Response to Space Environmental Stress, Space Seven & Eight, September 4, 2024, 3:00 PM - 4:00 PM

Biography:
Dr. Simon Gilroy has been a professor in the Department of Botany at the University of Wisconsin-Madison since 2007. His lab researches how plants sense and respond to environmental stresses using a suite of molecular, genetic and cell biology approaches. In addition to ground-based research to understand plant responses to gravity, hypoxia and radiation, he has run multiple experiments on the International Space Station investigating how Arabidopsis, cotton and tomato plants react to the stresses of growing in the spaceflight environment. His research is sponsored by NASA, CASIS and the NSF.

Introduction:
Spaceflight presents a stressful environment for biology. For example, plants grown in space show responses ranging from widespread changes in patterns of gene expression related to oxidative stress (e.g., Barker et al., 2020, 2023), to alterations in growth and development. Plants are important candidates for elements of future bioregenerative life support systems and so understanding how they interact with the spaceflight environment remains a critical goal.

We therefore capitalized upon NASA GeneLab's extensive, curated repository of spaceflight 'omics'-level data (Overbey et al., 2021) and mined this resource using a range of bioinformatics tools to search for common patterns of gene expression across multiple plant spaceflight datasets. These analyses highlighted changes such as altered cell wall composition, responses to hypoxia, altered mitochondrial function, disruption of defense pathways, and reactions to reactive oxygen species and oxidative stress.

We then focused on hypoxia and oxidative stress as two of the major plant responses to spaceflight. Hypoxia is thought to develop from the loss of buoyancy-driven convection in microgravity. Lack of convective mixing of gasses then leads to local depletion of oxygen by metabolically active tissues that is no longer readily resupplied from the atmosphere. Similarly, radiation exposure is significantly increased in the spaceflight environment and oxidative stress has been linked to plant responses to a host of environmental factors including the impact of radiation.

Results and Discussion:
Ground-based analyses of the phenotypes of mutants in components of hypoxia and reactive oxygen species signaling networks allowed us to target the genes CAX2, RBOHD and AVP1 as candidates where changes in expression would be predicted to alter plant spaceflight responses. We therefore performed a series of experiments with Arabidopsis, cotton or tomato plants growing on the International Space Station where we manipulated these genes or their associated signaling pathways. Genetically engineering increased tolerance to hypoxia (through altered CAX2 expression), reducing oxidative load (knockout of RBOHD), or increasing general stress resilience (AVP1 over-expression) all led to plants that exhibited significantly reduced negative effects of growing in spaceflight. This tolerance was evident in sustained root and shoot growth along with reduced accumulation of biochemical and transcriptional markers of stress.

In combination with increasingly effective approaches to engineering plant growth hardware, these biological approaches hold great potential as countermeasures to the stresses of spaceflight. Such strategies will be essential tools to make plants a viable component of a sustainable approach to life support on future long-duration missions.

Enhancing heat transfer during PCM melting via convective flows and container design

Mr. Andriy Borshchak Kachalov[1], Dr. Pablo Salgado Sánchez[1], Dr. Úrsula Martínez[1], Dr. José Miguel Ezquerro[1], Dr. Jacobo Rodríguez[1], Dr. José Fernández[1], Dr. Álvaro Bello[1]
[1]E-USOC, Universidad Politécnica De Madrid
4.3 - Physical Sciences: Marangoni convection, Space Nine, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Meet Andriy, a Ukrainian researcher and PhD student in Aerospace Engineering at the Technical University of Madrid, specialized in heat transport in phase change materials. His research focuses on the phase change with convective flows, i.e. thermocapillary convection, and the application of phase change materials as passive thermal control devices. Also, he works as an ISS payload operator at the Spanish Users Support and Operations Centre (E-USOC).

Introduction:
Organic phase change materials (PCMs) are used for energy storage and thermal management in numerous applications including space missions. Their low thermal conductivity, however, has impeded even wider use. Besides improvements in heat transport from natural convection, recent studies have shown that incorporating a free surface can significantly enhance performance via thermocapillary convection (Salgado Sánchez et al., 2020a).

Here, we analyze the enhancement achieved by combining natural and thermocapillary convection (Borshchak Kachalov et al., 2021) and by using optimal container geometries adapted to the natural shape of the evolving phase boundary to maximize the melting rate (Huang et al., 2022).

Method:
The melting of n-octadecane is modeled numerically using the enthalpy-porosity formulation of the Navier-Stokes equations, which considers the solid and liquid phases of the PCM as a single continuous phase whose physical properties depend on temperature.
The process is analyzed first in a rectangular container with purely conductive heat transport as a reference. Each enhancement strategy — natural convection, thermocapillary convection and container design — is then applied sequentially in the manner shown for the five optimization paths (P.1 – P.5) in the figure. With thermocapillary effects, we restrict consideration to containers having a flat thermocapillary interface, i.e., open containers with a pinned free surface (Salgado Sánchez et al., 2020b).

Results:
The PCM volume V significantly affects the melting process and largely determines the heat transport enhancement, measured by the ratio G between the melting time for the reference case and that of the given scenario. This improvement further depends on the type of dominant convective flow. While gravitational convection provides an enhancement ratio G on the order of 2 for small V and 5-8 for large V, thermocapillary flow can increase this relative enhancement by factors of 8-22 and 4-7, respectively.

Conclusions:
The results demonstrate the efficacy of all three strategies for improving PCM performance. Often the first implemented strategy provides the greatest improvement relative to the reference case while supplemental strategies yield more modest gains, although not negligible ones. On the whole, melting times can be reduced by factors between 5 and 32 compared to the purely conducting reference configuration.

ESA Academy Experiments programme

Dr Laura Borella[1], Joost Vanreusel[2], Jorge Galvan Lobo[3], Elise Denis[2]
[1]Redu Space Services, [2]ESA - ESEC, [3]Space Application Services

3.1 - ELGRA, SELGRA and buildings collaboration with ESA & partners to Drive Space Education, Space One & Two, September 5, 2024, 9:00 AM - 9:45 AM

Biography:

I have a background in Space Engineering and worked as a Research Scientist at DLR, contributing to missions like MMX and ReFex. During my time there, my work was submitted for two patents. I also completed a PhD focused on ISRU materials for the Moon, conducting experiments on parabolic flights and developing image analysis algorithms for samples onboard the Emirates Lunar Mission. Currently, I support the ESA Academy Experiments programme.

This paper examines the ESA Academy Experiments programme, which has been overseen by the ESA Education Office. The programme empowers university student teams across Europe by supporting them throughout the entire project lifecycle. This includes concept development, testing, and executing experiments in cutting-edge gravity-altering facilities. It focuses on industry-standard engineering practices, project management, risk mitigation and funding techniques. Professional engineers and scientists provide regular guidance and interaction. The outcome of participation is a unique practical experience and training with the European Space Agency and its partners. Participation offers a unique hands-on experience with ESA and its partners, enhancing the students' academic journey. The paper outlines the phases of the programme before selection and the portfolio of platforms, including the Large Diameter Centrifuge, Bremen Drop Towers, Parabolic Flights, ICE-Cubes facility on the ISS, Space Rider and Orbital Robotics Lab. During the Campaign, the teams will finally be able to carry out their experiment on the selected platform and collect the long-awaited data. This is a unique and highly valued opportunity for the students who learn about managing large projects and meet the facility experts before starting the design of their experiments. Four months after the campaign, the teams will have to submit a final version of the documentation, which will conclude their project with ESA Academy.

ESA Higher plants compartment development for closed regenerative life support system: status and challenges

Christel Paille[1], Chloe Audas[1], Sandra Ortega[1], Brigitte Lamaze[1]
[1]ESA/ESTEC

ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space, Space Seven & Eight, September 5, 2024, 9:00 AM - 10:40 AM

Biography:

Christel Paille is an environmental control and life support system engineer at the European Space Agency. With over two decades of experience in research and technology for regenerative life support system solutions, she is currently responsible for developments enabling the integration of higher plant production technologies in future space missions, which includes bridging these developments with the space food system as well as the waste management system.

In the framework of the long duration crewed missions preparation, ESA has been performing research and technology activities in life support. Since the early days, emphasis has been put on the development of closed regenerative systems fulfilling wastes management, air revitalisation, water recycling and food production.

Within this context, the particular case of the higher plant production to fulfil few of these functions will be addressed. The activities are performed under the umbrella of the MELiSSA (Micro-Ecological Life Support System Alternative) project and globally aim at the development of a higher plant compartment to fulfil a high level of food production with predictable and controllable impact on waste management, air revitalisation and water recycling.

The presentation will introduce an overview of the current developments and the challenges for future integration in a closed regenerative system as well as implementation in space.

ESA's Parabolic Flight Activities: An overview of our campaigns, capabilities, and new application routes

Neil Melville[1], Andreas Borggraefe[1], Angelique Van Ombergen[1], Sebastien Vincent-Bonnieu[1], Inês Antunes[2], Giuseppe Correale[3], Thierry Gharib[4], Frédéric Gai[4]
[1]European Space Agency, [2]Telespazio for the European Space Agency, [3]Vitrociset for the European Space Agency, [4]Novespace for European Space Agency
3.1 - ELGRA, SELGRA and buildings collaboration with ESA & partners to Drive Space Education, Space One & Two, September 5, 2024, 9:00 AM - 9:45 AM

Biography:
Parabolic Flight and Drop Tower Coordinator and Payload System Engineer at European Space Agency

ESA parabolic flights provide an accessible, low-cost, reduced gravity environment for scientific research, technology development, and astronaut training. The human-accessible nature of the Airbus A310 Zero-G aircraft platform from Novespace allows experimenters to operate their experiments in-person, enabling real-time optimisation of scientific and technical return, and human biomedical experimentation with statistically significant N values. A high cadence of the reduced gravity periods (ninety-three times 22s per flight week) provides for redundancy and repeatability, whilst variation of the reduced gravity level, in addition to high quality weightlessness (average absolute deviation <0.007g), provides a gravitational analogue of any planetary body with 0<g<1, including Lunar and Martian gravity.

In addition to ESA parabolic flights' long-standing service to the scientific community via the SciSpacE programme, two new application routes opened in January 2024: The first invites technology research proposals from academic institutions in ESA member states, offering platform access in a similar manner to the scientific community. The second invites proposals from commercial entities via an adaptation of the existing ESA process for evaluation commercial utilisation activities, offering access to ESA parabolic flights on a pro-rata basis according to the fraction of resources utilised. Together, these access routes represent the commitment of ESA's Directorate of Human and Robotic Exploration (HRE) to support research enabled by our platforms, and that which will enable our further exploration of LEO, the Moon and Mars.

This presentation will provide an overview of ESA parabolic flight activities, an introduction to the capabilities of the Novespace A310 Zero-G, examples of previous and ongoing parabolic flight research, and details of how the scientific, educational and engineering communities can submit research proposals via ongoing and recently developed application routes to join ESA parabolic flights.

European Space Agency's Plant Biology Research for Future Space Exploration

Dr Nicol Caplin[1]
[1]European Space Agency
ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture, Space Seven & Eight, September 6, 2024, 9:00 AM - 10:25 AM

Biography:
Dr Nicol Caplin is an Exploration Scientist at the European Space Agency. Dr Caplin is deeply involved in the scientific coordination of experiments in the astrobiology and plant biology fields destined for ISS, lunar orbit and beyond.

Plants play pivotal roles in sustaining human life beyond Earth, serving as sources of food, contributors to environmental control and life support systems (ECLSS), and buffers against psychological stress during space exploration missions. Understanding plant adaptation to the unique stressors of space environments, such as radiation, altered gravity, and toxic regolith, is paramount for successful long-duration missions. The European Space Agency (ESA) is actively engaged in advancing plant research across various space habitats, including Low Earth Orbit (LEO), Beyond Low Earth Orbit (BLEO) at the lunar Gateway, and conceptual experiments for the lunar surface, with a view toward future Mars exploration.
ESA's efforts encompass a comprehensive approach to investigate plant responses to space stressors, unravel the mechanisms of plant gravitational biology, and develop enabling technologies for crop production in space and their terrestrial applications. Here, we present a summary of ESA's activities in these areas, highlighting recent advancements, ongoing projects, and future research directions.
ESA's vision extends beyond space exploration, with a focus on translating technological developments to benefit Earth in line with the United Nations Sustainable Development Goals (SDGs). By making use of available platforms in space, fundamental knowledge can be gained while taking steps to secure future exploration endeavours. Through such advances, ESA aims to enhance food security and sustainability, mitigating challenges posed by climate change and resource scarcity.
This presentation will provide insights into ESA's current and planned activities in advancing plant biology research for future space exploration, emphasising the agency's synergistic approach to sustainable habitation beyond Earth, for Earth.

Experiment hardware for life science and astrobiology research in space

Dr Michele Balsamo[1], Gianluca Neri[2], Alessandro Donati[1], David S. Zolesi[1,2]
[1]Kayser Italia SRL, [2]Kayser Space Ltd

5.3 - Life Sciences: Gravity Related platforms, ageing and biology research, Space Nine, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

Ramón Nartallo is a Programme Manager at Kayser Space Ltd delivering projects that exploit the microgravity environment in Life Sciences' applicants, ranging from cancer research to technology development for use in future manned and robotic space missions. Ramón has 35 years of scientific and space engineering experience acquired in academia, international agencies, and industry, working in a variety of hardware and software development projects, specialising in instrument development and data analysis for ground and space-based astronomy missions, space environment effects and systems engineering.

Space life science research is of paramount importance for the future planned human activities on board Space Stations, Lunar Gateway, or for the colonization of Moon and Mars because either gives insights into the effects of space flight on several biological model systems or provides countermeasures to fight the hostile effects of the space environment on the human body. Kayser develops space hardware systems and provides mission support for investigations on biological systems in space. In particular, several types of space bioreactors have been developed. Among the different type of cell biology experiments performed on many types of eukaryotic cells, especially mammalian cells, and organisms many microbiology experiments are being performed by Kayser in the field of astrobiology/ISRU such as the BioRock and the BioAsteroid experiment onboard ISS, studying the ability of bacterial strain to biomine rare elements from basalt or asteroid's fragments. Beyond the experimentations performed inside the ISS, Kayser is developing for ESA an Exobiology facility to be installed on an external platform outside the ISS. OREOcube, Exocube (Bio and Chem) and IceCold experiments are currently under development and will evaluate the impact of space environment on different chemical and biological samples.

State of the art experiment hardware proven to be successful in space operations and scientific results is a valuable asset for the support of scientific investigations because it offers solutions that are reliable, cost-affordable, and scientific sound. Such space-proved hardware is also an asset for private entities exploiting research results stemming from the space environment (i.e. commercially-driven activities for utilizing space facilities). Together with the classical approach to perform space experiments (through the support of national or international granting agencies), and driven by current commercial space utilization programs, Kayser has established a partnership with ESA for the commercial exploitation of LEO, a service called BIOREACTOR EXPRESS, aiming to establish an "express" way to perform scientific and/or technological experiments on board the ISS. It offers a large portfolio of bioreactors complemented by a complete set of experiment containers for fully automatic execution of scientific protocols. BIOREACTOR EXPRESS is an end-to-end service that exploits the Kubik incubator facility of ESA which is permanently installed onboard the ISS. BIOREACTOR EXPRESS provides all services and resources necessary to perform the experiment, allowing the user to focus on the exploitation of the research results. Hence, details regarding Kayser activities and future opportunities for life science investigations will be presented.

Experimental Characterisation of Sloshing-Induced Thermal Mixing under Gravity-Dominated and Microgravity Conditions for Space Applications

Francisco Monteiro[1], Pedro Marques[1,2], Louis Carbonnelle[1], Alessia Simonini[1], Miguel Mendez[1]
[1]von Karman Institute for Fluid Dynamics, [2]Transfers, Interfaces & Processes (TIPs), Université Libre de Bruxelles
6.2 - Physical Sciences: Multiphase Flows, Space Two, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Francisco Monteiro is a passionate and driven first-year PhD student specializing in experimental fluid thermodynamics, focusing on non-isothermal sloshing for space applications at the von Karman Institute for Fluid Dynamics. Previously, he graduated in Aeronautical Engineering from Universidade da Beira Interior in Portugal and pursued the master-after-master program of the von Karman Institute for Fluid Dynamics, from which he graduated this summer. In his PhD journey, he aims to better understand the complex physics within propellant tanks and work towards implementing sophisticated control strategies to improve propellant storage solutions.

Introduction:
Cryogenic fluid management presents formidable challenges, especially within the context of orbital launcher missions, where different dynamical behaviours of the cryogenic propellants can be identified as a function of the flight stage (Dreyer, 2009). In the propelled phase, the liquid settles at the bottom of the tank, and the launcher's lateral motion governs the excitation of sloshing. Conversely, in the ballistic phase, when the upper stage performs manoeuvres to release the payload into orbit, capillary forces dominate. Consequently, any slight disturbance triggers substantial liquid motion (Werner et al. 2019). This fluid motion in the launcher's tank is responsible for mixing the superheated gas and subcooled liquid, causing significant pressure fluctuations (Marques et al., 2023).
In the current NT-SPARGE project, sloshing-induced thermal mixing in cryogenic propellant tanks is characterised for different launcher phases: normal gravity and microgravity conditions. The on-ground investigation was performed near the lowest eigenfrequency, usually found in space launcher tanks during the ascent phase (Arndt, 2012), while the microgravity characterisation was conducted at the 83rd ESA parabolic flight.

Experiment:
Figure 1 displays the experimental setup, which consists of an active-pressurisation system. It operates a pressurant reservoir containing superheated vapour to pressurise a small-scale tank. The tank is partially filled with liquid, and different liquid-gas interface dynamics arise depending on the acceleration conditions. These dynamics disrupt the cell's thermodynamic equilibrium by destroying the thermal stratification created during the pressurisation. For the experimental campaign, HFE-7000 was used as a cryogenic propellant substitute and a single-species environment guaranteed by pre-conditioning the system. The measurements were carried out in a quartz sloshing cell instrumented with a pressure transducer and three racks of thermocouples to measure the temperature distribution.

Results/Conclusion:
Figures 2 and 3 highlight the preliminary results for the non-dimensional pressure evolution. On-ground tests were conducted at the von Karman Institute's SHAKESPEARE shaking table. The sloshing experiments proved that the free surface motion is much stronger in microgravity, where the inertial wave at aircraft injection wets the ullage walls, triggering evaporation followed by an abrupt pressure drop as the subcooled liquid encapsulates the gas. On the other hand, only a characteristic pressure drop arises during on-ground tests since the liquid settles at the bottom of the cell.

In the extended version of this work, we present a detailed investigation of the free-surface dynamics and position both the microgravity and on-ground sloshing experiment within a non-dimensional map of sloshing regimes.

Experiments about evaporation of water droplet aerosols in microgravity

Charles Graziani[1], Dr Mathieu Nespoulous[1], Dr Renaud Denoyel[1], Pr Stefan Fauve[2], Dr Christian Chauveau[3], Dr Luke Deike[4], Pr Mickael Antoni[1]
[1]Aix-marseille University, [2]LP-ENS Paris, [3]ICARE University Orleans, [4]MAE/HMEI Princeton University
5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

My Name is Charles Graziani, I am a PhD student at the MADIREL Laboratory under the supervision of M. Antoni. My PhD subject is the study of aerosol stability in ground and micro-gravity conditions. I have a grant of the CNES and Region PACA.

Introduction:

Describing the evolution of aerosols is an important challenge in climatology. Several questions remain unanswered so far, particularly concerning cloud microphysics. Since 2018, CNES has supported the development of a new instrument that enables aerosol production under controlled conditions. This work presents the latest results of experiments conducted in reduced gravity conditions using parabolic flights. It focuses on the problem of experimental repeatability and on the droplet evaporation dynamics at different relative humidities.

Experiment:

Aerosols under consideration are comparable to clouds and are composed of micrometric water droplets (with an initial diameter of 5 µm) evolving in air. They are investigated with optical microtomography far from the edges of the experimental cell. During the microgravity phase, droplets move very little, resulting in a high degree of coherence between successive tomographic images. A 3D reconstruction is therefore possible, enabling the droplets to be tracked over time [1].

The experiments were conducted with varying relative humidity (H) ranging from 65% and 100%. A temperature-controlled cold point was used to monitor the humidity. When the conditions were unsaturated, the droplets evaporated. The reproducibility of this process was studied during the parabolic flight campaigns, performed in March and October 2023. The figure displays the evaporation time (t_evap) as a function of H for the 119 experiments carried out. The data was acquired through direct visual inspection of the tomographic videos.

Result:

The data follow the trend t_evap=k/(100-H(%)) where k is a fitting parameter (k=78 s) and seem therefore qualitatively in good agreement with diffusive evaporation theory [2]. The analysis of the tomographic videos using dedicated image processing software is still ongoing to minimize their variability.

Conclusion:

These experiments demonstrate the potential for studying the kinetics of water droplet aerosols evaporation under microgravity conditions. Forthcoming work will focus on experimentally describing the nucleation processes involved in the formation of aerosols, not only for air alone but also for air/heptane mixtures.

Fetal mouse long bones under continuous microgravity or periods of 1×g centrifugation as countermeasure.

Dr.ing. Jack Van Loon[1]
[1]Vu University Amsterdam
4.1 - Life Sciences: Bone, Muscle and Immune responses, Space One, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Jack J.W.A. van Loon obtained his PhD in bone cell biology and mechanosening at the Academic Center for Dentistry at the VU-University in Amsterdam and has experience in space and gravity related research for more than a quarter of a century. He was Co-I and PI of several space experiments on board the Shuttle, Bion, Soyuz the ISS and parabolic flight. He was experiment coordinator for all life sciences and education experiments for the Dutch Soyuz mission DELTA (astronaut André Kuipers). He also worked for some years in industry (Bradford Engineering) as responsible person for science implementation in microgravity payloads.

In an earlier experiment in the European facility for biological research onboard the Space Shuttle / Spacelab, Biorack (IML-1 on STS-42), we reported for the first time, direct responses of near weightlessness isolated fetal mouse long bones. The aim of the experiments addressed in this study was to verify the earlier results and to study, during microgravity, the effects of varying periods of daily 1×g exposure on growth and mineralization in isolated fetal mouse long bones. The paper describes the results of two experiments with mouse metatarsals, one performed on an American Space Shuttle mission (IML-2 on STS–65) and another on a Russian Bio-Cosmos flight (Bion-10 on Cosmos-2229). Experiments differed in hardware and experimental conditions, but were comparable in the biological material: 17-day-old fetal mouse metatarsal long bones cultured for 4 days. In both experiments, cultures under microgravity were compared with cultures in an on-board 1×g centrifuge. From ultrastructural analyses it appeared that proteoglycan numbers are reduced in the groups exposed to microgravity compared to the groups exposed to 1×g conditions. No differences were found in the nuclear / cytoplasmic ratio, cell divisions, glycogen granules and the size and orientation of collagen fibrils. The increase in overall metatarsal length appeared not to be affected by microgravity. In contrast, the increase in length of the mineralized diaphysis was significantly reduced under microgravity. These results are fully comparable with a previous microgravity experiment (IML-1 on STS-42) using 16-day-old mouse fetal metatarsals. We have also demonstrated, for the first time, that the microgravity-induced reduction of cartilage mineralization is completely abolished by exposing long bones daily for periods of at least 6 hours to 1×g while no effects were seen after 3 hours 1×g exposure. No effects of intermittent 1×g exposure were found on overall growth. These result indicate that rather long duration exposure might be required when on-board centrifugation is foreseen as, multisystem, countermeasure for spaceflight near weightlessness pathologies. Future research using in vivo systems, like rodents, should be explored to see of pars of a day exposure to 1g could prevent microgravity related diseases.

Filling of a tank with storable liquid under normal gravity and microgravity conditions

Sesha N. C. Govindan[1], Dr.-Ing. Michael Dreyer[1]
[1]ZARM, University Of Bremen
6.2 - Physical Sciences: Multiphase Flows, Space Two, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
The author completed Bachelors degree in Mechanical Engineering from SASTRA University in India in 2012. Later he moved to Germany to pursue his Masters in Computational Sciences in Engineering at TU Braunschweig. His specialization is fluid mechanics and computational fluid dynamics. Since 2019 he has been working at ZARM, University of Bremen in the research group of multiphase flows. He is working in a DLR-funded project called ZBOT-FT, to demonstrate the transfer and filling of liquid under microgravity conditions. This project contributes to the concept of building propellant depots in space for future space exploration missions.

The spacecraft tanks may have to be refilled in space to carry out long-term space exploration missions in the future. The refueling can be done with the help of propellant depots that help to store and transfer propellants to spacecraft tanks. A complete understanding of the physics that control fluid flow in reduced gravity is necessary to successfully refuel tanks in space. The stronger body forces are responsible for a flat interface in normal gravity. On the other hand, a change in the shape and position of the interface is caused by stronger capillary forces in reduced gravity. During liquid refueling, the gas present inside the tank may or may not be vented. The determination of the stability limits of an interface during the filling of liquid into a tank will help to regulate the self-pressurization of the tank and ensure a liquid-free venting.

This work discusses the vented and no-vent filling of a storable liquid into an experiment tank. The vented fill tests, which are performed under isothermal conditions in microgravity with a multi-species system are flow rate-driven. The no-vent fill tests, which are performed under non-isothermal conditions in normal gravity with a single-species system are driven by the pressure difference between two containers. The temperatures and pressures are measured in the experiment setup with the help of the sensors and the flow patterns inside the experiment tank are recorded using high-speed cameras.

While the vented fill tests investigate the stability of the free surface under microgravity conditions, the goal of the no-vent fill tests is to test various scenarios related to handling a single-species system and to understand how thermodynamics and fluid mechanics influence each other. Furthermore, the vented fill tests are modeled in CFD and compared with the drop tower experiments. All of the information gathered is in favor of designing an international space station experiment that will demonstrate the liquid removal, transfer, and filling processes in microgravity conditions.

Fluids Experiments in Commercial Sub-orbital Spaceflight

Professor Steven Collicott[1]
[1]Purdue University
6.2 - Physical Sciences: Multiphase Flows, Space Two, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Steven Collicott is a Professor in the School of Aeronautics and Astronautics, part of the College of Engineering at Purdue University. He enjoys teaching and research in zero-gravity fluid physics. His experiences include several dozen parabolic flight experiments, eight experiments on Blue Origin's New Shepard sub-orbital rocket, two experiments under construction for Virgin Galactic sub-orbital missions, drop-tower experiments, and design of the successful Vane-Gap fluids experiment in the International Space Station. He is a leader in the use of the Surface Evolver computer code for capillary=dominated fluids applications.

The commercial reusable sub-orbital rocket industry in the US provides approximately three minutes of weightlessness at 1-millig or better acceleration. Three automated and one human-tended sub-orbital two-phase fluids experiments, flying on two vehicles illustrate types of research feasible in these vehicles.

"Cryo-Gauging" is a room-temperature payload (Fig.1) to model positioning of a cryogen in the RFMG launched by others to ISS. The interior of the RFMG tank[1] lacked axisymmetry and thus, non-symmetric liquid positioning needed investigation. Cryo-Gauging flew a representation of the RFMG tank on Blue Origin's New Shepard rocket. It demonstrated critical-like wetting in between a circular post and a flat, variable-position panel, Fig.2. Post-flight analysis shows agreement with Surface Evolver modelling.

"2D Slosh" flew on New Shepard in December, 2023 to investigate contact line motion in response to periodic excitations, Fig.3. Fig.4 is one example of zero-g liquid positioning (near-planar interface was the goal). Static contact angles are substantial, between 40 and 90 degrees, and the test vessels are designed to produce largely two-dimensional flow. Two liquids and two different solids produced four combinations.

"Rotational Slosh" is nearing completion as an automated payload for Virgin Galactic sub-orbital missions. It examines the damping time of liquid propellant excited rotational maneuvers, such as for docking. Tank geometry is from the Cassini spacecraft[2], Fig.5. Fig.6 shows cradles that each hold one tank to be rotated about tank center or end. Video records liquid response. Eight tanks in the experiment, four with a good wetting liquid and four with a poor wetting liquid. Each set of four has 20%, 40%, 60%, and 80% fill fractions. This arrangement provides more data than could be acquired by pumping liquid out of or into tanks.

In December 2021, NASA Flight-Opportunities Program selected the author's proposal to fly a human-tended experiment on Virgin Galactic. All parties are working through steps preceding flight scheduling, there is not yet a flight date. The experiment examines non-linear contact line advance for three purposes: acquire high-quality zero-g data to advance CFD capabilities, learn to perhaps automate future experiments, and demonstrate a 1-g screening test to assess which combinations of liquid, solid, solid surface structure, etc., are likely to be dependable or undependable wetting in weightlessness.

Commercial re-usable sub-orbital spaceflight is a useful laboratory for at least fluids. Access is simpler and total cost is much lower than to orbit. Boost vibration is weak and thus experiment construction is simpler.

FLUMIAS – a novel facility for Live Cell Imaging on board the ISS

Phd Anna Catharina Carstens[1]
[1]DLR Space Agency
5.3 - Life Sciences: Gravity Related platforms, ageing and biology research, Space Nine, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

Study of Biology with focus on genetics at the University of Freiburg. Phd in Genetics/Microbiology at the University of Cologne. Project Manager at DLR Space Agency since 2014

Introduction:
High-resolution fluorescence microscopy is a fundamental technology in many research fields such as biology, physiology, immunology and more. While there have been several microscopes on the ISS, none offered the combination of fluorescence microscopy, sustaining life support to cells and the possibility to image while changing the acceleration levels.
The Facility
FLUMIAS is a novel facility for the ISS, developed by the German Space Agency at DLR and built by Airbus DS as a national contribution to ESA´s SciSpace program. ESA will upload and operate the facility under the Op-Nom “Live Cell Imaging”. The core of the facility is an innovative Structured-Illumination Microscope (by TILL I.D., Martinsried, Germany) that is so robust and compact that it can be rotated on a centrifuge. For the first time, it will be possible to image specimen in space with high resolution fluorescence microscopy while gradually altering the acceleration level between 0 g and 1g.
While the main part of the microscope is fixed to the rotating centrifuge plate, the Experiment Blocks that contain the objective for each experiment are stored in the magazine until one EB at a time transferred to the plate for imaging. This modular design makes it possible to adapt each EB to the specific needs of one experiment with respect to microscopy slide, fluorescent dyes and media, temperature control and choice of objective.
Goals:
The rationale behind the development of this multi-user facility is to enable a broad range of experiments including but not limited to cell biology, microbiology, biotechnology, immunology and molecular physiology. 10 science proposals for a first round of experiments were selected via an international joint DLR/ESA announcement of opportunity. ESA and DLR both intend to make this facility available also to international partners outside Europe.
Outlook:
FLUMIAS is scheduled for launch to the ISS in 2025. Here we will present a design overview of the hardware, science-relevant technical properties, a description of the currently selected experiments and an outlook to possible future applications for Live Cell Imaging in Space.

ForgeStar - a returnable and reusable in-space manufacturing and research vehicle

Neil Monteiro[1]
[1]Space Forge
2.2 - Physical Sciences: Material Science, Space Two, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Ana is an Aerospace Engineer with a Master's degree in Space Law & Policy. At Space Forge, she works on the Pridwen heatshield project as Product Lead. Ana has worked as an intern at the United Nations Office for Outer Space Affairs and was part of a research field campaign as an analog astronaut. One of her areas of interest is the sustainability of space activities and how these technologies can improve life on Earth.

Space Forge is an in-space manufacturing company growing advanced materials in the microgravity and vacuum environment of low earth orbit.

To achieve this, we have been developing the world's first returnable and reusable microgravity platform - the ForgeStar. With high-power density and frequent launch cadence, we are offering ForgeStars as a new research platform as an alternative to the ISS. We anticipate research related to biological studies, pharmacology and metallurgy - amongst others - and for researchers working on materials growth, we can offer additional facilities.

In this talk, we will outline the capabilities of the platform and explain how researchers can access it via our "Microgravity as a Service" process.

Fungal exposure to simulated microgravity on several artificial Martian and lunar regoliths

Mr Allen Matt Drews[1,2], Lei Jin[1,3], Célia Fortuna Rodrigues[4,5], Marta Filipa Simões[1,3]
[1]State Key Laboratory of Lunar and Planetary Sciences, Macau University of Science and Technology, [2]Division of Space Technology, Department of Computer, Science, Electrical and Space Engineering, Luleå University Of Technology, [3]China National Space Administration (CNSA), Macau Center for Space Exploration and Science, [4]Department of Pharmaceutical Sciences, Instituto Universitário de Ciências da Saúde, CESPU, [5]LEPABE, University of Porto
1.4 - Life Sciences: Plant Biology adaption and response to space, Space Seven & Eight, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Allen Matt Drews is an early career physicist with interdisciplinary experience in space instrumentation development and microbiology (mycology). He obtained his first postgraduate degree in astrophysics at Durham University in the UK, after which he stayed at the university as a research assistant in the biophysics department. Following his passion for space exploration, he moved to arctic Sweden to pursue further postgraduate studies at Luleå University of Technology. As part of these, he spent six months at the State Key Laboratory of Lunar and Planetary Sciences in Macau, China, where he researched fungi under simulated space conditions.

Various types of fungi have been found in all major past and present human-made space structures and will undoubtedly accompany future crewed space exploration missions [1]. Despite their prevalence, many questions about how different fungal species react to the extra-terrestrial environment when accompanying these missions remain unanswered [2]. For example, does their pathogenicity increase, making them more harmful to humans? Or, are their material bioleaching capabilities sufficient to be used for in situ resource utilization? With the advancements in analogue ground-based facilities that simulate different aspects of space environment (differential gravity, analogue regolith simulants), studies in this area can now readily fill these knowledge gaps.

We investigated different fungal species, two filamentous fungi: Aspergillus niger (19004 MUCL), Penicillium expansum (1282 DSMZ); and, two yeasts: Candida albicans (SC 5314T), and C. parapsilosis (ATCC 22019T). The filamentous fungi were grown in malt extract agar (MEA) and the yeasts in Sabouraud dextrose agar (SDA), all supplemented with up to 50% of artificial lunar (LMS-1, LHS-1) or Martian regolith (MGS-1, JEZ-1) (Space Resource Technologies, Exolith Labs). Additionally, the growth happened with exposure to simulated microgravity (SµG) (3D-clinostat, Gravity Controller Gravite®, AS ONE INTERNATIONAL, INC, Space Bio Laboratories Co., Ltd.). We then assessed their growth rate, pH and total iron concentration in the media (semi-quantitative strips), and morphology (stereo- and optical microscopy).

We found that SµG did not significantly affected fungal growth rate or morphology. However, A. niger exhibited enhanced growth on both lunar and Martian simulants, at 5% concentration, compared to controls grown without regolith. For P. expansum, growth on lunar simulants was either slightly reduced or the same as on controls. The best growth occurred on Martian simulants in both filamentous fungi, in particular on MGS-1. Microscopic structures did not appear visually different from controls. Regarding the tested yeasts, these did not show significant alterations in the presence of regoliths or exposure to SµG. Morphology was typical for both species in all the conditions tested, with C. parapsilosis exhibiting derby-shaped phenotype, and budding patterns that did not differ from the controls.

Overall, our study demonstrates for the first time the exposure of these four species to this range of artificial lunar and Martian regoliths. Moreover, the results of SµG exposure are in line with existing literature for fungal species.

Future planning of JAXA’s plant growth facility forlong-term cultivation experiments.

Dylan Shun Izuma[1], Yohei Anzai[1], Dr. Satoshi Adachi[1], Tsuyoshi Ito[1]
[1]Japan Aerospace Exploration Agency (jaxa)

ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space, Space Seven & Eight, September 5, 2024, 9:00 AM - 10:40 AM

Biography:
A new graduate with a master's degree in chemistry. Engaged in the development of cell culture equipment and plant cultivation equipment at JAXA.

1. Introduction:
The development of plant cultivation technology within the closed environment of spacecraft is being pursued by various nations, with a focus on securing fresh food supplies, providing mental support for astronauts, and advancing future life support systems. Recognizing plant cultivation technology as a core technology in manned space exploration, we have initiated the development of a device for long-term cultivation. Plant cultivation requires a significant amount of water, yet water is a precious resource in space exploration. Therefore, we aimed to design a device capable of cultivation with minimal water usage.

2. Method:
To enable cultivation with minimal water, the following three aspects were considered.
2.1 Design of the water supply
To ensure a long-term stable water supply, a simple structure is adopted with pipes positioned inside the substrate (Figure 1).

2.2 Substrates to replace soil
Materials suitable for microgravity environments are limited, and substances that scatter like soil are undesirable. Therefore, we conducted the selection of substrates to replace soil. We used six materials shown in Figure 2. Cultivated plants are listed in table 1. The amount of yield fruit was evaluated.

2.3 Condensation/reuse of transpired water
The planned device under development aims to have specifications allowing temperature and humidity control. Therefore, we designed a dehumidifier to enable the condensation and reuse of transpired water emitted by plants. Transpired water was collected by cooling the Aluminum alloy (AlSi10Mg) slit, formed using a 3D printer, using a Peltier device (Figure 3).

3. Result:
Cultivation results are shown in Figure 2 and Table 1. It was observed that different substrates are suitable for different plants, and a common factor contributing to good growth is the substrate's ability to incorporate both air and water around the roots adequately. Clay pebbles were not able to absorb water. As a result, water accumulated at the bottom of the container, leading to root rot. Upon operating the dehumidifier in a closed space with a volume of 53,856 cm^3, we observed a temperature decrease of 1.4 ~ 2.7°C and a humidity decrease of 22 ~ 35 wt.% within 7 minutes.

4. Conclusion:
It was observed that different substrates are suitable for different plants, indicating the need for further investigation. The dehumidifier has been confirmed to efficiently dehumidify and cool the air in a short period. Further details and the future prospects of the apparatus will be presented during the event.

Gene circuits to engineer plant form and function for agriculture on Earth and beyond

Dr James Lloyd[1], Patrick Gong[1], Florence Ly[1], Prof Ryan Lister[1]
[1]The University Of Western Australia
ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture Continued..., Space Seven & Eight, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Dr James Lloyd is a plant molecular geneticist who has turned his attention to engineering plants for space-based agriculture as part of the Australian Research Council's Centre of Excellence in Plants For Space (P4S). Dr Lloyd led the team that developed memory gene circuits for plants to allow for spatiotemporal control over gene expression (Nature Biotechnology, 2022). In the past he has worked on fundamental biology of how genes are turned on and off with genomics datasets.

On earth, plant carbon fixation, a vital process for capturing energy, profoundly influences various aspects of our lives, including food, clothing fibers, medicines, building materials, and even the production of human therapeutics. However, current plant biotechnology relies on a limited repertoire of genetic parts, restricting the customization of spatiotemporal and conditional gene expression patterns. Synthetic gene circuits have the potential to integrate multiple customizable input signals through a processing unit constructed from biological parts to produce a predictable and programmable output. Such technology would supercharge our engineering efforts to add new traits to crops both on earth and for space.

Here, we present here a suite of recombinase-based gene circuits to achieve activation of transgenes in YES, OR, and AND gates, repression in NOT, NOR, and NAND gates, and both activation and repression in an A NIMPLY B gate (Lloyd et al., 2022). This work demonstrates the successful manipulation of plant gene expression, both in isolated cells and stably transformed multicellular plants, by utilizing specific developmental cues to trigger activation. Prototyping of our system in the model plant Arabidopsis has been very successful, with efforts now on translating this research into crops and to confer traits of importance for sustaining life away from earth as part of the Australian Research Council’s Centre of Excellence in Plants For Space.

This highly compact programmable gene circuit platform provides new capabilities for engineering sophisticated transcriptional programs and previously unrealized traits into plants.

Gene expression changes of neuronal cell types induced by altered gravity

Sarah Schunk[1,2], Ilse Holbeck[1], Dr. Robert Prior[1,2], Dr. Yannick Lichterfeld[1], Sebastian Feles[1], Theresa Schmakeit[1], Zoe Meerholz[1], PD Dr. Ruth Hemmersbach[1], Prof. Dr. Volker Busskamp[2], Dr. Christian Liemersdorf[1]

[1]German Aerospace Center, Insitute of Aerospace Medicine, [2]University of Bonn, Medical Faculty, Department of Ophthalmology

1.1 - Life Sciences: Cell Biology, Genetics and omics, Space One, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Sarah Schunk is a second-year PhD student at the German Aerospace Center, Cologne (Gravitational Biology) and works in cooperation with the University Clinic of Bonn (Department of Ophthalmology). She received a B.Sc. in Biology at the University of Bonn and a M.Sc. in Biological Sciences, with specialization in Neuroscience, at the University of Cologne. In her PhD she investigate the functional stability of human neuromuscular junctions under altered gravity conditions.

Introduction:

Astronauts face a variety of health risks during spaceflight, most of which are due to the absence of gravitational, i.e. mechanical, forces and exposure to space radiation. The musculoskeletal and sensorimotor systems, consisting of sensory and motor neurons, are most affected by microgravity. It is important to study the response of these systems affected by altered gravity to gain a deeper understanding of the effects of spaceflight conditions, to investigate whether reduced neuromuscular transmission in microgravity causes muscle weakness in astronauts, and to identify possible countermeasures.

Methods:

The Laminar Inflight Fixation Technology (LIFT) module is a DLR frequent-flyer payload to enable a fast and reliable chemical fixation of biological samples during different phases of a sounding rocket flight. The samples were cultured on slides and chemically fixed directly after the hypergravity phase (launch) and following the microgravity phase to provide prolonged durations of approx. 6 minutes with respect to potential cellular adaptive processes. Corresponding controls at normal gravity (1g) were fixed during a test-countdown procedure as well as in standard lab conditions. The obtained samples are currently subjected to extensive analyses for proteomic, transcriptomic, and microscopic profiling to investigate changes in cell morphology, gene expression, and protein content.

The MAPHEUS sounding rocket was employed so far for the LIFT module, fixing two models of human-induced pluripotent stem cell (hiPSC)-derived motor neurons, as well as primary murine astrocytes. Analysing the effects of microgravity on these cell types compared to matched 1g ground controls will further our understanding of altered gravity exposure on the brain and central nervous system of astronauts at the cellular level.

Results:

Neural cells subjected to real microgravity on the rocket flights MAPHEUS-13 (05/2023) and -14 (02/2024) have been subjected to preliminary analysis. Post-flight phase contrast microscopy revealed no morphological differences between flight samples and ground controls. We thus were able to verify sample integrity and successful fixation in the LIFT module. The samples were lysed and cryopreserved for further analyses in regards of protein content and gene expression, as well as immunofluorescence analyses to investigate overall cell morphology and ultrastructural changes on a synaptic level.

Conclusion:

The modularity and reliability of the LIFT module were proven with motor neuron and astrocyte cultures during two rocket launches. We are currently investigating potential alterations of motor neurons induced by altered gravity conditions. The technology will be used to further investigate neuromuscular models and more complex co-culture systems.

Granular gases consisting of non-spherical and non-convex particles: experiments, simulations and data analysis

Dr. Dmitry Puzyrev[1,2], Prof. Dr. Kirsten Harth[1,3], Dr. Torsten Trittel[1,2,3], Prof. Dr. Raúl Cruz Hidalgo[4], Prof. Dr. Ralf Stannarius[1,2,3]
[1]Department of Microgravity and Translational Regenerative Medicine and MARS, Otto von Guericke University Magdeburg, [2]Institute of Physics, Otto von Guericke University Magdeburg, [3]Department of Engineering, Brandenburg University of Applied Sciences, [4]Department of Physics and Applied Mathematics, University of Navarra

4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography:

Dr. Dmitry Puzyrev graduated in 2010 from St. Petersburg State University. He has then obtained his PhD in Humboldt University of Berlin under supervision of Prof. S. Yanchuk and Prov. A. Vladimirov, working in the field of nonlinear dynamics and delay equations. Since 2019, he is working on the DLR microgravity research projects in the groups of Prof. R. Stannarius and Prof. D. Grimm, specializing in AI-aided analysis of experimental data and simulations of granular gases. Besides that, he is interested in experimental music, PC games and philosophy.

Introduction:

Exploring the behavior of granular gases in microgravity holds an immense scientific and practical significance, advancing our understanding of physics, engineering, and space exploration. The ensembles of inelastically colliding macroscopic particles offer unique perspectives on the basic laws of multiparticle physics. While most previous experiments and theoretical investigations were focused on monodisperse ensembles of simple particles [1,2], more realistic studies have to take into account that such systems may be polydisperse and consist of complex-shaped grains. We have made a step towards the study of complex granular gases by investigating the heating and cooling properties of a mixture of rod-shaped particles. In addition, we present first results on a granular gas of non-convex 3D crosses (JACKS).

Methods:

The tracked colored and "background" particles are put in the cuboid container with two vibrating side walls. To achieve the microgravity state, the experiments were performed at ZARM drop tower in Bremen. For JACKS, longer periods of microgravity are achieved in ESRANGE sounding rocket flight. Resulting two-view videos are analyzed with help of custom AI-aided software package [3]. In addition, DEM simulations are performed on GPUs, where rods are represented as single spherocylinders, while JACKS particles can be modelled as their clumps.

Results:

For the granular gas mixture of rods, cooling dynamics follows Haff's law [4], while the ratio of the average kinetic energy between components remains constant during both heating and cooling stages [5]. Interestingly, the simulations show relatively high amount of energy corresponding to rotation around long rod axes, which was not confirmed by the experiment so far.

For non-convex JACKS particles, clustering is immediately observed during both heating and cooling, see Fig.1. Clustering happens at relatively low packing fractions in comparison to spherical particles and rods, and seems to be increasingly pronounced for higher particle numbers.

Conclusion:

The study of granular gases of rods and 3D crosses has proved that they demonstrate immediately evident but highly non-trivial emergent phenomena. Fundamental features of such systems were confirmed, i.e., Haff's cooling law for rods and their mixtures and tendency towards clustering for non-convex particles. At the same time, we have observed surprising features which require thorough investigation, e.g. the partition of energy between DOFs for the rod-like particles and dependence of granular temperature ratio of the mixture components on their relative sizes. For the 3D crosses, the intensity of clustering was even higher than expected.

Gravitational effects on lower limb perfusion observed during a parabolic flight.

Mrs Jacqueline Forss[1], Mrs Justine Tansley[1,2]
[1]University of Brighton, [2]Torbay and South Devon NHS Foundation Trust
2.1 - Life Sciences: Cardiovascular Physiology, Space One, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Rachel has been a Podiatrist in the UK for 29 years, working within the NHS and the Education sectors during this time. During her time in the NHS, Rachel specialised in wound care, predominantly diabetic and Rheumatic foot ulceration. Rachel has recently been PI for a UK Space agency funded research project on a parabolic flight investigating gravitational effects on lower limb perfusion.

Introduction:
Potential consequences of prolonged microgravity exposure to lower limb perfusion, may present in the same way as ischaemic disease[1]. Complications of ischaemia in the lower limb are known to include pain – effecting mobility and quality of life, and tissue death – presenting as ulceration and gangrene. Healing of traumatic wound injuries is also likely to be impaired until reperfusion takes place. When wound healing is delayed, risk of further complications such as infection and limb amputation increases[2]. With an anticipated increase in human involvement in future space projects and the potential for future space tourism, the development of rapid assessment and risk modification strategies are essential[3].

Methods:
This observational study simultaneously measured key factors used to determine lower limb perfusion: peripheral arterial oxygen saturation (Sp02%), capillary bed oxygen saturation (S02%), toe systolic blood pressure (mm/hg) and peripheral skin temperature(°C). The experiment was conducted onboard a parabolic flight and lower limb perfusion values were compared from periods of steady flight (1G) hypergravity (1.75G+) and microgravity (<0.05G). Four pieces of frequently used clinical equipment were secured to each participants' foot and perfusion continuously monitored for five parabolas. A Friedmans test of variance was used to explore the impact different gravitational conditions had on the lower limb perfusion values obtained.

Results:
18 healthy participants (10 male, 8 female) took part in the experiment. When comparing lower limb perfusion values to 1G (control) the study found: 1) no significant difference between Sp02 values in hyper or microgravity was detected when using a pulse oximeter; 2) a significant difference in S02 in microgravity was detected by white light spectroscopy; 3) a significant difference in skin temperature of the foot was detected by thermography in both hyper and microgravity with the lowest mean temperatures recorded in microgravity (19.6^{o}C).

Conclusion:
This study found evidence that S02 and peripheral skin temperature decreases in microgravity compared to 1G, suggesting a reduction in blood flow. White light spectroscopy and thermography devices demonstrated they functioned the same in altered gravity conditions offering a quick, reliable method of assessing the acute effects of hyper and microgravity on lower limb perfusion. These methods may be useful to predict healing potential when injuries occur and highlight early warning signs of tissue damage due to poor perfusion. However, additional work to further establish the impact on lower limb micro circulation in sustained microgravity and whether vascular adaptation occurs, would be beneficial.

Gravity sensing in plants: the contribution of ground and space experiments. Unresolved questions

Valérie Legué[1], Dr Bruno Moulia[1], Dr. Yoel Forterre [2], Dr. Oliver Pouliquen[2]
[1]Université Clermont Auvergne INRAe, PIAF, [2] Aix Marseille University, CNRS, IUSTI
ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics Continued..., Space Seven & Eight, September 5, 2024, 2:15 PM - 4:10 PM

Biography:
I am a professor in Plant Biology in University Clermont-Auvergne. My research topics are focused on the root growth in response to Gravity mechanical signals and on gravi-sensing. Performing space experiments has given me the opportunity to gain a better understanding of the mechanisms involved in the perception of gravity.

Plants are able to sense and respond to minute tilt from the vertical direction of the gravity, which is key to maintain their upright posture during development. When a shoot or a root is tilted, a complex signaling pathway involving the redistribution of growth hormones within the tissue is triggered. This leads to differential growth between the two sides of the plant organ and the bending of the organ toward the vertical direction. It has long been assumed that this starts by gravisensing in plants relies on a sensor made of starch-rich grains (statoliths), located in specific cells, called statocytes. How such a sensor can detect inclination is not fully clear, and two hypotheses have been proposed. Experiments including space experiments and results apparently support that the hypothesis of a force sensor, where gravity was detected by sensing statoliths' weight on the cell edges (1) or on the cytoskeleton network (2). More recent studies using a biophysical approaches on Earth provide support to the hypothesis of an inclination sensor, independently of the force level (3, 4). The contribution of space experiments designed to asses these hypotheses, and their comparison with ground experiments will be presented. We will show that a biophysical model called A-SD-M (5) can unify both hypotheses and explain the gravisensing in the whole range from micro- to hyper-gravity.

Growing beyond Earth: Telomere tales of Arabidopsis in lunar regolith and on the ISS

Dr. Borja Barbero Barcenilla[1], Dr. Alexander Meyers[2], Dr. Sarah Wyatt[3], Dr. Dorothy Shippen[1]
[1]Texas A&M, [2]NASA, [3]Ohio University

ISLSWG Plants in Space Workshop - Theme 1: Plant Adaptation and Response to Space Environmental Stress Continued..., Space Seven & Eight, September 4, 2024, 4:30 PM - 6:15 PM

Biography:

Dorothy E. Shippen, University Distinguished Professor and Regents Fellow of Biochemistry & Biophysics at Texas A&M University, received her PhD from the University of Alabama, Birmingham and postdoctoral training at the Universities of California, Berkeley and San Francisco. She pioneered Arabidopsis thaliana as a model for understanding telomere biology. She has received numerous academic honors including the Rose Award from the American Society of Biochemistry and Molecular Biology for outstanding contributions to biochemical and molecular biological research and commitment to training younger scientists, and the Eminent Scholar Award from the Texas Aggie Women Network for outstanding research, scholarship and service.

Introduction/Background:

NASA aims to establish sustainable colonies on the moon and Mars by 2050, with plants playing crucial roles in these ventures. Understanding how space flight and growth in extraterrestrial soil simulants affect the telomeres and telomerase of Arabidopsis thaliana is essential for successful plant cultivation in space environments. Measuring telomeres and telomerase serves as crucial indicators of prosperity and longevity in organisms. Telomeres, protective caps at the end of chromosomes, shield genetic material from degradation and maintain chromosomal stability. Understanding the dynamics of telomeres and telomerase activity provides insights into cellular aging, disease susceptibility, and overall organismal health. Thus, monitoring these markers offers valuable clues about an organism's potential for long-term survival and well-being.

Method/Experiment:

In this study, we investigated the impact of space flight and growth on extraterrestrial soil simulants on the telomeres and telomerase of Arabidopsis thaliana. Plants were grown aboard the ISS and in lunar regolith simulant to simulate extraterrestrial conditions. We utilized Southern blot and PCR-based assays to quantify telomere length and measure telomerase activity in our study. Levels of genome oxidation and oxidative stress were determined using biochemical assays. Organellar stability was evaluated through PCR-based amplification of specific genes.

Results:

Telomere length remained stable in plants grown on the ISS, despite a significant induction of telomerase enzyme activity, particularly in roots, where it increased by up to 150-fold. Ground-based studies confirmed that telomerase activity in Arabidopsis is elevated by various environmental stressors, independent of telomere length changes. A strong inverse correlation between genome oxidation and telomerase activity levels was observed, suggesting a potential redox protective role for plant telomerase. In lunar regolith simulant, Arabidopsis exhibited arrest at a terminal vegetative state and activated multiple stress responses. Pre-washing the simulant with an antioxidant cocktail facilitated seed setting and viable second-generation plants. However, plants grown in lunar regolith simulant displayed increased genome oxidation and reduced biomass compared to Earth soil cultivation. Additionally, progressive telomere shortening and reduced telomerase enzyme activity were observed across various Arabidopsis accessions and regolith simulants.

Conclusion:

These findings underscore both the promise and challenges of ensuring genome integrity for successful plant growth in extraterrestrial environments. Telomere dynamics and telomerase activity are crucial factors to consider in the development of sustainable agricultural systems for space colonization efforts. Further research is needed to address these challenges and optimize plant growth in extraterrestrial habitats.

Growth and transcriptomics of Arabidopsis grown under fractional gravity in the EMCS

Dr. Chris Wolverton[1], Emma Canaday[2], Dr. Colin P.S. Kruse[3], Dr. Alexander Meyers[2], Nathan Madonich[1], Dr. Sarah Wyatt[2]
[1]Department of Biological Sciences, Ohio Wesleyan University, [2]Environmental and Plant Biology, Molecular and Cellular Biology Program, Ohio University, [3]KruSeq Consulting

1.4 - Life Sciences: Plant Biology adaption and response to space, Space Seven & Eight, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Emma Canaday is pursuing a Ph.D. in environmental and plant biology in the lab of Dr. Sarah Wyatt at Ohio University. Her current research focuses on using bioinformatics to assess how plants alter their transcriptomes and translatomes when grown in space. They are passionate about studying how plants adapt to the harsh, novel, environments of spaceflight and plan to continue in this field after graduating

Plant Gravity Perception (PGP), launched aboard the SpaceX-13, was designed to test the threshold for gravity perception in wild-type and starchless mutants. Seedlings were grown aboard the ISS on the European Modular Cultivation System with white light stimulating polar directional growth prior to centrifugation in the dark at gravity treatments ranging from 0.003-1.00G. Phenotypic measurements identified distinct response thresholds for starchless and WT roots and were supplemented with comprehensive transcriptomic analyses across the gravity spectrum for both Col-0 and pgm plants. The phenotypic analyses showed that both genotypes were able to respond to gravity eventually but that pgm mutants required a greater force than WT before responding. At low levels of gravity where only WT responded, there was an increase in transcripts associated with transmembrane transporters and lipid membrane restructuring. In plants without starch, visible gravitropism was matched with a sudden transcriptional shift at the same intensity of gravity. Genes turned on at this level include proteins involved in vacuolar acidification, cell wall remodeling, and cytoskeletal restructuring. These genes appear to be involved in starch-independent gravitropic signaling. To maximize the utility of the PGP transcriptomic datasets, every gene expressed across the replicates was fitted to both tan-1 and polynomial ($ax^2 + bx + c$) regressions of normalized gene count vs. G-level to identify genes that were activated/repressed followed by a stable expression (tan-1) or that have a linear or exponential (or combination thereof) relationship with gravity (polynomial). This analysis identified a set of master regulators (circadian clock, mitogen-activated protein kinase kinase kinases, chloroplastic heat shock components as well as a cytochrome B and phytochrome interacting factor) where expression can be fit to a tan^{-1} or a 2-degree polynomial fit with respect to the environmental G-level experienced by the sample groups/replicates. Taken as a whole, the PGP experiment has allowed starch-dependent and starch-independent responses to gravity–and even some that only occur in starchless mutants–to be identified. These findings and the broader dataset hold special relevance to the variable G-levels that will be faced during disparate ventures in extraterrestrial space agriculture.

High Frequency Impulse for Microgravity (HIFIm): The future of exercise countermeasures

Professor Daniel John Cleather[1,2,3], John Edward Kennett[2]
[1]St Mary's University, [2]Physical Mind London, [3]Institute for Globally Distributed Open Research and Education (IGDORE)
4.1 - Life Sciences: Bone, Muscle and Immune responses, Space One, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Dan is Professor of Strength and Conditioning at St Mary's University, Twickenham, a former Director of the UK Strength and Conditioning Association and the author of 3 popular books on physical training. Prior to his career in academia, he worked as a coach with World and Olympic champions in track and field athletics, rowing, canoeing and rugby. He is currently on sabbatical to Physical Mind London where he is helping to develop HIFIm, a next generation exercise countermeasure.

Countermeasure exercise is a ubiquitous feature of long duration spaceflight as prolonged exposure to microgravity (µG) on the International Space Station (ISS) results in a reduction in physical fitness, bone mineral density, and muscle strength. Approximately 25% of each working day on ISS is spent on countermeasure exercise but the effectiveness of the current program has not been optimized and some astronauts still experience significant de-conditioning.

Jumping and hopping exercises are potentially highly effective forms of countermeasure exercise and their efficacy has been demonstrated by the European Space Agency (ESA) during long-term bed-rest. The 'High Frequency Impulse for Microgravity' (HIFIm) is a novel supine jumping sled which is designed to overcome the current limitations of traditional CM exercise by facilitating repeated horizontal jumping in microgravity. A key feature of HIFIm is that it is designed to reduce the forces produced during exercise to levels within the capabilities of standard aircraft vibration isolation systems. In addition, HIFIm is a multi-exercise system that provides a repertoire of over 100 exercises that can work all parts of the body.

A microgravity environment can be simulated terrestrially during parabolic flight. Despite this, the current resistance training device used on ISS was not tested in parabolic flight due to the technical challenges and safety limitations involved in using this platform. Similarly, it has not been possible to test E4D, one of the main candidates for the Gateway countermeasure in parabolic flight. In contrast, HIFIm has been tested in two different parabolic flight campaigns, and has been tested for almost 70 minutes in microgravity. Firstly, during the 77th ESA Parabolic Flight Campaign (PFC) we showed that repeated jumping in microgravity is possible using HIFIm, and that the loading provided by this exercise is similar to that experienced terrestrially. Secondly, during the 64th CNES PFC we validated HIFIm's engineering approach and showed that HIFIm isolates the force and vibration to levels that are within the operational window for Gateway, without the need for additional vibration isolation systems. The combination of these results mean that HIFIm is at a TRL of 6, and that repeated jumping is at a countermeasure exercise readiness level of 7.

How effective is the Random Positioning Machine in providing an analogue for plant spaceflight studies?

Dr. John Z. Kiss[1], Dr. Ariel Hughes[1]
[1]Florida Institute of Technology

1.4 - Life Sciences: Plant Biology adaption and response to space, Space Seven & Eight, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

John Z. Kiss serves as Provost and Senior VP for Academic Affairs at the Florida Institute of Technology. His research focuses on the gravitational and space biology of plants. He served as PI on grants from NASA, USDA, NSF, and the NIH as well as PI on eight spaceflight experiments on the Space Shuttle and the International Space Station. He received the NASA Outstanding Public Leadership Medal. In 2021, he received the International Cooperation Medal from the Committee on Space Research (COSPAR), and asteroid Kiss 8267 was named in his honor.

The future of space exploration will be contingent upon the use of plants in bioregenerative life support systems. Therefore, it is important to understand the effects of microgravity and reduced gravity on plant development. Several instruments, including the Random Positioning Machine, RPM, have been developed as microgravity analogues to help supplement the information from true spaceflight experiments (Kiss et al. 2019). The RPM is one such device designed to provide an analogue for the effects of microgravity by rotating plants and other organisms in three dimensions.

In this study, we compare the results from experiments conducted in true microgravity on the International Space Station (Medina et al. 2022) with those conducted using the RPM (in the 3D clinostat mode) on the ground. Seedlings of Arabidopsis thaliana wild-type and phytochrome mutants were grown in ISS experiments and in the omnidirectional gravity on a rotating RPM on the ground. We found that the RPM treatment caused less stress in the seedlings than did true microgravity. We also report that phytochromes A and B play roles in phototropic responses to unilateral light and that these roles differ in the two gravitational environments.

Thus, we conclude that while root phototropism in unilateral red and blue differs significantly between the microgravity and omnidirectional stimuli, the RPM can serve as an effective analogue of microgravity conditions for assessment of shoot phototropism. Our results support the more general conclusion that depending on the parameters studied, the RPM can be good analogue for true spaceflight studies and can be used to support and supplement space experiments in plant biology.

How gravity contributes to perceived weight

Ms Denise Cadete[1], Miss Maryam Haq, Professor Matthew Longo, Professor Elisa Raffaella Ferre
[1]Birkbeck University Of London

6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:

I am a PhD student in Psychology and Cognitive Neuroscience

On Earth, body weight is given by Newton's laws as mass times gravitational acceleration. That is, an object's weight is determined by the pull of gravity on it. Thus, the perceived body weight is – like actual weight – dependent on the strength of gravity. No single sensory signal informs the brain about the weight of the body. However, the vestibular organs constantly detect gravity. We therefore hypothesize that vestibular input is central to the perception of body weight.

We have recently demonstrated that experimental alterations of gravity produce rapid changes in the perceived weight of specific individual body parts (Ferrè et al., 2019). We have asked participants to estimate the weight of two body parts, their hand or their head, both in normal terrestrial gravity (1g) and during exposure to experimentally altered gravitational fields, 0g and +1.8g during parabolic flight and +1g using a short arm human centrifuge. For both body parts, there was an increase in perceived weight during the experience of hypergravity, and a decrease during the experience of microgravity.

However, how mechanistically vestibular signals shape weight perception is not clear. To address this question, we combined Galvanic Vestibular Stimulation (GVS) with psychophysics measure of perceived hand weight (Ferrè et al., 2023). We used bilateral bipolar galvanic vestibular stimulation (GVS) to non-invasively stimulate the vestibular receptors. Brief left anodal and right cathodal GVS (L-GVS, which predominantly activates vestibular networks in the right cerebral hemisphere), or right anodal and left cathodal GVS (R-GVS), or sham stimulation were delivered at random, while participants estimated whether a weight placed on their wrist feels heavier or lighter than their left hand in two psychophysical staircases. We then used a planned comparisons approach to directly compare L-GVS and R-GVS conditions, in order to investigate how vestibular projections in each hemisphere might influence the neural processes responsible for weight perception. Preliminary results show a trend in which L-GVS, which enhances the gravity signal in the right hemisphere, make the hand feel heavier compared to R-GVS, reducing a baseline bias for underestimation. We also compared GVS stimulation of both hemispheres against sham stimulation to test a non-hemisphere-specific hypothesis regarding indirect effects of vestibular stimulation, such as those mediated by arousal. Results do not support this hypothesis, indicating that GVS inputs per se do not influence weight judgments.

How to squeeze your lab setup into a space instrument

Malika De Ridder[1]
[1]Redwire Space
2.2 - Physical Sciences: Material Science, Space Two, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Malika's career started 25 years ago in the company - now known as Redwire Space - as a materials and process engineer. She has worked in various roles and contributed to several successful science missions. Now she uses that knowledge to expand the science and operations portfolio.

The core of any scientific research is to investigate the impact of variable parameters on the obtained result. The amount of independent parameters is high, the possible combinations are nearly endless. If gravity would be a selectable parameter, this would likely be in the top three test conditions to better understand two phase material or multiple component behavior, especially in combination with thermal settings.

It is clear that most lab equipment is not designed to be launched for operation in microgravity, let alone for a human space flight environment. Objectives of scientific research can often be translated into requirement specifications that allow to redesign the lab set-up into a configuration that captures all essential test features and at the same time ensures (astronaut) safety and reliability.

Redwire has microgravity equipment heritage in this field that has been highly successful:

- SODI has been (intermittently) operational from 2009 till 2023, imaging liquid mixtures under thermal gradients while exposed to controlled vibrations. Every test campaign only required the upload of a cell array that contained 2 experiments to be tested consecutively.
- The Transparent Alloys instrument is operational since 2017 and is really a lab-in-a-box. The core element is a Bridgman Furnace with two microscopes to image the adiabatic zone. Glass cartridges with different dimensions can be translated to investigate directional solidification in a very wide temperature range. Materials with toxic hazard level (THL) 2 have been safely uploaded and tested.
- COLIS is ready to be launched in September 2024 and will investigate the origin, formation and dynamics of colloidal crystals, glasses and gels. The optical diagnostics in 6 different orientations combine various lab set-ups in one configuration. The crew replaceable Cell Module has its own thermal control and a stirrer to ‘reset’ the experiment liquids.

Miniaturization of different scientific lab setups - adding robustness for launch and ensuring crew safety - is confirmed to be feasible with comparable test results to ground based lab set-ups. The flexibility towards the on-orbit experiment protocols is provided by making scientific data available in (almost) real time, so the science teams are able to fine tune the scientific parameters of their experiment on orbit, thus optimizing the science return.
The development of a new space instrument takes a few years, but the re-use capability allows relative fast iterations to boost science to new levels.

ICE Cubes Service for fast and direct access to the International Space Station

Dr Miguel Ferreira[1], Mr Andrei Sapera[1], Dr Hilde Stenuit[1]
[1]Space Applications Services
2.3 - Gravity Related platforms and Launch Services, Space One, September 4, 2024, 4:30 PM - 6:15 PM

Biography:
Miguel Ferreira works with the ICE Cubes Service as Biosciences Space Business Developer. He has an MSc in Bioengineering (U. Porto, Portugal) and a PhD in Regenerative Medicine (U. Manchester, UK). Prior to his current position, he was Senior Scientist at Quest Meat (Birmingham, UK). During his studies, he served as President and Committee Member of the Student European Low Gravity Research Association (SELGRA) for a total of 6 years.

The International Commercial Experiment Cubes (ICE Cubes) service set up by Space Applications Services provides fast, direct and affordable access to space for research, technology and education. The service facilitates a frequent and regular 'launch-and-return' capability to/from the International Space Station (ISS), and offers a unique real-time interaction capability.
The ICE Cubes Service makes use of the ICE Cubes Facility, permanently installed within the Columbus module of the ISS. Since its launch in May 2018, over 25 payloads and experiments have been successfully flown and operated using the ICF. These included projects focused on protein crystallization, plant biology, IOD/IOV of technologies, an artificial intelligence and machine learning server, a media set that allows direct interaction between the user and the astronauts on a commercial basis, and an interactive artwork. Payloads can be developed by the customer or made available by the ICE Cubes Service as ready-to-fly hardware that can be reused over the course of multiple missions
The ICE Cubes Facility can accommodate-plug-and-play Experiment Cubes of various form factors or large inserts, and provides the functional interfaces to the ISS infrastructure for powering and controlling the payloads. The use of a sliding Framework and "plug-and-play" Experiment Cubes, or sliding inserts, with standardized interface connectors simplifies the system, thus minimizing crew time for installation and removal. Depending on the specific needs, experiment data can be downlinked in (near) real-time, deferred to a later time or physically downloaded with a return vehicle from orbit via data storage media. The ICF also provides Wi-Fi and Bluetooth connection for payloads that may operate outside of the facility. The ICF can also operate centre aisle payloads and provide those payloads with data and power.
In addition to the Experiment Cubes flown until now, other currently funded and under development initiatives include a platform to support microfluidic organ-on-a-chip devices, a magneto-acoustic 3D bioprinter, and a multi-user platform to culture tumours, organoids, and spheroids for high-throughput drug screening onboard the ISS.

Imaging analysis of emulsions in the EDDI-PASTA experiments onboard the ISS

Mickael Antoni[1], Luigi Cristofolini[2], Libero Liggieri[3], Davide Orsi[2], Sébastien Vincent-Bonnieu[4]
[1]Aix-Marseille Univ, CNRS, MADIREL, [2]Department of Mathematics, Physics and Computer Sciences, University of Parma, [3]CNR-ICMATE, [4]ESA-ESTEC

4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography:

Mickaël ANTONI got a position of Maître de Conférences at Aix-Marseille Université in 1999 and became a full professor in 2010. Since 2010 he has been teaching Analytical Chemistry at the chemistry department of the Institute of Technology of Aix-Marseille Université. His research interests focus on the development of new diagnostics for emulsions and droplet evaporation and on on direct navier-Stokes simulations of free interface systems. His focus recently evolved to Fourier-Transform Infra-Red Imaging spectroscopy and to aerosol science.

Describing the ageing of emulsions is a major challenge for both fundamental and industrial applications. When looking more specifically at the contribution of the phenomena occurring at interfaces, a basic problem is the influence of gravity drainage. It tends to mask the phenomenology associated with capillarity, such as ripening, flocculation or droplet coalescence. The aim of the ISS EDDI-PASTA experiment is to investigate emulsions into microgravity conditions for sufficiently long periods of time to allow such phenomena to be described.

This work focuses on recent experiments performed using the ESA Soft Matter Dynamics (SMD) facility with MCT (Medium Chain Triglyceride, supplied by IOI Oleo) oil-in-water emulsions, stabilized with a non-ionic surfactant (C12EO21, supplied by Nikko Chemicals). Emulsions are generated onboard in small sample cells (3.7 mL) using a magnetically coupled mobile piston. For the aims of the study, we used 12 interchangeable sample cells housed in the SMD carousel, with oil volume fraction between 20% and 50% and surfactant concentrations covering about one decade below the cmc.

The aging dynamics of the emulsions is analyzed with optical microscopy in transmission mode (see figure). Images are acquired using the so-called Overview Camera of the SMD facility. The focal plane is located about a millimeter inside the emulsion. The emulsification procedure and the high volume fraction of oil produce emulsions with a large number of droplets acting like thick lenses. Images are therefore subject to important optical distortion, making it impossible to identify individual droplets. However, their contrast is sufficient to perform gray levels analysis (see figure).

To describe the temporal evolution of the emulsion, the idea is to identify a specific family of contours for each image (in black on the figure) which give rise to a typical pattern. As evolution of the emulsions is slow, successive images exhibit a good coherence making this pattern easy to follow as time runs. Any events or modifications occurring anywhere inside the emulsions therefore result in a number of changes in this pattern that can be easily spotted and counted.

In the transient phase, the evolution of the emulsions shows phases of relative calm punctuated by bursts of activity during which tens of correlated events occur. Their amplitude tends to decrease with time, indicating a gradual relaxation of the emulsions towards a quieter evolutionary phase. The role of MCT-oil volume fraction and surfactant concentration in the overall statistics of these bursts are investigated.

Impact of light on plant growth and product quality in candidate crops for space farming

Simonetta Caira[1], Sabrina De Pascale[2], Antonio Dario Troise[3], Nafiou Arouna[4], Dr Antonio Pannico[4], Dr Luigi Giuseppe Duri[4], Professor Stefania De Pascale[4], Professor Roberta Paradiso[4]
[1]Proteomics, Metabolomics and Mass Spectrometry Laboratory, [2]Institute for the Animal Production System in the Mediterranean Environment, [3]National Research Council (ISPAAM-CNR), Portici, Italy
[4]Department of Agricultural Sciences, University of Naples Federico II, via Università, 100 - 80055 Portici, Naples
ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space Continued..., Space Seven & Eight, September 5, 2024, 11:00 AM - 12:00 PM

Biography:
I am Nafiou Arouna, from Togo, and I am currently pursuing my PhD in Food Science at the Department of Agricultural Science of the University of Naples Federico II. My PhD is funded by the Italian Space Agency (ASI), as part of the MELiSSA (Micro Ecological Life Support System Alternative), the life support system program of the European Space Agency (ESA). My research focuses on exploring the modulation of light (in terms of intensity, quality, and duration) to optimize resource regeneration and food production by plants, while minimizing energy consumption in the higher plant compartment within the MELiSSA loop.

The success of future space exploration will rely on the development of Bioregenerative Life Support Systems (BLSSs) to regenerate resources to sustain human life. BLSSs consist of artificial ecosystems where carefully selected organisms, including bacteria, algae, and higher plants, are arranged in a series of recycling steps to convert crew waste into oxygen, potable water, and fresh food. Among these, plants show the greatest potential as bio-regenerators, since they can regenerate air, purify water, and provide nutrient-rich food. Light plays a crucial role in plant growth in controlled environments as it provides energy for photosynthesis and regulates various functions like transpiration and photomorphogenesis. Light intensity, photoperiod, and spectral composition significantly impact crop productivity and nutritional and nutraceutical value of plant-based foods. Therefore, one of the main challenges in growing plants within BLSSs is providing artificial lighting with sufficient intensity and the right spectrum.
The objective of the experiment was to assess the effects of supplementary lighting using monochromatic light-emitting diodes (LEDs) with red:blue (R:B) at the ratio of 2:1 compared to natural light (control), on potato (Solanum tuberosum L. cv. 'Colomba') as candidate staple crop.
The experiment was carried out in an unheated greenhouse, using a prototype system simulating vertical farming, which can be easily adapted to a BLSS. The plot with supplementary LED treatment was shaded with a polystyrene panel, and the light intensity deficit was integrated with R:B light up to a maximum of 400 µmol s-1m-2 Photosynthetic Photon Flux Density (PPFD). The emitted light intensity was dynamically regulated in the shaded plot via two PPFD sensors placed at canopy level, based on the difference between the shaded area and the unshaded control.
Various morphological and growth parameters, as well as the nutritional and nutraceutical value of the edible products, were measured.
Results revealed that supplementary R:B light significantly enhanced leaf photosynthesis and improved plant growth compared to sunlight. Specifically, net photosynthesis increased about 1.5 times compared to the control. Accordingly, leaf biomass and leaf area increased twice and 1.6 times, respectively, and tuber yield was 28.6% higher compared to natural light.
These findings demonstrate that manipulation of light spectrum is an efficient tool to improve plant performance in potato and provide valuable insights for designing optimal lighting strategies in crop modules in BLSSs, maximizing both the food production and the plant regeneration potential.

Keywords: LEDs, Solanum tuberosum L., controlled environment, Bioregenerative Life Support Systems (BLSSs)

INFLUENCE OF GRAVITY VARIATIONS ON THE CALCIC ACTIVITY OF NEURONAL SPHEROIDS IN ACOUSTIC LEVITATION

Pierre-Ewen Lecoq[1,2], Guillaume Viraye[1,2], Jean-Michel Peyrin[2], Jean-Luc Aider[1]
[1]PMMH ESPCI, [2]NPS Sorbonne Université

1.1 - Life Sciences: Cell Biology, Genetics and omics, Space One, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

I'm a PhD student working on the influence of gravity on living organisms. In my thesis I am mainly focusing on the behaviour of neuronal activity in microgravity, but during my Master's degree I have also worked on topics such as the relationship between gravity and the conservation of symmetry in living organisms, particularly insects. All my work has been done from the perspective of a physicist dealing with biological systems.

Introduction:

The impact of altered gravitational conditions, such as hyper-gravity or micro-gravity, on the neurological health of astronauts presents a significant challenge for extended space missions, whether destined for the Moon, Mars, or prolonged stays aboard the International Space Station (ISS). Extensive research has underscored the critical importance of monitoring brain activity, both pre- and post-mission, revealing profound and enduring effects on the cognitive functions of astronauts [1]. These findings demonstrate the intricate relationship between gravitational variations and brain physiology. It becomes necessary to understand the real impact of microgravity down to the cellular level to ensure the well-being and performance of space travelers during extended voyages beyond Earth's orbit.

Methods:

In this talk, we focus on the influence of gravity variations on the activity of cellular spheroids of primary hippocampal neurons, which were trapped and maintained in acoustic levitation (Fig. 2). Indeed in a Bulk Acoustic Wave resonator, spherical objects, such as particles in suspension in a fluid, can be moved toward an acoustic pressure node where they can be maintained in an equilibrium position, between the walls of a resonant cavity. In the so-called acoustic levitation plane, the gravity is counterbalanced by the Acoustic Radiation Force (ARF) created when the resonance condition is respected (h = 1/2 λ_a, with h the height of the cavity and λ_a the acoustic wavelength) [2].

A dedicated setup has been designed and built to perform live calcium imaging during parabolic flights (Fig. 1) funded by the CNES (Centre National d'Etudes Spatiales) and organized by Novespace. The setup has already been used to monitor 2D neuronal networks showing an influence of gravity variations on the neurons activity [3].

Results:

Using this imaging platform, we were able to record the electrical activity of 3D neurons spheroids trapped in acoustic levitation during gravity changes over different parabolas. The analysis of these experiments will allow us to better understand the impact of gravity on neuronal activity in 3D.

We will present in this talk experimental evidences showing that indeed ARF can be used to move and levitate large objects in weightlessness conditions. We will also show that it is indeed possible to monitor calcic activity of neuronal spheroids in acoustic levitation (Fig 3). Preliminary results after this campaign show that indeed the calcic activity of neuronal spheroids seems to be influenced by the variation of gravity, from hyper-gravity (1.8g) to micro-gravity (0g).

Intrinsic evolution of oil in water emulsions observed by experiments in microgravity on the ISS.

Prof Luigi Cristofolini[1], dr Valentina Lorusso[1], Prof Davide Orsi[1], dr Marco Vaccari[1], dr Francesca Ravera[2], dr Eva Santini[2], dr Angeliki Chondrou[3], prof. Margaritis Kostoglou[3], prof Thodoris Karapantsios[3], dr Robert Mc Millin[4], prof. James Ferri[4], dr Sebastien Vincent-Bonnieu[5], dr Libero Liggieri[2]

[1]University of Parma, Department of Mathematics, Physics and Computer Sciences, [2]CNR- Institute of Condensed Matter Chemistry and Technologies for Energy, [3]Aristotle University of Thessaloniki, Department of Chemical Technology and Industrial Chemistry, [4]Virginia Commonwealth University, School of Engineering, [5]European Space Agency

4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography: Birth: October 4th 1966, Trieste – Italy

Education

1985	“Maturità Scientifica” with full marks (60/60) Bologna
1989	Summer Student Fermi National Accelerator Laboratory, Batavia, IL (USA)
1990	Degree in Physics (110 cum laude) University of Parma
1994	Ph.D. in Physics

Work

1991-1992	Civil Service helping schoolchildren with disabilities
1995-1996	Research Fellow- School of Chemistry, Sussex University (UK)
1996-1997	Post Doc - Physics Department, University of Parma
1997-2005	Research Associate in Solid State Physics, Physics Department, University of Parma
2005-2021	Associate Professor in Physics, University of Parma
2021-today	Full Professor in Physics, University of Parma

Introduction:

Emulsions are colloidal dispersions of two or more immiscible liquids, very important in several processes and products, (e.g. oil industry, lubrication and detergency, with serious concerns about environment preservation…) and as enabling technologies for space exploration (food, pharma detergency, smart materials). Technological advances are hindered by the lack of fundamental knowledge on such complex systems. We report results about the evolution of oil in water emulsion formulated with a non-ionic surfactant. The investigation, performed in weightlessness conditions onboard the ISS, allows to isolate intrinsic evolution processes from creaming/sedimentation typically dominant in terrestrial conditions, as shown in the figure.

Methods:

The main experimental technique employed was Diffusing Wave Spectroscopy (DWS) [1-4], implemented in the ESA Soft Matter Dynamics [5] facility onboard the International Space Station. To overcome strong limitations of some traditional interpretation schemes, concerned f.i. with shadowing important dynamical features, we applied an original interpretation scheme [6] based on optical Monte Carlo simulations. The analysis was supported by ground-based characterizations of initial drop size distribution and of properties of the oil/water interface in the presence of surfactant.

Results:

By detailed analysis of the DWS correlation function, we obtained information on the evolution of mean drop radius and of the droplet dynamics, which features a Brownian stationary regime punctuated by transient ballistic accelerations.

Based on this, we identified different de-emulsification mechanisms and tentatively assessed their relative importance as a function of the properties of the droplet population and of the interfaces. At early stage of the emulsion life, in all emulsions investigated, the drop population evolves mainly via interaction between small droplets. Nevertheless, in some emulsions a transition to a different regime is found at later times, in which the dominant interaction is between small and large droplets. This regime is particularly important at late stage of de-emulsification.

Conclusions:

These findings shed a new light on the phenomena relevant to emulsion stability, with potential impact not only on industrial processes on earth, but also as enabling technology for long flights and space colonies.

Introduction of Kibo utilization missions for plant production in microgravity

Mr. Kirima Junya[1], Higashibata Akira[1], Tamaoki Daisuke[2]
[1]Japan Aerospace Exploration Agency, [2]UNIVERSITY OF TOYAMA

ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture Continued..., Space Seven & Eight, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Jun. 2022- Japan Aerospace Exploration Agency
Human Spaceflight Technology Directorate

Various challenges exist in the cultivation of plants towards the realization of future lunar farms. One of these challenges includes the limited resources, like especially water usage, as well as harsh environments like low gravity and intense radiation, which differ from Earth and are expected to have distinct effects. JAXA has conducted several experiments on plant biology missions under microgravity conditions using Plant Experiment Unit (PEU) which can give controlled light cycle. Cell Biology Experiment Facility (CBEF) placed the Japanese Experiment Module (JEM) can provide temperature and humidity control for PEU. It has become apparent from such experiments that microgravity significantly affects plants growth (Resist tubule, Aniso tubule, Ferulate). Based on the technical insights gained from these experiments, three experiments: Plant UV-B mission, Plant Cell Division mission, Space Surface Spirulina mission are prepared. Plant UV-B mission design to elucidate the synergistic effects of high ultraviolet stress on plants in addition to gravitational effects, and gain insights into resistance to those effects. Plant Cell Division mission aims to understand the effects of the space environment on plant growth through observation of single-cell level cell division by Confocal Space Microscope (COSMIC), then provides hints for plant production in space. Space Surface Spirulina mission verify the biological stability of Spirulina, which allows efficient protein intake and CO_2 processing, in the space environment, and develop highly efficient, resource-saving cultivation methods. Here we introduce an overview of these plant biology missions and the experimental equipment owned by JAXA.

Investigating the Vibro-Fluidization of Lunar Regolith in Closed and Open Systems

Mr Peter Watson[1], Professor Marcello Lappa[1], Dr Sebastien Vincent-Bonnieu[2], Dr Ali Anwar[3]
[1]University of Strathclyde, [2]European Space Agency, [3]Weir Advanced Research Group

4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Peter Watson is a 2nd year PhD student in the department of Mechanical and Aerospace Engineering at the University of Strathclyde working closely with Professor Marcello Lappa on a project entitled " "Vibrations as a novel tool for particle self-assembly and regolith vibro-fluidization in space environments" in conjunction with the European Space Agency.

Following the major current focus on the return to the Moon to further explore and eventually inhabit our closest celestial neighbor, it has never been more important to understand how to manipulate the abundantly available resources found on the lunar surface. In such a context, new methods to manage and transport the lunar regolith, based on the application of vibrations, are being investigated. This research builds on an existing line of inquiry dealing with the "vibro-fluidization" of monodisperse granular media constituted by particles of all the same size and shape. Being made of particles of differing sizes and shape, lunar regolith is a multidisperse material, which adds a new level of complexity to such an endeavor.

Two different scenarios were investigated in the framework of this research, one dealing with the vibrationally-driven behavior of regolith encapsulated in closed containers and another one concerned with its response in terms of mass flow rate when flowing through the orifice of a (vibrated) hopper configuration. Moreover, this study was articulated in a parametric investigation involving several disjoint influential parameters, namely, the frequency and amplitude of the applied vibrations, the composition (in terms of particle size distribution) of the considered lunar regolith simulant and even the inclination of the shaking direction (vertical, horizontal, and inclined with respect to gravity).

The experiments conducted in the closed configuration have shown that lunar regolith can indeed enter a fluidized state under the influence of vibrations. This effect has been quantified by using the vertical distance between vibrationally induced peaks and valleys (starting from a distribution of lunar regolith having a perfectly horizontal top surface). For a fixed amplitude of vibrations, this distance displays a non-monotonic dependence on the related shaking frequency in the range of 30 – 50 Hz . These phenomena also display a complex relationship with the particle average size. Most notably, similar trends are observed when the open (hopper) configuration is considered. In this case, at a fixed amplitude, there exist peak values of mass flow rate at values of specific frequency very close to those maximizing particle convective motion in the closed container.

Different metrics (the peak-to-valley vertical distance and the mass flow rate in the closed and open system cases, respectively) have confirmed that a non-monotonic relationship exists between the intensity of applied vibrations, in terms of frequency and amplitude, and the degree of fluidization of lunar regolith.

Ionizing radiation and higher plants in space exploration: challenges, constraints, and opportunities

Dr. Chiara Amitrano[1]
[1]University Of Naples Federico Ii, Dept. Agricultural Sciences
ISLSWG Plants in Space Workshop - Theme 1: Plant Adaptation and Response to Space Environmental Stress Continued..., Space Seven & Eight, September 4, 2024, 4:30 PM - 6:15 PM

Biography:
Full Professor of Environmental and Applied Botany at University of Naples Federico II, Italy.

Her studies regard the links between plant structure/function and environmental/crop factors with particular attention to the analysis of hydraulic and photosynthetic efficiency. Such kind of studies are applied to the productivity and sustainability of natural and agricultural ecosystems on Earth in a context of climate change and in artificial ecosystems in extreme environments. In Space-related research, she has combined studies of fundamental plant biology with applied studies for the definition of crop production requirements, with a focus on the plants' responses to ionizing radiation.

The space exploration goals are pointing towards long-term manned missions to the Moon and Mars. To achieve such goals, the negative effects of ionizing radiation on organisms must be kept under a threshold. High levels of ionizing radiation can influence the functioning of Bioregenerative Life Support Systems (BLSS) due to their effects on both biotic components (i.e. producers, consumers, and decomposers) and non-living elements, which are integrated to achieve self-sustenance.
The higher plants, key elements of BLSS, show better radio-resistance than animals but a standard behaviour has not been identified also due to the multiplicity of studies using different endpoints, plant materials (e.g. species/cultivar, phenological stage, nutritional status), and radiations (e.g. type, dose, protocols). Most available information derives from ground-based experiments with exposure to photon-type radiation rather than charged particles (i.e., protons and heavy ions), as well as to acute doses rather than chronic exposure, leaving the poor space fidelity of the 'radiation analogues' accelerators still an open issue.
This presentation will summarize the main results we obtained, in the last 15 years, within ESA (European Space Agency) and ASI (Italian Space Agency) projects also in collaboration with the GSI Helmholtzzentrum für Schwerionenforschung (GmbH). The research has been aimed at understanding the effects of low and high LET (Linear Energy Transfer) radiation on morpho-anatomical, eco-physiological, biochemical, and nutritional aspects of different plant systems (e.g. seedlings, microgreens, adult plants) of various species including Asteraceae, Brassicaceae, Fabaceae, and Solanaceae.
Such studies are useful to understand: a) the main mechanisms of radio-resistance, b) the impact on plants' "regeneration" efficiency, and c) the effects on the nutritional quality of fresh food produced onboard. The results obtained also provide useful information to define the shielding requirements during the cultivation cycle of plants in different space contexts. They can also be applied to design nutritional countermeasures to intensify the physiological defences of astronauts against radiation exposure, through the integration of their diet with plant-derived fresh food, produced onboard, rich in antioxidants whose content is primed by the exposure to radiation itself. Finally, the presentation highlights the need for the scientific community to converge towards common standardization schemes and protocols as well as to adopt a multidisciplinary and transdisciplinary approach bringing together plant biology, medicine, microbiology, physics, and biotechnology, since the integration of skills and knowledge is a promising way to achieve the common goal of countermeasures development for radiation protection of astronauts.

Is space a stressful environment for plants?

Dr. Karl Hasenstein[1]

[1]University Of Louisiana Lafayette

ISLSWG Plants in Space Workshop - Theme 1: Plant Adaptation and Response to Space Environmental Stress Continued..., Space Seven & Eight, September 4, 2024, 4:30 PM - 6:15 PM

Biography:

Dr. Hasenstein studied Biology, Physics, and Chemistry in Germany and received his PhD in 1982. After post-doctoral studies at San Diego State University and the Ohio State University he accepted a faculty position at the University of Louisiana at Lafayette. His research focused on auxin, gravitational and radiation biology. He was PI on four space experiments including the ill-fated STS-107 flight. He published more than 130 papers and mentored 12 PhD and 9 MS students. His research is mostly funded through NASA and NSF.

The growth of plants under weightlessness and other space conditions such as lack of buoyancy, elevated carbon dioxide (CO2) and substrate restrictions is commonly assumed to induce stress responses in plants. This 'space syndrome' has been defined based on experiments that compared ground controls with space-grown plants, but a comparison of subsequent space grown growth cycles has not been accomplished until the Advanced Plant Habitat (APH) 2 experiment, where radish plants were grown from seeds in two successive experiments on the International Space Station (ISS) for 27 days each. Leaf and bulb tissue from the space experiments (SEs) were compared with ground controls (GC) grown at Kennedy Space Center (KSC) under the same conditions as on the ISS, notably elevated CO2 (about 2500 ppm), and from lab controls (LC) grown under atmospheric CO2 but light and temperature conditions similar to the GC. Based on high-stringency RNAseq data (greater than 4-fold differences in up and downregulation and P values < 0.001) resulted in 4547 differentially transcribed genes for leaves and 1157 genes for bulbs, indicating that leaves are more sensitive to environmental conditions than bulbs.

Comparing leaf data from the first and second SE showed differential transcription of 227 genes, a number comparable to differences between the first SE and GC control (295 genes) and LC and SE 1 (183 genes). Comparing LC with SE 2 resulted in 820 differentially transcribed genes. The large difference between the two SE and the variability between the LC and GC material (1947 altered genes) suggests that space conditions per se do not cause consistent changes in gene transcription.

A similar conclusion can be reached from bulb data. SE 1 and 2 showed 175 differentially transcribed genes (61 up-, 114 downregulated). This number was higher than a comparison between GC and SE 1 (39 up- and 15 downregulated) but less than a comparison between LC and SE 1 (93 up- 125 downregulated) and SE2 (164 up- and 119 downregulated).

These comparisons and the inconsistent identity of affected genes lack of common pathways based on enrichment analyses and little overlap between the SEs but large discrepancies between KSC and laboratory controls suggest that the CO2 conditions may have a greater impact on plant cultivation than weightlessness. Therefore, the notion that plant cultivation in space leads to stress responses needs to be reexamined.

LAZY but effective: Deciphering the role of LAZY genes in regulating root architecture

Dr Suruchi Roychoudhry[1], Dr Adam Binns[1,2], Mr Louis Samuel[1,3], Prof. Stefan Kepinski[1]
[1]University Of Leeds, [2]University of Nottingham, [3]Aberystwyth University
1.4 - Life Sciences: Plant Biology adaption and response to space, Space Seven & Eight, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
I completed my PhD and a short postdoc in the lab of Prof. Stefan Kepinski in 2009 at the University of Leeds in Plant Developmental Biology exploring the role of the plant hormone auxin in regulating plant architecture. Next, I moved to the lab of Prof. Jean Greenberg at the University of Chicago to work on systemic plant immunity. I then moved back to Leeds to work with Stefan, and am currently employed as a senior research fellow within the Centre for Plant Sciences investigating angle-dependence in gravitropism in Arabidopsis whilst applying for (and being rejected from!) independent fellowship positions.

Overall plant architecture (consisting of the number, spacing and angle of secondary root and shoot branches) determines the efficiency of crops to capture essential resources such as water and nutrients below-ground, and light above-ground. Plant architecture is critically regulated by gravitropic growth, and recently, members of the highly conserved LAZY gene family have been demonstrated to play crucial roles in regulation of branching angle, a key determinant of plant architecture. Our previous work identified a novel dominant point mutation in LAZY4, (described as lazy4D) through an EMS mutagenesis screen in the model plant, Arabidopsis. Lateral roots in the lazy4D mutant demonstrate steeper rooting, a highly desirable trait, that maximises nitrogen uptake, drought tolerance and carbon sequestration in cereal crops, making LAZY4 (and related LAZY genes) attractive targets for gene editing to engineer deeper rooting in crop plants. However, the mechanistic basis for LAZY4 dependent regulation of root angle remains uncharacterised. Using live cell bioimaging and molecular genetic techniques, we determined that lazy4D influences root growth angle in a dose-dependent manner, and further, that unlike the WT protein, lazy4D is targeted to the actin cytoskeleton, presumably for intra-organellar plastid membrane to plasma membrane trafficking required for GSA maintenance and gravitropism. Further we show that an MKK-MPK3 phosphorylation module is required for LAZY4, but not lazy4d dependent regulation of growth angle. Collectively, our work sheds novel insights into the molecular mechanisms that underpin the lazy4D (and more broadly, LAZY gene) dependent regulation of root and shoot branching angle, and an attractive locus for the targeting manipulation of root architecture.

Leafy Greens: Exploring Physiology and Consumer Acceptability on Earth and Space-Simulated Environments using Digital Technologies

Dr Sigfredo Fuentes[1,2], Dr Eden Tongson[1], Ms Natalie Harris[1], Dr Claudia Gonzalez Viejo[1]
[1]The University of Melbourne, [2]Tecnologico de Monterrey

ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture Continued..., Space Seven & Eight, September 6, 2024, 11:00 AM - 1:00 PM

Biography:

Sigfredo Fuentes is an Associate Professor at The University of Melbourne and Distinguished Professor at Tecnologico de Monterrey. His scientific interests range from climate change impacts on agriculture, development of new computational tools for plant physiology, food, and wine science, new and emerging sensor technology, proximal, short and long-range remote sensing using robots and UAVs, machine learning and artificial intelligence.

Given the scheduled crewed long-duration missions to the Moon and Mars under the NASA – Artemis program (2030-2040), there is a critical need to cultivate genetically modified (GM) plants for space applications. These plants are essential not only as a primary food source but also as potential sources of pharmaceuticals and materials for repairs, including plastics. However, due to ethical concerns about GM foods consumption for consumer sensory tests, it is essential to develop Machine Learning (ML) models and Digital Twins with non-GM plants to simulate the process without the need for humans to taste these GM foods on Earth. Hence, this study aimed to assess six different leafy greens (sweet basil, Thai basil, coriander, kale, lettuce and Beetroot) using a low-cost and portable electronic nose (e-nose), which were used as inputs of seven ML models to predict plant physiology (Models 1-6) and consumers acceptability (Model 7). These leafy greens were grown in three robotic farms (Farmbots), and e-nose measurements along with the ground-truth physiological data (stomatal conductance, total conductance, transpiration and leaf vapour pressure) using the Licor 600 were obtained per plant before harvest. Leafy greens were harvested on the day that the consumer sensory acceptability session was conducted. For this session, 59 participants were recruited and used the BioSensory© app to record the questionnaire data for the ML Model 7 ground truth. Sessions were conducted in two simulated immersive environments (Earth and Space). Models 1-6 were developed per leafy green using the Bayesian Regularisation algorithm, while Model 7 was developed using the data from all samples and the Levenberg Marquardt algorithm. Based on the correlation coefficient (R) and slope (b), Models 1-6 had very high accuracy in predicting plant physiology (R=0.91 to 0.96; b=0.83 to 0.93); likewise, Model 7 resulted in high accuracy (R=0.93; b=0.87) for consumers acceptability predictions in both Earth and Space simulated environments. These models are the foundation for creating digital twins, enabling advanced simulations to evaluate plant physiology, consumer sensory acceptability, and other sensory experiences of future GM plants in Earth and Space environments. Moreover, these models can facilitate the management of growth and utilisation of plant resources in Space, tailoring sensory characteristics such as flavour, aroma, and texture to meet specific requirements.

Lessons From Terrestrial Anti-Ageing Trials for Nutraceutical Support of Skeletal Muscle Oxygenation in Microgravity (SMB)

Dr. Ivan Petyaev[1]
[1]Lycotec
4.1 - Life Sciences: Bone, Muscle and Immune responses, Space One, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Dr. Ivan Petyaev, MD, PhD, founded Lycotec Ltd. as a spin-off of his work at the Pathology Department of Cambridge University to turn his academic discoveries into new diagnostics and treatments of inflammatory and hypoxic pathologies, to prevent and treat cardiovascular and other chronic and age-associated diseases

Background:
Exposure of the human body to prolonged microgravity causes a significant reduction in skeletal muscle and bone mass, SMB, loss. This negatively affects the physical performance of astronauts during space flights and the process of their adaptation back to life on Earth. Apart from the loss of gravity, the other main factor responsible for SMB loss in microgravity, is space anaemia, when the loss of erythrocytes is combined with a decrease in the volume of blood plasma, which is responsible for the transfer of O2 through the capillary wall to tissue.
This reduction in peripheral tissue oxygenation would down-regulate mitochondria growth/biogenesis and energy production, hence SMB mass and performance.

Terrestrial Studies:
At the Symposium we would like to present the results of our studies on the range of carotenoid-based nutraceutical products, developed by our team, and which can increase peripheral tissue oxygenation including in skeletal muscle. The efficacy of the products has been validated in a number of clinical trials on elderly people and / or patients with moderate muscle atrophy.

Different people age at different rates and respond differently to the same health challenges, including to microgravity. To personalise intervention with our products, hence improve their efficacy, we have developed for self-diagnostics a point-of-care express test to measure tissue oxygen supply levels. This test can be performed by a medically untrained person and does not require any equipment other than a smartphone camera. The results can be ready in 2 minutes.

Proposal for Microgravity Study:
In addition, we would also present a proposal for a study on personalised administration of one of our leading nutraceuticals to support peripheral tissue oxygenation, and skeletal muscle mass and performance in volunteer astronauts flying in microgravity conditions at the International Space Station.

A potential benefit of this study would not only be helpful for astronauts to improve their quality of life and work at the ISS, but could perhaps also help to extend their living and working time beyond the current average duration of their space missions of six months.

Live-cell imaging of astrocytic reactivity adaptations under space conditions using FLUMIAS-ISS

Dr. Yannick Lichterfeld[1], Theresa Schmakeit[1], Lisa Mühlbeyer[1], Sarah Schunk[1], Laura Kalinski[1], Dr. Anna Catharina Carstens[2], Dr. Christian Liemersdorf[1]
[1]Institute for Aerospace Medicine, German Aerospace Center (DLR), [2]German Space Agency, German Aerospace Center (DLR)
5.3 - Life Sciences: Gravity Related platforms, ageing and biology research, Space Nine, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Dr. Yannick Lichterfeld studied biology at the University of Cologne and followed this with a PhD at the Institute of Aerospace Medicine at the German Aerospace Center (DLR). During his PhD he worked with primary neuronal cells and subjected them to simulated microgravity using clinostats, hypergravity using incubator centrifuges and live-cell imaging of cells on a human centrifuge, as well as several sounding rocket, drop tower and parabolic flight experiments. At the moment he is continuing this work as a Post-Doc and is evaluating and establishing the FLUMIAS microscope system for the ISS.

Introduction / Background:
The project LAARA (Live Assessment of Astrocytic Reactivity under Space Conditions) aims to investigate how astrocytes, the most prominent type of glial cell in the brain, adapt to altered gravity using the automated FLUMIAS-ISS live-cell fluorescence microscope. Astrocyte reactivity has been shown to be influenced by altered gravitational loads (Lichterfeld et al., 2022) and is thus relevant for astronaut health as it is thought to play an important role in brain physiological changes in prolonged space missions.

Method / Experiment:
FLUMIAS (FLUorescence MIcroscopic Analysis in Space) is a newly developed research platform, which combines an automated microscope with a life support system and a centrifuge to apply variable gravitational loads up to 1g onboard the ISS. The FLUMIAS microscope enables live visualization of astrocytic adaptation processes and sensitivity thresholds at altered gravity conditions. To increase the knowledge on astrogliosis and the impact of space conditions on the reactive state of astrocytes, cytoskeletal dynamics and mitochondrial activity will be investigated. To prepare for this unique and complex microscopy platform, extensive testing protocols and procedures in ground-based facilities have been devised and are currently ongoing.

Result:
As ground-based preparation studies for the LAARA mission on FLUMIAS-ISS, we have established various pretesting protocols for our primary murine astrocyte samples which can be generalized for future missions on FLUMIAS. The imaging properties of the FLUMIAS science-reference model (SRM) and engineering model (EM) have been tested with mission-relevant samples and compared to other standard microscope systems. Biological samples and culturing protocols have to be adapted and tested with the FLUMIAS-specific microslides and fluid system to verify their viability under the challenging conditions of an ISS mission.

Conclusion:
The FLUMIAS microscope enables fast live-cell microscopy with confocal-like resolution. Living samples can be grown on FLUMIAS microslides and survive under simulated upload conditions as well as simulated on-orbit life-support system operations. Staining protocols and imaging procedures have been adapted to work with the FLUMIAS life-support system and microscope facility. The testing protocols will be published and recommended for other science teams utilizing FLUMIAS.

Lunar and mars gravity induce similar changes in spinal motor control as microgravity

Dr Jaap Swanenburg[1], Dr Anita Meinke[1], Dr David A. Green[2]
[1]Innovation Cluster Space and Aviation, University Of Zurich, [2]King's College London, Centre of Human & Applied Physiological Sciences
5.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
I am a senior researcher and lecturer at the University of Zurich's Institute of Anatomy, focusing on spinal motor control in healthy individuals, as well as those with low back pain and neck conditions. My research also explores the effects of microgravity conditions and axial load on spinal health in astronauts.

Introduction: Once more, plans are underway to send humans to the Moon or possibly even to Mars. It is therefore, important to know potential physiological effects of a prolonged stay in space and to minimize possible health risks to astronauts. It has been shown that spinal motor control strategies change during microgravity induced by parabolic flight. The way in which spinal motor control strategies change during partial microgravity, such as that encountered on the Moon and on Mars, is not known.
Methods: Spinal motor control measurements were performed during Earth, lunar, Mars, and micro-gravity conditions and two hypergravity conditions of a parabola. Three proxy measures of spinal motor control were recorded: spinal stiffness of lumbar L3 vertebra using the impulse response, muscle activity of lumbar flexors and extensors using surface electromyography, and lumbar curvature using two curvature distance sensors placed at the upper and lower lumbar spine. The participants were six females and six males, with a mean age of 33 years (standard deviation: 7 years).
Results: Gravity condition had a statistically significant (Friedmann tests) effect spinal stiffness ($p < 0.001$); on EMG measures (multifidus ($p = 0.047$), transversus abdominis ($p < 0.001$), and psoas ($p < 0.001$) muscles) and on upper lumbar curvature sensor ($p < 0.001$). No effect was found on the erector spinae muscle ($p = 0.063$) or lower curvature sensor ($p = 0.170$). Post hoc tests revealed a significant increase in stiffness under micro-, lunar-, and Martian gravity conditions (all p's < 0.034). Spinal stiffness decreased under both hypergravity conditions (all p's ≤ 0.012) and decreased during the second hypergravity compared to the first hypergravity condition ($p = 0.012$).
Discussion: Micro-, lunar-, and Martian gravity conditions resulted in similar increases in spinal stiffness, a decrease in transversus abdominis muscle activity, with no change in psoas muscle activity and thus modulation of spinal motor stabilization strategy compared to those observed under Earth's gravity. These findings suggest that the spine is highly sensitive to gravity transitions but that Lunar and Martian gravity are below that required for normal modulation of spinal motor stabilization strategy and thus may be associated with LBP and/or IVD risk without the definition of countermeasures.

Lunar Dust and Lunar Gravity Impacts on Human Cellular Function

Dr Alamelu Sundaresan[1], Dr Vivek Mann
[1]Texas Southern University
4.1 - Life Sciences: Bone, Muscle and Immune responses, Space One, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Dr Sundaresan presently serves as the Chairperson- (Int) for the Department of Biology, housed in the College of Science, Engineering and Technology at Texas Southern University, Houston, Texas. The main goal of her research is to study human immunology in adverse environments, and what happens when the immune system is compromised such as in cancer, ageing, microgravity, nutritional deficiency, and auto immune conditions.

Introduction/Background: Moon expeditions pose unique challenges due to the lunar environment's characteristics, including lunar dust and reduced gravity. Understanding the impact of lunar dust exposure and lunar gravity on human health is crucial for future missions. This study encapsulates the ongoing research endeavor utilizing an Earth-based Differential Gravity Analog Random Positioning Machine (RPM) to investigate these hazards in simulated lunar conditions. Lunar dust, composed of abrasive and reactive particles, poses considerable health threats, including respiratory issues and potential long-term health implications from inhalation. Moreover, lunar dust's propensity to adhere to surfaces raises concerns about spacecraft contamination and life support system integrity. Additionally, adaptation to lunar gravity, approximately one-sixth of Earth's gravity, presents physiological challenges such as muscle atrophy, bone density loss, and cardiovascular deconditioning.
Method/Experiment: We explored two experimental scenarios: a. In the first set of experiments, we exposed human lung epithelial cells and dermal fibroblasts to lunar dust simulant (JSC-A1). to evaluate their responses. The second experiment was performed with human B cells and to analog lunar gravity using the new RPM 2.0
Results: Analysis of the two sets of experiments revealed several significant findings. Firstly, exposure to lunar dust simulant under reduced gravity conditions led to significant functional deficits in skin fibroblasts, lung epithelial cells and lymphocytes. Secondly, the cells exhibited altered behavior and gene expression patterns when exposed to lunar dust. Separate experiments were conducted with a new apparatus called the RPM 2.0 which has specific algorithms to simulate microgravity, moon, and mars gravity for cell culture. We exposed human B lymphocytes to lunar gravity on the RPM over 72 hours. We harvested the cells and supernatants. We then examined the cytokine expression in lunar gravity exposed cells by Luminex multianalyte profiling. Inflammatory cytokines such as RANTES, VEGF-alpha and TGF-beta were found to be significantly upregulated in lunar gravity cultured B cells. These results indicate that lunar gravity by itself might produce immune function decline in human cells.
Conclusion: Our study highlights the importance of considering lunar dust exposure and reduced gravity impacts in the planning and execution of moon expeditions especially for humans. The findings suggest that lunar dust, and reduced gravity, can affect the function of biological systems. Understanding these effects is critical for designing effective countermeasures and ensuring the success and safety of future lunar missions. Further research is warranted to explore potential mitigation strategies and refine our understanding of lunar environment interactions.

Lunar Effects on Agricultural Flora (LEAF) Beta Experiment, An Overview

Christine Escobar[1], Adam Escobar[1]
[1]Space Lab
ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture Continued..., Space Seven & Eight, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Christine co-founded Space Lab® in 2016, with the mission of advancing sustainable human space habitation. She is a space habitat systems engineer with expertise in space agriculture, ecology, bioastronautics, information systems, and robust design for quality engineering. As Space Lab's Vice President, she leads business administration and development and several R&D projects, with over 12 years of engineering management experience in the space industry. Christine researches duckweed for space life support and the robust design of controlled ecological life support systems. She is co-founder of the Propagule Space Ecology Institute and Principal Investigator of the LEAF Beta mission.

Artemis III will bring humans to the surface of the moon for the first time in this century. LEAF, which stands for Lunar Effects on Agricultural Flora, will study how the Lunar environment affects the germination and growth of plants that may be used to feed astronauts of the future. The Lunar Effects on Agricultural Flora (LEAF) β ("Beta") mission applies system biology and engineering to investigate the effects of partial gravity and elevated radiation in a cabin-like atmosphere on the short-term organism-wide physiological responses of model space crops. LEAF β aims to answer:

1) How will biophysical stressors in space environments past LEO affect growth, photosynthetic productivity, and nutritional quality? (Figure 1)
2) To what extent do space crops vary in resilience to oxidative stress (via induction of pathways that detoxify reactive oxygen species)? (Figure 2)
3) Which biomolecular signaling pathways are triggered by Lunar stress?
4) What genomic traits afford stress-resilience and hence space-crop fitness for space life support?

The LEAF β payload (Figure 3) will protect the plants within from excessive Lunar sunlight, radiation, and the vacuum of space, while observing their photosynthesis, growth, and responses to stress. The experiment includes a plant growth chamber with an isolated atmosphere, housing red and green varieties of Brassica rapa (Wisconsin Fast Plants®), Wolffia (duckweed), and Arabidopsis thaliana (Figure 4). Instrumentation includes a Lunar Environment Monitoring (LEM) System to measure radiation, acceleration, and Lunar gravity; a Plant Habitat System (PHS) to monitor photosynthesis and control the plant growth conditions; and a Plant Health Imaging (PHI) System to monitor seed germination, seedling growth, and morphology. By having astronauts collect seedling samples for return to Earth, the research team will be able to apply advanced system biology tools to study physiological responses at a molecular level. Only one other payload has studied plants on the moon; the 2019 Chinese Chang'e 4 mission provided a picture of a 4-day old cotton sprout then suffered thermal control failure. The Lunar Effects on Agricultural Flora (LEAF) research will provide the first, comprehensive assessment of organism-wide effects of the Lunar environment, reducing risks for sustainable off-planet crop production and paving the way for a future sustained Lunar habitation and missions to Mars. This presentation reviews the LEAF β science objectives, hypotheses, and β payload concept to be developed for the Artemis III mission.

MicroAge Missions: Microgravity as a Model for Accelerated Skeletal Muscle Ageing

Dr Samantha Jones[1], Dr Shahjahan Shigdar[1], Miss Kay Hemmings[1], Dr Kai Hoettges[1], Dr James Henstock[1], Dr Samuel Ball[1], Dr Elizabeth Sutton[1], Dr Michael Mueller[1], Miss Karolina Wikaryjczjk[1], Dr Christopher McArdle[1], Dr Kareena Adair[1], Dr Philip Brownridge[1], Dr Megan Hasoon[1], Professor Andy Jones[1], Professor Claire Eyers[1], Professor Anne McArdle[1], Professor Malcolm Jackson[1]

[1]University Of Liverpool

5.3 - Life Sciences: Gravity Related platforms, ageing and biology research, Space Nine, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

I am a Research Project Manager based at the Institute of Life Course and Medical Sciences, University of Liverpool. I'm responsible for the microgravity research portfolio within the Institute, including two UK Space Agency (UKSA) funded missions to the ISS, MicroAge and MicroAge II and a joint UKSA-ESA supported project, FLUMIAS-ISS. Previously the lead post-doctoral researcher for the MicroAge Mission, I focused on researching the effects of microgravity on skeletal muscle function and how it relates to musculoskeletal ageing. My expertise are in micro-tissue engineering, microgravity research, hardware validation for life science payloads and coordination of mission operations.

Introduction:

Demographic changes show rapidly increasing numbers of older adults with poor health. Age-related skeletal muscle loss contributes to the development of frailty but the mechanisms by which this occurs are yet to be fully identified. We have demonstrated that muscle from older humans adapts poorly following exercise, compromising the maintenance of muscle mass/function. In a similar yet accelerated manner, the muscles of astronauts exposed to microgravity (µg) rapidly lose muscle mass and are relatively unresponsive to exercise training in spaceflight. As part of a series of UK Space Agency (UKSA)-funded national missions to the International Space Station (ISS), we performed studies using tissue-engineered, human muscle constructs to determine whether analogous maladaptations to contractile activity occur rapidly under the influence of microgravity as that which occurs in older adults on earth.

Methods:

Muscle constructs were fabricated using immortalised human myoblasts encapsulated in fibrin hydrogels and anchored onto bespoke, 3D-printed scaffolds. Scaffolds were integrated into bespoke 'life-support' systems, designed in collaboration with Kayser Space Ltd, to autonomously perform fluid exchanges, electrical stimulations to initiate contractions and monitor contractions whilst in spaceflight. Upon return to earth, a ground-matched study was performed. Muscle constructs underwent LC-MS using a timsTOF mass spectrometer in dia-PASAF mode. Bioinformatic analyses determined differential expression patterns and gene ontology (GO) term functional enrichment. Culture medium samples were recovered and analysed using a Bio 27-Plex immunoassay panel for human cytokines.

Results:

In the proteomic analysis, 2934 human proteins were identified across all samples. When determining the effects of microgravity on the proteome at rest, there were 541 proteins differentially expressed (DE) compared with the ground-matched samples (287 upregulated and 254 downregulated, $p < 0.05$). When performing function enrichment analyses, pathways such as mitochondrial metabolism/gene expression were highlighted. Electrical stimulation of the muscle constructs on ground resulted in the enrichment of pathways associated with muscle adaptive responses. However, these responses were perturbed in microgravity.

Fifteen cytokines/chemokines were released from the muscle constructs and data supported the hypothesis that exposure to µg resulted in a pro-inflammatory response and suppressed beneficial contraction-induced responses observed in the ground reference experiments.

Conclusion:

In summary, the study demonstrated major modification to the muscle construct proteome and secretome at rest and in response to electrical stimulation in microgravity compared to those seen on ground. These results have led to a subsequence UKSA-funded mission to the ISS, MicroAge II. Due to be flown in 2025.

Microgravity Studies of Emulsions Destabilisation within the ESA MAP project EDDI

Dr. Libero Liggieri[1], Dr. Francesca Ravera[1], Dr. Eva Santini[1], Prof. Luigi Cristofolini[2], Prof. Davide Orsi[2], Dr. Valentiona Lorusso[2], MSc Marco Vaccari[2], Prof. Thodoris Karapantsios[3], Prof. Margarithis Kostoglou[3], Dr. Angeliki Chondrou[3], Dr. Reinhard Miller[4], Prof. Emanuel Schneck[4], Prof. Mickael Antoni[5], Prof. Boris Noskov[6], Prof. James Ferri[7], Dr. Robert McMillin[7], Prof. Kazutami Sakamoto[8], Dr. Hidaki Sakai[8], Prof. Yuji Yamashita[9], Dr. Sebastien Vincent-Bonnieu[10], Prof. Davide Cassi[11], Dr. Christos Koukiotis[12], Dr. Alexander Makievski[13], Dr. Jallil Ouazzani[14], Dr. Satoru Hashimoto[15], Dr. Takeshi Misono[15]

[1]CNR - Institute of Condensed Matter Chemistry and Technologies for Energy, [2]DMPCS - University of Parma, [3]Aristotle Univ. Thessaloniki, [4]Dept.Physics TU Darmstadt, [5]MADIREL, Univ. Aix-Marseille, [6]St.Petersburg State Univ., [7]Virginia Commonwealth Univ., [8]Tokyo Univ. of Science, [9]Kanagawa Univ., [10]ESA-ESTEC, [11]Future Cooking Lab, [12]Loufakis Chemicals, [13]Sinterface Technologies, [14]Arcofluid, [15]Nikko Chemical

4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography:

Libero Liggieri is a Senior Researcher at the CNR-Institute of Condensed Matter Chemistry and Technologies for Energy in Genoa, Italy. His scientific interests are in the physical-chemistry of anphiphiles adsorption layers and corresponding applications to emulsion, foams, biomedicine and materials. In the above fields he is author of more that 200 publications. He has been involved as investigator or coordinator in a number of projects and experiments related to microgravity research. He is a member of ELGRA since 1990, also serving the association as a member of the MC and as General Secretary.

Typical emulsions are constituted by fine dispersions of microscopic droplets in a matrix liquid, common in natural and synthetic products and serving several technologies or processes. Emulsions are intrinsically unstable and their kinetic stability warranted by the presence of amphiphilic species, such as surfactants, polymers, proteins and even particles. These species segregate at the droplet interfaces and warrant the kinetic stability of these droplets against the typical destabilisation mechanisms, such as, droplet-droplet coalescence and Ostwald ripening. The action of these species on the destabilising mechanism, even known from a general point of view, it is not sufficiently detailed to allow for an on-design formulation, so that emulsion technology relies still of semi-empirical models and practices.

Aiming at overcoming these limitations, warranting a more efficient utilisation of resources in emulsion-related technologies and products, the relations between interfacial adsorption layer properties and the mechanisms of destabilisation of emulsions have been the subject of many studies. On ground these studies are complicated by the presence of buoyancy, inducing creaming or sedimentation of the droplets, which results strongly coupled with the above mechanisms.

Microgravity conditions offers therefore a unique environment to study the evolution of emulsions under the sole effects of the mechanisms responsible for emulsion destabilisation, such as droplet coalescence and Ostwald ripening, allowing deriving more clear correlations with the features of adsorption layers at the droplet interface.

With above aims, the project EDDI (Emulsion Dynamics and Droplet Interface) has been proposed to ESA by an international partnership, In the envelop of the project, two campaigns of experiments (PASTA-1 and PASTA-2) have been succesfully performed between 2022 and 2014, using the ESA FSL-Soft Matter Dynamics facility, onboard the ISS. More experiments are planned in 2025, within a recently approved project (SEEDS). Here we present the concepts underlying the EDDI project and the PASTA experiments, also providing some overview of the results.

Besides obvious terrestrial applications, the results of these studies can also serve the optimisation and development of technologies where emulsions are utilised in reduced-gravity conditions, such as space vehicles and planetary environments.

Mitochondrial hydrogen peroxide: mediator of skeletal muscle loss under microgravity and during ageing on earth

Miss Karolina Wikaryjczyk[1], Ms Karolina Wikaryjczyk[1], Dr Samantha W Jones, Dr David A Turner, Dr Kai Hoettges, Professor Malcolm J Jackson
[1]University Of Liverpool
5.3 - Life Sciences: Gravity Related platforms, ageing and biology research, Space Nine, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Karolina holds a BSc in Psychology and a MSc in translational Neuropathology. She is a young investigatore - the core laboratory technician working on the FLUMIAS project at Liverpool and responsible for advancing the science application and testing for the FLUMIAS microscope. She has a keen interest in 'all things space' and is actively involved in our wider outreach programme at Liverpool.

Loss of skeletal muscle mass and function is the major factor in increasing weakness in older people, and in astronauts exposed to microgravity during spaceflight. Best practice for maintaining muscle in astronauts on the International Space Station (ISS) and older people on earth requires exercise, although current protocols cannot fully maintain muscle mass in either situation. There is a need to understand the mechanisms leading to loss of muscle mass and function in ageing and in microgravity in order to optimise preserving muscle mass in both situations.
Altered mitochondrial morphology and increased mitochondrial formation of Reactive Oxygen Species (ROS), particularly hydrogen peroxide (H2O2) are associated with ageing in skeletal muscle. ROS are critical signalling molecules that modulate changes in muscle homeostasis and increased mitochondrial ROS generation is proposed to play a key role in pathological changes in muscle loss in microgravity. Unfortunately, studies are inconclusive, in part because of the lack of definitive methods to study specific ROS in biological tissues under microgravity and previous limitations to studies in space.
The new FLUMIAS microscope installed on the ISS will, for the first, time allow definitive studies to take place under microgravity conditions. This study will examine the role that mitochondrial dysfunction and H2O2 production plays in loss of muscle mass in microgravity and how this relates to muscle loss in older people on earth.
The concentration of individual ROS is low in cells and it has not been possible to measure individual species in biological systems. HyPer is a specific probe for H2O2 that can be localised to mitochondria. Mitochondria form a dynamic interconnected reticulum which can be imaged in confocal microscopy. Mitochondrial dynamics are regulated by fission and fusion. Studies indicate that in ageing and in microgravity, mitochondria may change to reflect modified fusion with increased H2O2 production and disorganisation of the actin cytoskeleton, creating a functional link between cytoskeletal-mitochondrial dynamics and muscle loss.
This study will use the FLUMIAS microscope (https://www.dlr.de/en/research-and-transfer/projects-and-missions/horizons/flumias) to test the hypothesis that increased H2O2 plays a key role in mediating loss of muscle mass that occurs rapidly following exposure to microgravity and over a longer period of time during ageing on earth with disrupted mitochondria as the key intracellular site for increased H2O2 generation. Data will demonstrate the ability to monitor H2O2 generation in mitochondria on the ISS and the process to determine associated changes in the structure and function of the mitochondrial reticulum.

Monitoring the degradation of bone elastic properties induced by microgravity: a proposal.

Prof. Francesca Cosmi[1], M.S. Alessandra Nicolosi[2]
[1]University of Trieste, [2]M2TEST srl
4.1 - Life Sciences: Bone, Muscle and Immune responses, Space One, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Associate professor at University of Trieste. MA in Biomechanical Engineering and PhD Degrees from Polytechnic University of Milan. Research at JPL NASA-CalTech (USA), UC Berkeley (USA), MITI (Japan), UFRJ (Brazil) and continuing cooperation with UBA (Argentina). Author of over 170 papers targeting new numerical methods and the behavior of complex structure materials. Author of two U.S. and three Italian patents concerning BES TEST (Bone Elastic Structure TEST), a software medical device improving identification and monitoring of fragility fracture risk, and co-founder of a spin-off active on the market and winner of numerous recognitions. Nominated for VinFuture Prize 2024.

Background:
Important alterations occurring in living organisms during space flight concern the trabecular compartment of load-bearing bones, and result in significant bone mineral loss and decay of mechanical properties [1, 2].
Composition, mineral content, and the complex micro-scale trabecular microarchitecture contribute together to the macro-scale functional strength of bone as a whole [3]. Bone alterations, including those due to reduced gravitational load conditions, are mainly assessed by measuring bone density, even though, alone, it cannot comprehensively assess skeletal integrity [4]. Micro-tomographic techniques [5], not suitable for monitoring, allow for a pre- and post-mission examination of the trabecular bone component, which undergoes the fastest and most important alterations, placing astronauts at serious risk of fracture upon re-entry [5]. Mesoscale studies in modeled microgravity conditions combined with numerical simulations, show that degradation of apparent mechanical properties must be considered to achieve an accurate description of bone performance [6, 7].
To quantify the pathological alterations in the bone micro-architecture in a clinical setting, a patented, CE marked, software medical device, the Bone Elastic Structure Test, BES TEST, has been developed. Results are uncorrelated to BMD and independent of load [8, 9]. BES TEST has a diagnostic accuracy of 78% as a 3-year fracture risk estimator [10] and can be used to complete the densitometry picture and as monitoring tool for bone follow-up in in rheumatology [9], oncology [11], nephrology [12] and rare bone diseases [13].
Its prospective application for bone alteration monitoring during spaceflights is discussed.
Method:
BES TEST simulates the application of forces on an X-ray functional biopsy of the patient's hand [14-19]. Results are combined in an index, BSI, and its T-score and Z-score (Fig.1). Characteristics: X-ray dose < 0.0005 µSV; CV intra-operator=0.06; 95%CI±8 BSI; CV inter-operator =0.11; 95% CI=±10.8 BSI [20, 21], in line with the diagnostic gold standard.
Requirements for investigation of BES TEST space application:
- Acquisition: x-ray scanner, small detector. Several possible arrangements are possible, tests in simulated space flight will clarify the best configuration.
- Calibration: the acquisition set-up will likely differ from the clinical one.
- Analysis: radiograms upload to automatic service.
Results:
BES TEST monitors trabecular bone, which changes more rapidly than cortical bone and BMD in response to physio-pathological alterations, like those occurring during spaceflight.
Conclusion:
BESTEST is fast, easy to perform, cost-effective and can be significantly repeated within just weeks, showing potential for monitoring the changes in bone functionality during long-duration space missions.

Multisensory integration for verticality perception.

Drs Catho Schoenmaekers[1], Professor Floris Wuyts[1], Professor Elisa Ferre[2]
[1]University of Antwerp, [2]Birkbeck University of London
5.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Elisa Raffaella Ferre is a Professor of Cognitive Neuroscience at Birkbeck University of London (UK) where she established the Vestibular Neuroscience Lab. Her research combines experimental psychology, cognitive neuroscience, neuroimaging, vestibular physiology and space science methods to understand how gravity shapes behaviour and, in a more forward-looking way, how non-terrestrial gravities may impact cognition and performance during spaceflight. She serves as the elected Secretary for ELGRA.

Introduction:
Verticality is determined in relation to gravity, where a vertical orientation runs parallel to gravity, while a horizontal orientation is perpendicular to it. Verticality perception plays a crucial role in balance and spatial orientation. Exposure to microgravity during spaceflight is known to elicit verticality illusions. The brain constructs a representation of verticality by integrating vestibular and visual information. However, how mechanistically these sensory cues are integrated for the perception of verticality has been largely debated. Here we systematically investigated the dynamic integration of vestibular and visual cues, considering their respective reliability, in the perception of verticality.

Material and methods:
Twenty-four participants (10 male, 14 female), aged 18-50, engaged in a Verticality Detection Task (VDT). The task involved discriminating between vertical lines and those tilted 2.5 degrees clockwise or counterclockwise while seated upright with head support. To manipulate cue reliability, we introduced stimulations inducing artificial roll-tilt sensations using visual optokinetic stimulation cues (OKS), galvanic vestibular stimulation cues (GVS), or a combination of both (OKS+GVS). Sham controls were implemented to account for non-specific effects. Correct answers, perceptual sensitivity (d'), and post-perceptual bias (C) were measured and analyzed using signal detection approaches.

Sensitivity (d’) was then calculated as:
$d' = Z(PropHit) - Z(PropFA)$

Criterium was calculated as:
$C = (-(Z(PropHit) + Z(PropFA)))/(2)$

Data were analyzed using JMP® (version Pro 16. SAS Institute Inc, Cary, NC, 1989-2001). We built three linear mixed models (LMM) for each variable (correct answer, sensitivity, and criterion) with condition as fixed effect and subject as random effect for each LMM.

Results and discussion:
Linearly increasing errors in detecting verticality were observed from vestibular to visual and combined conditions. Sensitivity significantly differed between vestibular and combined visual-vestibular stimulations, with no discernible response bias variations. Results indicate that both visual and vestibular cues influence verticality perception, emphasizing the dominance of visual cues. Combining modalities produced summation effects, influencing how verticality is perceived.
Our findings not only contribute to understanding the mechanistic aspects of verticality but also provide insights for spaceflight countermeasures. Recommendations include providing astronauts with vertical visual cues, particularly during lunar surface motor tasks, to enhance orientation. Visual cues can prove advantageous in the recovery phase, aiding astronauts in regaining their upright perception and enhancing balance and spatial orientation upon return to Earth.

NASA Human Research Program Food and Nutrition Risk Strategy

Dr. Becky Brocato[1], Dr. Michael Stenger[1], Dr. Stuart Lee[1], Dr. Grace Douglas[2]
[1]HRP NASA, [2]Spaceflight Food Systems Laboratory NASA

ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture, Space Seven & Eight, September 6, 2024, 9:00 AM - 10:25 AM

Biography:

Becky Brocato began her career as an aerospace engineer at the U.S. Army's Yuma Proving Ground, testing parachutes for aerial delivery. Following graduate school, Brocato joined the U.S. Army Research Institute of Infectious Diseases, developing medical strategies to counter the effects of highly infectious viruses. She joined NASA's Human Research Program in 2021.

Brocato received a bachelor's degree in aerospace engineering from Saint Louis University in Missouri, a master's degree in space studies from the University of North Dakota, and a doctorate in microbiology and immunology from Tulane University in New Orleans.

The Human Health Countermeasures (HHC) Element of NASA's Human Research Program (HRP), along with other organizations within NASA, conduct research and capability developments to buy down the risk of performance decrement and crew illness due to inadequate food and nutrition. Food and nutrition are critical for health and performance both in low Earth orbit and on exploration missions. On the International Space Station (ISS), crewmembers share a defined set of pantry foods, and have limited preference and shelf-life foods (e.g. fruits and vegetables) from resupply missions. Exploration design reference missions (DRMs) will likely be more constrained than missions to ISS, where those crewmembers would be subject to a more restricted food system due to resource limitations. HRP food and nutrition research consists of studies to close the following research gaps: determination of the nutritional requirements to maintain health and performance for the defined DRMs, determining the nutrient content, safety, and acceptability of the spaceflight food system specific to DRM and vehicle constraints, development of countermeasures either within or in addition to the food system to mitigate decrements to health and performance by DRM, and the validation and integration of food system countermeasures in analogs and in flight. The current spaceflight food system is shelf-stable, consisting of freeze-dried foods, thermostabilized foods, natural form foods, and powdered beverages. Crops represent a food system countermeasure that has the potential to supplement the pre-packaged food system. As an applied research program, HRP goals for crop research are centered around three main themes: nutrition, safety, and acceptability. As crops advance through Crop Readiness Level evaluations, HHC partners with the sponsoring organization to ensure that HRP goals are met for crops to be consumed in spaceflight.

Neural correlates of vestibular adaptation in cosmonauts after long duration spaceflight

Catho Schoenmaekers[1], Dr Steven Jillings[1], Prof Elena Tomilovskaya[2], Dmitrii Glukhikh[2], Dr Ilya Rukavishnikov[2], Prof Peter Zu Eulenburg[3], Professor Floris Wuyts[1]

[1]LEIA - University Of Antwerp, [2]IBMP - Russian Academy of Sciences, [3]Ludwig Maximilians University

5.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

Catho Schoenmaekers's academic research focuses on the physiological challenges of human spaceflight, with the aim of enhancing astronaut safety and well-being during long-duration space missions. As a doctoral candidate in Aerospace Biomedicine, her thesis investigates the effects of prolonged microgravity on the peripheral and central vestibular system. Utilizing various clinical and neuroimaging approaches, this research provides a multifaceted evaluation of the vestibular system, allowing for an in-depth investigation of the adaptations resulting from long-duration spaceflight.

Introduction:

Our research team has previously investigated the otolith-mediated ocular counter-roll (OCR) where we found a difference in eye torsion pre- to postflight [1], which was moreover governed by previous flight experience. Moreover, resting-state functional magnetic resonance imaging (rsfMRI) analysis in a largely overlapping cosmonaut cohort has revealed functional connectivity (FC) changes after spaceflight [2]. The current study aimed to investigate retrospectively if OCR changes from pre- to postflight correlate with functional connectivity changes in specific vestibular cortical regions after a long duration mission to the International Space Station (ISS).

Methods:

Fourteen cosmonauts were included in this analysis (mean age: 46.8 (SD=5.17); mission duration=186.92 (SD=51)). Brain MRI scans were acquired before the ISS mission (89 days (SD=199)) and after (9 days (SD=3)). The OCR was assessed through an independent study at 154 days (SD=109) before launch and 3 days (SD=1) after landing. Resting-state functional MRI (rsfMRI) data were acquired at each time point, from which FC was derived. We adopted a regions-of-interest (ROI) approach based on a cortical vestibular atlas from a previous fMRI study [3]. The vestibular function was measured using the OCR, which is an otolith-induced eye reflex generated by off-axis centrifugation. The pre- to post-flight difference in SBC was correlated with the pre- to post-flight difference of the OCR. The voxel-level threshold was set at $p<0.001$ uncorrected followed by a cluster-level threshold of $p<0.05$ corrected with the false discovery rate (FDR).

Results:

Significant alterations in FC were identified between the vestibular seed region, OP2_PIVC r, and clusters (+38 -72 +52) involving the right angular gyrus (AG) and (-52 -62 +48) encompassing the left angular gyrus (AG) (Figure 1). Location of both clusters was confirmed by using the AAL3 atlas toolbox of SPM12 as an additional atlas to the one of CONN. These changes corresponded with a simultaneous decrease in OCR ($p(FDR)<0.021$, $p(FDR)<0.038$), indicating a correlation with a higher decrease of the OCR and a lower connectivity post-flight. Highlighting the angular gyrus' role in spaceflight vestibular adaptation3–8, contributing to our understanding and facilitating accelerated adaptation in experienced cosmonauts during gravitational transitions. The more the otoliths are affected after spaceflight, the less the connectivity has changed between those regions.

[1] Catho Schoenmaekers. 10.1038/s41526-022-00208-5
[2] Jillings. 10.1038/s42003-022-04382-w
[3] Peter zu Eulenburg. 10.14293/S2199-1006.1.SOR-.PPCSDUO.v1.
[4] Hupfeld: 10.1093/cercor/bhab239.
[5] Linnea Banker. ID : NBK544218
[6] Joseph DiGuiseppi. ID: NBK549825
[7] Ruba R. Al-Ramadhani . 10.1684/epd.2021.1257
[8] Adnan A S Alahmadi: 10.1186/s13244-021-00993-9

New Depths of Plant Regulation in Spaceflight through profiling of miRNA, mRNA, and ribosome-associated mRNAs

Emma Canaday[1], Eric Land[2], Alexander Meyers[3], Imara Perera[2], Sarah Wyatt[1]
[1]Ohio University, [2]North Carolina State University, [3]Kennedey

ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics Continued..., Space Seven & Eight, September 5, 2024, 2:15 PM - 4:10 PM

Biography:

Emma Canaday is pursuing a Ph.D. in environmental and plant biology in the lab of Dr. Sarah Wyatt at Ohio University. Her current research focuses on using bioinformatics to assess how plants alter their transcriptomes and translatomes when grown in space. They are passionate about studying how plants adapt to the harsh, novel, environments of spaceflight and plan to continue in this field after graduating

Long-duration missions will require plants adapted to the spaceflight environment. Limitations in growth chamber area and down mass returned from the International Space Station prevent many experiments from producing enough tissue for robust proteomic analyses. Transcriptional profiling has shown that plants grown during spaceflight exhibit altered molecular responses. However, changes in transcript levels do not necessarily correlate with changes in protein abundance. Instead of directly assessing protein content, Targeted Ribosome Affinity Purification (TRAP) followed by RNAseq allows for quantification of transcripts that are actively recruited to ribosomes. These transcripts make up the translatome. The goal of the APEX-07 spaceflight experiment was to compare the transcriptome, translatome and small RNA landscape of Arabidopsis seedlings grown on the ISS to obtain a deeper understanding of spaceflight regulation. APEX-07 successfully identified core points of post transcriptional regulation in both roots and stems. Less than 50% of the differentially expressed genes had consistent patterns of expression in both the transcriptome and translatome. Genes that did share patterns in both the polysomal and total mRNA show ontological enrichment in regulatory proteins including phosphatases, kinases and small molecular binding proteins. Some genes, including several ion and small molecule transporters, showed opposite patterns of expression across extraction types. The opposing patterns in transcription and translation points towards post transcriptional regulation being especially important for transmembrane transporters. The polysomal fraction also identified pathways that were not differentially regulated in the total mRNA. Transcripts for cell wall remodeling genes were only upregulated in the polysomal fraction with the same genes showing no significant difference in the total mRNA. The miRNA sequencing also identified targets of post transcriptional regulation. Several miRNAs known to target MYB and ARF family transcription factors were increased in spaceflight suggesting that those transcription factors were post transcriptionally downregulated in response to flight. This trend was seen in ARF 6, 8, 10 and 16 where miRNA was increased, and mRNA decreased in response to flight. Processes related to ROS and telomeric function were also significantly regulated at the transcript level suggesting processes important to spaceflight are potentially regulated at levels which are not visible when only using standard RNAseq. Total mRNA sequencing has the power to reveal transcripts that are differentially expressed in space, post transcriptional regulation gives better insights into the functional response of the plant to the spaceflight environment. Partially supported by NASA grant 80NSSC19k1481 to PIs S.E.W. and I.Y.P.

No Longer Earthlings: Fieldwork on the MEILI Space Exploration Analogues

Michael Murphy[1]
[1]University College London - ETHNO-ISS Research Group
1.3 - Life Sciences: Human Physiology and Performance, Space Nine, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Michael Murphy is an explorer, anthropologist, and associate researcher at UCL. His work examines the impact of extreme journeys on the deepest part of people's subjective being: their identity. He has worked with refugees in Jordan and Bangladesh, undocumented migrants in the US-Mexico borderlands, and analogue astronauts in the US and Europe. He uses innovative ethnographic methods to reach remote communities and bridge language barriers, such as art, photography, and storytelling. His current project uses analogue missions to investigate how journeys to space change astronauts' concepts and constructions of 'self', aiming to create a dialogue between terrestrial and extraterrestrial migration.

No Longer Earthlings: Results
Introduction:
This presentation will explore the processes by which astronaut identities are transformed in the extreme environment of space. Drawing on terrestrial migration theories, I will explore how astronauts and analogue astronauts define and modify "the self" while alienated from their territories and their planet. I will anthropologically frame these extreme journeys as 'rituals of transformation' and 'rites of passage', in which cohorts experience liminality and communitas, and are thereby reconstructed in themselves. This is inspired by cosmonaut Lebedev's self-observation, "no longer earthling," and Leninger's, "untranslatable to oneself."

Methods:
Building on pilot fieldwork conducted on the MEILI-I Space Health Research analogue mission, in which I was a participant observer and employed extensive ethnographic techniques, I will explore findings and (crucially) tie them back to terrestrial migration theories. These methods included in-depth pre- and post-mission interviews with space industry astronauts and analogue astronauts, as well as MEILI-I analogue mission astronauts. MEILI-I astronauts also engaged in participatory action research, creating interpretive art and, most impactfully, creative journaling.

Results:
Using these methods, I was able to trace transformations of deeply held personal beliefs, qualities, and relationships that analogue astronauts experienced over the course of the mission, as they were alienated not just from their local social context, but seemingly from the bounds of Earth entirely. These transformative experiences were echoed in contextual interviews and resembled experiences that astronauts have reported in various literature. The results suggest that profound reconstructions of identity and social relations may be commonplace, yet understudied, in space migration and simulated space migration.

Moreover, these findings bear a striking resemblance to processes in extreme terrestrial migration and displacement. This may suggest that, despite the overwhelming differences between terrestrial displacement and extraterrestrial exploration, the commonality of a dramatic removal from sociocultural contexts followed by a journey of intense discovery and survival in both cases may offer a bridging theory via 'rites of passage' and themes of liminality, ritual, and communitas. The presentation is meant to open a conversation on how terrestrial migration can inform extraterrestrial migration, and vice versa. What can we learn from extreme journeys on Earth as we make plans to send astronauts to space stations, the Moon, and Mars? Reciprocally, how can we look back from our journeys in space to gain a new perspective of journeys on Earth?

Note: This presentation will take place after the follow-up MEILI-II mission, which may impact findings.

Onsager variational principle for granular fluids

Dr Martial Noirhomme[1], Pr Nicolas Vandewalle[1]
[1]University Of Liege
4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Mr. Noirhomme presented a doctoral thesis at the University of Liège in 2018. This thesis focused on phase transitions within granular materials in microgravity. Since then, he has been a PRODEX researcher at the University of Liege and is also working on an experimental subject relating to the active material.

Granular fluids, as defined by a collection of moving solid particles, is a paradigm of a dissipative system out of equilibrium. Inelastic collisions between particles is the source of dissipation, and is the origin of a transition from a gas to a liquid-like state. This transition can be triggered by an increase of the solid fraction. Moreover, in compartmentalized systems, this condensation is driving the entire granular fluid into a Maxwell demon phenomenon, localizing most of the grains into a specific compartment. Classical approaches fail to capture these phenomena, thus motivating lots of experimental and numerical works. Herein, we demonstrate that Onsager's variational principle is able to predict accurately the coexistence of gas/liquid states in granular systems, opening ways to model other phenomena observed in such dissipative systems like segregation or the jamming transition.

Optical diagnosis of melting bridges in the MarPCM microgravity experiment

Dr. Pablo Salgado Sánchez[1], Mrs. Carmen Haukes[1], Mr. Dan Gligor[1], Dr. Jose Miguel Ezquerro[1], Dr. Ursula Martínez[1], Prof. Jeff Porter[1], Dr. Álvaro Bello[1], Dr. Jacobo Rodríguez[1]
[1]E-USOC, Universidad Politécnica de Madrid

4.3 - Physical Sciences: Marangoni convection, Space Nine, September 5, 2024, 11:00 AM - 1:00 PM

Biography:

Pablo Salgado Sánchez is associate professor at E.T.S.I. Aeronáutica y del Espacio. He investigates phenomena associated with fluid and phase-changing systems subjected to vibrations and thermal excitation in microgravity, combining experiments and simulations. Since 2016, he has been a member of the Spanish Users Support and Operations Centre (E-USOC) as an ISS payload operator certified by ESA and NASA.

Introduction:
In the context of the MarPCM experiment (Porter et al., 2023), we develop a neural network-based algorithm to help process images from the melting bridge experiments (Varas et al., 2021). Both solid and liquid phases are present during melting and, since the liquid PCM has a higher refractive index than air, traversing light rays are concentrated, as with a converging lens, which visually enlarges the shape of the solid PCM. This distortion can be a major obstacle in the optical measurement of the time-dependent liquid fraction since the apparent amount of solid is magnified.
The network is trained using synthetic images generated with a ray-tracing algorithm. This technique is based on following light rays backwards from the camera to the source and accounts for reflection, refraction, and absorption in the formation of the images. The rendered scene replicates the MarPCM setup.
Further details can be found in Martinez et al. (2023).
Methods:
We combine the following methods:
- Numerical simulation of the phase change with thermocapillary effects. PCM melting is described using an enthalpy-porosity-based formulation of the Navier-Stokes equations and resolved using the finite element method (Varas et al., 2021).
- Generation of synthetic images of the melting process via ray-tracing. Images are produced using an in-house code. The rendered melting bridge scene is created using simulations of the melting process in microgravity while the code is validated using images from ground experiments; see the left panels of the figure.
- Image classification using neural networks. Synthetic images are used as inputs to a multiple-layer neural network. The network classifies each image in accord with its liquid fraction and provides an estimate of the real liquid-to-PCM volume fraction. Images are pre-processed using singular-value decomposition.
Results:
An example of experiment image processing is given in the right panel of the figure. The liquid fraction is a critical parameter determining how well the real phase boundary can be determined from the image.
Conclusions:
The results indicate that the melting process can be tracked much more accurately during the latter stages of melting. The initial melting stage, associated with a shallow layer of liquid near the surface of the bridge, is largely obscured by optical effects. Judged by the present numerical simulations and synthetic images, the developed neural network is capable of classifying the images and providing a good estimate of the liquid fraction over time.

Optimal Greenhouse Design for Applications in Life-Support Systems

Dr. Lucie Poulet[1], Dr. Daniel Florez-Orrego[2], Prof. Claude-Gilles Dussap[1], Prof. François Maréchal[2]
[1]Université Clermont Auvergne, [2]Ecole Polytechnique Fédérale de Lausanne
ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space Continued..., Space Seven & Eight, September 5, 2024, 11:00 AM - 12:00 PM

Biography:
Currently a researcher at Institut Pascal (University Clermont Auvergne) on a Marie Sklodowska-Curie fellowship, her research work focuses on developing a methodology to design space greenhouses that are optimized in terms of mass, energy, and crew time, for BLSS applications. This is done in collaboration with the IPESE laboratory at the Ecole Polytechnique de Lausanne (Switzerland). She worked for 3 years in the Space Crop Production group at NASA's Kennedy Space Center. Her research led her to participate in 4 Mars analog missions - including a 4-month NASA-funded mission - and 10 parabolic flights to test experiments she had developed.

Given the challenges of regular resupply missions to distant destinations, such as the Moon or Mars, it's imperative to prioritize resource recycling and in situ food production. In this view, greenhouse modules, which enable food production, atmosphere regeneration, and water recycling, will be the central piece of bioregenerative life-support systems for long-duration crewed missions. To be sustainable, they will need to use few resources, present low risk, be robust, reliable, and resilient.
Current plant growth systems for space missions, whether small research facilities or oversized engineering concepts, fail to adequately meet the challenges of sustaining astronauts with food in space. Existing space greenhouse modules have typically been designed based on spacecraft volume limitations or as ambitious engineering designs for planetary missions.
The objective of the SERENITY (Space & Earth Reliable greENhouse desIgn meThodologY) project is to develop a methodology starting from the mission scenario (i.e., location, duration, crew size, nutritional targets, available utilities) and enabling users to generate different design solutions, with requirements on the system's mass, energy, crew time, efficiency, reliability, sustainability, and risk for humans. These solutions are generated using the multi-objective optimization platform for energy systems, OSMOSE (OptimiSation Multi-Objectifs de Systèmes Énergétiques) developed at the laboratory of Industrial Processes and Energy Systems Engineering (IPESE) at the Ecole Polytechnique Fédérale de Lausanne (EPFL). The approach is incremental, starting from simplified systems and limited requirements to more complex systems. The end goal is to provide a framework for users and developers, where they can interact with each other, add subsystems that are tailored to their needs, and choose their own level of complexity, while contributing to the improvement of this methodology.
The entirety of the codes is deposited in a GitHub repository (https://github.com/LuciePoulet/SERENITY) to be widely available and to allow a modular use of the methodology.
In this talk, the overall framework is presented with its potential and its limitations. The main subsystems, corresponding to the main greenhouse module functions, with their different options for unit operations, are detailed. The different scenarios, with their associated constraints are reviewed and, as an illustration of this methodology, a case study on a simplified greenhouse module is detailed, for one of the four scenarios, with the goal of minimizing the system mass.
This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Sklodowska-Curie grant agreement N° 101067017.

Optimizing Thermal Performance in Microgravity through timely melting-solidification cycle interruption

Dr Diana Dubert[2], Dr Berin Seta[3], Prof Jaume Massons[2], Prof Josefina Gavaldaa[2], Prof Mounir M. Bou-Ali[1], Prof Javier Ruiz[2], Prof. Valentina Shevtsova[1,4]
[1]Mondragon University, [2]Universitat Rovira i Virgili, [3]Technical University of Denmark, [4]Basque Foundation for Science
4.3 - Physical Sciences: Marangoni convection, Space Nine, September 5, 2024, 11:00 AM - 1:00 PM

Phase change materials (PCMs) possess the unique ability to absorb and release heat during phase transitions, making them invaluable for passive thermal control mechanisms. Since the 1970s, solid Phase Change Material (PCM) systems have played an important role in various space missions. In terrestrial applications, the presence of convective flows in the liquid phase helps to solve the problem of PCM low thermal conductivity. However, this approach is not applicable in microgravity. As an alternative strategy, the use of the thermocapillary effect, where a non-uniform temperature induces surface tension gradients driving convective motion, has been proposed as a source of convective heat transport in microgravity PCM devices. The upcoming MarPCM/ISS project aims to explore alternative methods for optimizing heat management [1]. The numerous numerical simulations of the melting phase highlighted enhancing heat transfer efficiency due to Marangoni convection.

In practice, thermal operations typically involve complete solid-liquid-solid conversion cycles. To optimize PCM performance, we explored three different scenarios based on the temperature configuration between sidewalls before and after melting. We identified the most promising case, which involves the timely switching of temperatures between cold and hot walls at a certain moment, preceding full melting or attaining steady state. This specific moment corresponds to the beginning of a decrease in heat extraction efficiency. To implement this concept in practice, we propose rotating the PCM material inside the package while maintaining wall temperatures fixed. The suggested rotation approach has the potential to simplify technological design and facilitate manipulation of the system. Future microgravity experiments could validate the efficacy of this innovative solution.

[1] Porter at al. The “Effect of Marangoni Convection on Heat Transfer in Phase Change Materials” experiment, Acta Astronautica, Volume 210, 2023, Pages 212-223

Orthostatic Intolerance in a Model of Lunar Descent and Ascent and Possible Countermeasures

Jason Lytle[1], Stuart Lee[1], Stephanie Melvin[3], Annelise Miller[2], Cambria Ogrady[2], Matthew Poczatek[3], Sondra Perez[1], Steve Laurie[1], Millennia Young[4], James Pattarini[4], Brandon Macias[4]
[1]KBR, [2]Aegis Aerospace, [3]JES Tech, [4]NASA
2.1 - Life Sciences: Cardiovascular Physiology, Space One, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Jason Robert Lytle is a senior scientist working in the Cardiovascular and Vision Laboratory at NASA Johnson Space Center as a contractor through KBR. Jason received his B.S. in Kinesiology from California Polytechnic State University, SLO in 2015 and his M.S. and PhD from Texas A&M University in Applied Exercise Physiology in 2016 and Cardiovascular Physiology in 2020, respectively. Jason works as an applied cardiovascular physiologist for spaceflight research. He is currently the principal investigator and study lead of numerous studies investigating cardiovascular risk associated with spaceflight. Jason is a current member for American Physiological Society.

Artemis astronauts returning to the Moon will experience head-to-foot (+Gz) accelerations during the descent to and ascent from the lunar surface. Weightlessness induced cardiovascular deconditioning increases the risk of orthostatic intolerance (OI) during +Gz exposures. Given that females are more susceptible to OI when re-exposed to 1-G, the effect of sex on OI and OI countermeasures (CM) must be considered for these missions. Compression garments are used as an OI CM after spaceflight, but data are limited in females. The goals of this study are to to assess the effect of sex on 1) OI and 2) the efficacy of the Orion orthostatic intolerance garment (OIG), over a range of hydrostatic pressure challenges simulating the range of +Gz anticipated during Artemis missions. Thirty-eight (19 females) healthy participants will be recruited to participate. First, baseline OI will be assessed using a 20-minute 80° head-up tilt (HUT) test. Second, we will induce hypovolemia (20mg furosemide) and participants will complete three HUT tests (20-min or until presyncope) simulating 0.50-, 0.75- and 1.00-Gz, (randomized order). Finally, participants will complete the same protocol, while wearing a custom-built OIG. Plasma volume, tilt tolerance time, blood pressure, heart rate and stroke volume will be measured. To date, ten participants (36.8±8.8 years, 178.0±12.4 cm, 75.5±12.2 kg) have completed this study. Two males and four females became presyncopal during the baseline 80° HUT. Infusion of furosemide reduced plasma volume by 11.7 ± 2.0 and 13.0 ± 0.8 % in males and females, respectively. While hypovolemic without the OIG, four males and two females became presyncopal at 80° HUT, and three males and two females became presyncopal at 50° HUT. One male became presyncopal at 30° HUT. Females became presyncopal earlier than males during 0.5, 0.75 and 1-Gz tilts. While hypovolemic with the OIG all, participants tested to date completed the HUT at each angle. Based on the preliminary data, OI occurs in males and females simulated 0.50-, 0.75- and 1.00-Gz without the OIG and females appear to be more susceptible to OI. Further, the OIG appears effective in mitigating OI across the range of G-levels expected during descent to and ascent from the lunar surface.

Oxytocin's Role in Space Team Dynamics and Cognition: A Neuroeconomic Perspective

Miss Kavya Murali Parthasarathy, Dr Vaishnav Prakash, Dr Shaijumon C. S.
6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Dr. Prakash is a Specialty Doctor with the Community Resource Team at NHS,wales, currently preparing for his Internal Medicine Training (IMT). Passionate about the intersection of medical radiology and space medicine, Dr. Prakash is actively engaged in research exploring the role of oxytocin in enhancing team dynamics and cognitive functions in space environments. His interest in radiology drives his innovative approach to neuroeconomic studies, focusing on how imaging technologies can elucidate neurological changes under spaceflight conditions. Dr. Prakash aims to contribute to the development of space medicine by integrating advanced radiological insights into understanding and improving astronaut health and performance.

Abstract:
This paper outlines a proposed theoretical study to explore the application of oxytocin in enhancing cognitive functions and team dynamics in simulated space environments. Utilising a neuroeconomic framework, it investigates how oxytocin inhalation could improve collaborative decision-making, reduce stress, and promote social cohesion—critical components for success and crew well-being during long-duration space missions.
The proposed multi-phased experiment, set in simulated microgravity conditions, will examine the hypothesis that oxytocin can modulate social behaviors, trust, and psychological resilience. Theoretical underpinnings from seminal works, including McEwen (1998) and Sterling and Eyer (1988), support oxytocin's role in restoring homeostasis and adapting to environmental stressors, crucial for maintaining crew health under the rigors of space travel.
Objectives:
1. Examine oxytocin's effects on neural mechanisms of stress and decision-making, drawing on empirical findings by Baumgartner et al. (2008) and Heinrichs et al. (2003).
2. Assess its impacts on economic behaviors and social cohesion using neuroeconomic frameworks from Fehr and Rangel (2011).
3. Evaluate the practicality and safety of oxytocin use in space missions, informed by recent research such as Quintana et al. (2021).
This research intends to extend the application of oxytocin from a neurobiological tool to a practical solution for enhancing interpersonal relations and decision-making capabilities in space missions. Although the findings will not be completed by the conference, the study aims to provide a foundational framework for developing targeted interventions to optimize team performance and mental health in space, further enriched by a wide body of literature including Carter (2014) and De Dreu et al. (2010).
Baumgartner, T., Heinrichs, M., Vonlanthen, A., Fischbacher, U. and Fehr, E., 2008. Oxytocin shapes the neural circuitry of trust and trust adaptation in humans. Neuron, 58(4), pp.639-650.
Carter, C.S., 2014. Oxytocin pathways and the evolution of human behavior. Annual review of psychology, 65, pp.17-39
De Dreu, C.K., Greer, L.L., Handgraaf, M.J., Shalvi, S., Van Kleef, G.A., Baas, M., Ten Velden, F.S., Van Dijk, E. and Feith, S.W., 2010. The neuropeptide oxytocin regulates parochial altruism in intergroup conflict among humans. Science, 328(5984), pp.1408-1411.
Fehr, E. and Rangel, A., 2011. Neuroeconomic foundations of economic choice—recent advances. Journal of Economic Perspectives, 25(4), pp.3-30.
Heinrichs, M., Baumgartner, T., Kirschbaum, C. and Ehlert, U., 2003. Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. Biological psychiatry, 54(12), pp.1389-1398.
McEwen, B.S., 1998. Protective and damaging effects of stress mediators. New England journal of medicine, 338(3), pp.171-179.

P4S: an international research centre re-designing plant, food and bioresource production for Space and Earth

Professor Matthew Gilliham[1]
[1]ARC Centre of Excellence in Plants for Space
ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture Continued..., Space Seven & Eight, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Matthew Giliham is Director of the ARC Centre of Excellence in Plants for Space, a >$AU100M, multi-disciplinary program to develop technologies that allow humans to survive and thrive remote from Earth and improve sustainable production on Earth. His group studies the transport and signalling processes that underpin improvements in crop nutrition stress tolerance, yield, and quality in production systems, specifically salinity, water use, and GABA signalling. He has been a Clarivate/Web of Science Highly Cited Author since 2019. He gained a BSc in Ecology from Lancaster University and a PhD in Plant Physiology from the University of Cambridge, UK.

Plants for Space (P4S) is an Australian headquartered collaborative initiative linking international partners focused on providing plant-based solutions for the sustainable production of nutrition and biomaterials for Space and Earth.

With over 30 partners, we have combined multidisciplinary skillsets in Plant and Food Science, Systems and Process Engineering, Nutrition, Psychology, Law, and Education to explore the fundamental breakthroughs required to develop fit for purpose biomanufactured products.

We are in our foundational year and have funding to at least 2031. Our programs will use molecular-based techniques to deliver food from plants: tailored ‘pick & eat’ crops to supplement dietary needs, and a suite of ‘complete nutrition’ plants to solve the challenge of total caloric replacement. Plant biofactories and bioprocessing technologies developed will be vital to sustain closed environments for extra-terrestrial settlement, and provide new advances for on-Earth manufacturing of pharmaceuticals and plant-based foods. Our aim is to develop engineering solutions and new experimental platforms that have undergone rigorous lifecycle and techno-economic analyses, and explore legal and ethical frameworks to ensure our innovations are fit-for-purpose and readily translatable to meet current timelines. We are also instigating a bold, long-term approach to education and training to inspire more students into STEM subjects and a new generation of Space-fluent researchers.

P4S aims to provides a touchpoint for plant and food focused researchers, to deliver the efficiencies and synergies needed internationally to deliver plant-based technologies that will assist in enabling sustainable long-term deep-space habitation as part of the Artemis moon-to-mars framework. We also recognise the importance and value of translating many of these innovations to Earth to improve the sustainability of food, plant and bioresource production on Earth.

This presentation will outline our programs, initial projects, touchpoints for synergies with the broader research community, and offer opportunities for collaboration and leverage of P4S internationally.

For more information see www.plants4space.com.

Particle Structure Formation in Thermo-vibrational Convection Driven by Differentially Heated Corners Under Microgravity

Mr Balagopal Manayil Santhosh[1], Prof Marcello Lappa[1]
[1]Department of Mechanical and Aerospace Engineering, University Of Strathclyde
5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
2nd year PhD student pursuing research on Particle Accumulation Structures in multiphase flows under microgravity conditions.

Key activities include but not limited to, performing CFD simulations in the James Weir Fluids Laboratory, undertake experiments as needed, deliver Computer Aided Engineering Design Laboratory sessions to year-4 students and carryout quality research in the various fields of interest.

Attended several National and International conferences, published an article in Physics of Fluids (Phys. Fluids, 2023, 35(10), 103316) titled 'On the relationship between solid particle attractors and thermal inhomogeneities in vibrationally-driven fluid-particle systems' and another research item is soon to be published as conference proceedings.

Experiments conducted on board the International Space Station in the framework of the Particle Vibration project (T-PAOLA) confirmed the existence of a new class of solid-particle attractors, which had been previously predicted through numerical and theoretical analysis in 2014. These experiments and the underpinning theory were originally conceived for the case of cubic cavities with a uniformly heated and uniformly cooled wall subjected to vibrations perpendicular to the resulting temperature gradient. In this study, an attempt is made to extend such a framework by considering a new thermal configuration, where the corners of the cavity are differentially heated rather than entire walls. The ensuing novelty being the multiple directions in which local temperature gradients can be oriented (involving directions both parallel or perpendicular to the walls and “diagonal” directions).
In view of the preparation of a future space experiment, the problem is approached numerically, through the solution of the governing (Eulerian) equations for mass, momentum and energy of the fluid phase and the (Lagrangian) equations accounting for the motion of each separate solid (spherical) particle immersed in the fluid. The two sets of equations are properly coupled by allowing the liquid to exert an influence on the solid particles (one-way coupled approach).
Several influential parameters are considered. More specifically, the Prandtl number, particle Stoke’s number and particle-fluid density ratio (ξ) are switched between two values; Pr = 6.11 and 18.69 (of water and ethanol at ambient temperature, respectively), St= $4x10^{-6}$ and $5x10^{-6}$, and ξ= 1.65 and 2 whereas the vibrational Rayleigh number and angular frequency of vibrations are varied through the ranges $10^4 \leq Ra\omega \leq 10^5$ and $10^3 \leq \Omega \leq 10^4$ respectively.
It is shown that in the considered space of parameters, new phenomena show up, which differ from those observed in the space experiments due to the particle structure morphology and the presence of a new category of formations. These do not display an external particle-dense boundary such as that produced in the case for which a unidirectional temperature gradient is considered; rather they resemble those observed in an earlier numerical study pertaining to the same line of inquiry (Phys. Fluids, 2023, 35(10), 103316) where the otherwise uniformly heated and cooled opposing walls were perturbed with a central temperature spot of variable size. Notably, the emerging particle structures in the corner heated cavity generally consist of a central columnar structure with two surrounding sets of dense particle structures, each including four distinct conical surfaces

Patterns and instabilities: understanding Marangoni and buoyant convection in LiBr – H20 binary solution

Dr. Peru Fernandez-Arroiabe Txapartegi[1], Manex Martinez-Agirre[1], M. Mounir Bou-Ali[1], Valentina Shevtsova
[1]Fluid Mechanics Group, Faculty of Engineering, Mondragon University, [2]IKERBASQUE, Basque Foundation for Science
4.3 - Physical Sciences: Marangoni convection, Space Nine, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
I am a researcher in Advanced Modeling of Thermofluidic Processes in the Fluid Mechanics Group of Mondragon University since 2007. After several years working mainly in technology transfer to companies, I obtained the PhD degree in Applied Engineering from the Mondragon University (2021). I have participated in more than 50 R&D projects, both through direct contracts with companies for product development, as well as subsidized ones. After the doctoral thesis, my main activity has been focused on the development of advanced numerical models of heat and mass transfer processes with phase change (absorption, evaporation, batteries,...).

Absorption technology can play a vital role in solving global warming problems. Among all the components of absorption machines, the absorber stands out as the main factor contributing to the reduction in heat and mass transfer. Since the 1990s, the concept of using Marangoni convection to enhance heat and mass transfer on an absorbing interface has become widespread. Marangoni convection is a flow driven by surface-tension gradients, which result from interfacial inhomogeneities in either temperature or solute concentration. To highlight the influence of Marangoni convection in absorption problems, various soluble as well as dissolved in gas-phase surfactants were used in experiments and numerical simulations. The addition of a surfactant to the absorbing interface locally induces solutal convection, further accompanied by thermal and buoyant convection. The overall conclusion of previous research was that the existing research recognized the critical role played by the Marangoni convection, but there is still uncertainty about the physical background.

Solutal Marangoni convection is an intricate phenomenon exhibiting complex and unsteady flow patterns. The interplay of solutal, thermal, and buoyant convection in the presence of absorption adds further complexity.

To clarify the role of Marangoni convection we present the results of comprehensive numerical simulations in presence [1] and absence of gravity. The conventional solution used in an absorber is the binary mixture of LiBr–H2O. Thus, we investigate the convective instability in a LiBr–water binary mixture, triggered by a local perturbation of uniform absorption. The decrease in mass fraction initiates solutal convection, leading to a local temperature change that, in turn, induces thermal Marangoni convection. We explore fluid dynamics, heat and mass transfer, revealing different regimes. The level of absorption and pattern formation and strongly influenced by gravity

Perception of self-motion on the International Space Station

Dr Laurence Harris[1], Dr Björn Jörges, Dr Nils Bury, Dr Meaghan McManus, Ms Ambika Bansal, Dr Robert Allison, Dr Michael Jenkin
[1]York University
5.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

PhD Cambridge University, 1979; lecturer Physiology, Cardiff 1983-1990; Professor Psychology at York University, Toronto 1990-. Director Centre for Vision Research 2011-2020. Chair Psychology Department 2006-2009. York Research Chair in Multisensory Integration (2017-2022). Founding editor Multisensory Research (journal). Over 160 peer reviewed papers including articles in Nature, Science, Vision Research, Journal of Physiology, Experimental Brain Research, Scientific Reports, Nature Microgravity, J. Vision, and Multisensory Research. Research concentrates on how information from multiple senses is combined especially in unusual environments such as in Space. Funded by NSERC, the Canadian Space Agency, and the Canadian Foundation for Innovation.

Gravity affects the perception of self-motion and of size on Earth. Any errors in these perceptions while in space could represent serious risks to astronauts, for example, for locating and moving to an escape hatch. When perception of self-motion is induced using only visual motion, vestibular cues indicate that the body remains stationary which may bias an observer's perception. When lowering the reliability of the vestibular cue by lying down or adapting to microgravity, these biases may decrease, accompanied by a decrease in precision. Previous studies on the ISS using the perception of the shape of a cube have suggested that perceived size may be compressed also.

To assess these perceptions, we used (task 1) a move-to-target task and (task 2) a size comparison task in virtual reality. For task 1, astronauts (6 female, 6 male) and Earth-based controls (10 female, 10 male) were shown a simulated target. After the target disappeared, self-motion was induced by visual motion. Participants indicated when they had arrived at the target's previously seen location. For task 2, they compared the height of a virtual square simulated at three distances with the length of a physical rod held in their hands. Astronauts completed these tasks on Earth (supine and upright) prior to space travel, twice onboard the International Space Station (ISS) (within 3-6 days of arrival, after ~85 days in space), and after landing (within 3-6 days of return and ~85 days later). Controls completed the experiment on Earth using a similar regime.

While variability was similar across all conditions, astronauts displayed higher gains (target distance/perceived travel distance) when supine than when upright in terrestrial sessions. No differences could be detected between astronauts' performance on Earth and in space or between the controls' sessions. We found no immediate effect of microgravity exposure on perceived object height. However, astronauts robustly underestimated the height of the target relative to the haptic reference and these estimates were significantly smaller after 60 days after return to Earth. No differences were observed in the precision of astronauts' judgements.

We conclude that no countermeasures are required to mitigate acute effects of microgravity exposure on self-motion or object height perception. Despite adapting to a floating mode of travel in the ISS, astronauts' performance in judging self-motion distance appears largely unaffected by exposure to microgravity.
However, space travelers should be warned about late-emerging and potentially long-lasting changes in these perceptual skills.

Plant posture in space: proprioception as a new player in gravitational biology

Dr Melanie Decourteix[1], Dr Alexandre Caulus[1], Jérôme Franchel[1], Dr Félix Hartmann[1], Kinza Khan[1], Dr Nathalie Leblanc-Fournier[1], Pr Valérie Legué[1], Stéphane Ploquin[1], Dr Eric Badel[1], Dr Nicole Brunel-Michac[1], Dr Bruno Moulia[1]
[1]1Université Clermont Auvergne, INRAE, PIAF
1.4 - Life Sciences: Plant Biology adaption and response to space, Space Seven & Eight, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
After a PhD in Plant Genetics and Physiology on the role of sugar in winter biology of walnut tree, I have worked as a post-doctoral fellow on tree integrative physiology. Since 2012, I have been a lecturer at the PIAF laboratory. My scientific interests are now on the response of wood formation to mechanical stimuli. In recent years, I have focused on the effect of curvature (transient or long-term) on the anatomical features of wood. These studies led me to work on gravitropism and autotropism with the support of CNES, and to get naturally interested in space biology.

Introduction:
To grow straight and upright, plants need to control actively their posture through tropic movements. Gravitropism has long been considered as a major feature of this postural control. However, mathematical modeling approaches demonstrated that the dynamics of the tropic movement and the final shape of the plants organs are actually the result of a conflicting control by (1) graviperception, that tends to curve the plants organ toward the vertical, and (2) proprioception (the sensing by the plant of its local curvatures), that tends to counteract this curving-up movement and straighten the organ [1, 2, 3, 4, 5].
Methods:
Here, we will describe original experimental devices developed in our laboratory, which we use in combination with image analysis and model-associated phenotyping [6].
Results:
They allow us to (1) quantify graviperceptive and proprioceptive sensitivities, and (2) identify as yet uncharacterized proprioceptive structures and cellular motors driving straightening movements. By detailing the example of the gravitropic response of Arabidopsis floral stem – which involves differential growth- and of poplar stem – which involves the formation of tension wood - to tilting we will show how such approaches can lead to new and original knowledge in plant biology. Moreover, we will explain how such approaches can benefit from space experiments.

Point of care ultrasound (POCUS) beyond lower earth orbit and space exploration

Dr Lucas Rehnberg[1,2,3], Dr Anton Ahlbäck[4], Prof Thais Russomano[2], Dr Matthieu Komorowski[5]
[1]University Hospital Southampton, [2]InnovaSpace, [3]Centre for Altitude, Space and Extreme Environment Medicine (CASE Medicine), [4]Department of Anaesthesia and Intensive Care, Örebro University Hospital, [5]Department of Surgery and Cancer, Faculty of Medicine, Imperial College London
2.1 - Life Sciences: Cardiovascular Physiology, Space One, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
I am an intensive care doctor working at University Hospital Southampton with an special interest in point of care ultrasound (POCUS). I have also been working in the area of space medicine for over 10 years with an interest in critical care and resuscitation in microgravity.

Ultrasound (US) as an imaging modality has expanded rapidly in recent decades finding itself in the hands clinicians for point-of-care ultrasound (POCUS). Proven beneficial in isolated and austere environments including micogravity since 1982. Onboard the International space station (ISS), US has solidified its place as the imaging modality of choice being versatile, small volume and low power, as well as non-invasive with non-ionising radiation.

As we look to travel beyond lower earth orbit (LEO) to the Moon and Mars we need to change the paradigm of how we practice medicine, including the use of newer technologies and the training of crew members.

US has been used in space for several decades now, albeit exclusively in LEO and likely will be the diagnostic tool of choice for exploration missions. Currently, POCUS training in microgravity is based on a 'just-in-time' training model with real time remote guidance from experts, with some basic training for crew medical officers. Additional challenges include delayed communication, limited resources and no immediate evacuation for definitive care. This will force crews to be more autonomous during medical emergencies.

POCUS has good diagnostic accuracy for a range of pathologies in different organ systems, including cardiac, pulmonary, vascular, and intra-abdominal. US has been shown to be superior to X-ray in detection of life-threatening pathologies, such as pneumothorax, pulmonary oedema, tamponade and pleural effusions, and comparable to computed tomography.

Integrating artificial intelligence (AI) systems to support image capture and interpretation can help bridge gaps in training. AI shows promise in healthcare, but US is highly operator dependent with image variability, both in +1Gz and then there is the complexity of body fluid distribution in microgravity.

Our review continues the discussion into research for enhanced medical training in POCUS. Research is needed to determine optimal training duration with POCUS to be automonous, also how to maintain skill retention. This can be done using ground-based analogues and ISS. Can also learn from terrestrial accreditation pathways for POCUS. We need research to assess the practicality and usefulness of AI in aiding image acquisition and diagnostic interpretation, potentially needing large microgravity data sets.

As the space sector grows, integrating POCUS technology and medical training will be essential. There will be debate amongst space experts on the optimal training. But a combination of increased hours of medical and POCUS training combined with enhanced hardware and AI will equip crews for autonomous medical capabilities for exploration missions.

Prisoners of Gravity: Gravity as a Hyper-Prior for Human Behaviour

Prof Elisa Raffaella Ferre[1]
[1]Birkbeck University Of London

6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:

Elisa Raffaella Ferre is a Professor of Cognitive Neuroscience at Birkbeck University of London (UK) where she established the Vestibular Neuroscience Lab. Her research combines experimental psychology, cognitive neuroscience, neuroimaging, vestibular physiology and space science methods to understand how gravity shapes behaviour and, in a more forward-looking way, how non-terrestrial gravities may impact cognition and performance during spaceflight. She serves as the elected Secretary for ELGRA.

Since the beginning of time, all living organisms have evolved under a terrestrial gravitational acceleration of 9.81 m/s2. It's hard to imagine a more fundamental and ubiquitous aspect of life on Earth than gravity. When the head moves with respect to gravity, the vestibular otoliths shift with the direction of gravitational acceleration, moving the hair cells receptors and signalling to the brain the magnitude and direction of gravity. Thus, the pull of gravity generates a constant sensory flow from early foetal life until death. But what can we say about the first human to be born in a non-terrestrial gravitational field? Little is known about how the information from the vestibular otoliths is coded by the brain to construct a model of Earth gravity, and whether this internalised model is innate and fixed to terrestrial gravity, or whether it can adjust to other gravitational environments, such as weightlessness or partial gravity on the Moon or Mars. Most recent neurocognitive models emphasize the predictability of sensory signals that make the organism feel anchored to the physical world. This construct invokes the idea of minimizing prediction error. A prediction error reflects the mismatch between a prior prediction or expectation and the actual sensory signals. On Earth gravity is always there and may play a primary role in minimizing prediction errors by providing a strong prior reference. Here I suggest that this "gravity hyper prior" is optimal in the terrestrial environment and permits regulation of multiple aspects of cognition by reducing unpredictability, and situating any behaviour within a general repertoire. I will share our research findings that endorse the gravity hyper prior in basic sensorimotor functions (Gallagher et al., 2021) and cognitive representations (Pavlidou et al., 2022). Across various models, from animals to humans, I will explore evidence supporting the idea that we possess innate predispositions towards a gravity hyper prior (Bliss et al., 2023). Furthermore, our research indicates that this gravity hyper prior can dynamically adjust when exposed to environments with non-terrestrial gravity.

Quantum Biology of Plant Magnetoreception: growing plants outside the Geomagnetic Field

Professor Massimo Maffei[1]
[1]University of Turin
ISLSWG Plants in Space Workshop - Theme 1: Plant Adaptation and Response to Space Environmental Stress, Space Seven & Eight, September 4, 2024, 3:00 PM - 4:00 PM

Biography:
Massimo Maffei is full professor of Plant Physiology at the Dept. Life Sciences & Systems Biology in the University of Turin. He has been Director of the Doctoral School of Nature Sciences and Innovative Technologies, Coordinator of the PhD in Pharmaceutical and Biomolecular Sciences, Deputy Director for Research of the Department of Life Sciences and Systems Biology, Vice Dean of the Faculty of Mathematical, Physical and Natural Sciences, Director of the Department of Plant Biology and Coordinator of the Ministerial Center of Excellence for Plant and Microbial Biosensing. The scientific activity focuses on Plant quantum biology responses to environmental stress.

The quantum biology of plant magnetoreception delves into the still unknown ways in which plants perceive and respond to the Earth's magnetic field at the quantum level. Plant magnetoreception has long captivated scientists, challenging traditional notions of plant growth and development. How do plants respond to Earth's magnetic fields? What role does quantum biology play? These questions lead us to explore the intricate interaction between quantum mechanics and the life processes of plants.
The urgency to unravel the quantum biology of plant magnetoreception is underscored by several factors. First, advancements in quantum technology and experimental techniques provide unprecedented tools to peer into the quantum realm of biological systems. Second, our growing awareness of the interconnectedness of ecosystems highlights the pivotal role of plants in sustaining life on Earth. Third, as we contemplate space exploration and the potential for extraterrestrial agriculture, understanding how plants sense and respond to variability in external magnetic fields becomes crucial. In sum, the study of plant magnetoreception has tangible implications both for advancing basic research as well as for agricultural practices, in mitigating environmental stressors, enhancing resilience in the face of climate change, and ultimately in transfer to extraterrestrial environments.
In this presentation I will briefly summarize the state of the art of quantum biology with particular reference to quantum coherence in photosynthesis, magnetic sensing mechanisms, the interplay between cryptochromes and iron-sulfur complex assembly, models and simulations as well as ongoing interdisciplinary studies.
I will also try to answer to the following key questions:
- what is(are) the primary plant magnetosensor(s)?
- how many different magnetic field sensing mechanisms are there in plants? What for?
- what are the primary magnetosensing mechanisms?
- is there an ecological significance in plant magnetoreception?

I will then focus of the next generation experiments involving dark/light-dependent reaction, the combined study of microgravity and hypo/hypermagnetic conditions and the role of reactive oxygen species in plant magnetoreception.
I will also present recent results on lettuce RNASeq analysis under combined microgravity (with an RPM) and hypomagnetic field (with a triaxial Helmholtz coils system) conditions.
As we stand at the nexus of quantum biology, plant physiology, and ecological interconnectedness, delving into this subject promises not only to deepen our understanding of the natural world but also will inspire innovative solutions for sustainable coexistence with plants on Earth and beyond.

Recommendations from The ESA Space Omics Topical Team for Plant Space Biology development in Europe

Dr Raul Herranz[1]
[1]CIB Margarita Salas (CSIC)

ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics, Space Seven & Eight, September 5, 2024, 12:00 PM - 12:55 PM

Biography:

PhD in Biochemistry including his first spaceflight experiments as PhD student (Drosophila GENE/AGEING experiments in the Spanish Soyuz Cervantes Mission, 2003), Raul Herranz worked as posDoc in several ESA ground simulation labs, mainly at the ESTEC (Head Dr. van Loon, 2008) on LDC biological validation. Then, he joined the µG lab in Spain (CSIC, Head Dr. Medina) as transcriptomics expert, focused on suboptimal spaceflight environments. He was the coordinator of several ESA and United Nations ground simulation projects, Co-I in the ESA/NASA SEEDLING GROWTH exp and invited as expert for UN, ESA and NASA working groups.

Introduction:

The European life science community in space research has been always limited in numbers but fully devoted to microgravity research leading the international scenario in particular organisms. In the last fifteen years, the financial crisis, together with the emergence of private partners for NASA, made ESA related researchers vulnerable to the lack of manned mission launch capabilities. This has particularly affected the Space Omics research in which ESA funded activities have been reduced. European PIs have been forced to partner up with international colleagues to keep the pace in their research goals, in some cases with outstanding results (Herranz et al., 2019; Vandenbrink et al., 2019).

Methods:

Our Space Omics Topical Team was created as an offshoot of a successful NASA initiative called Genelab (Ray et al., 2019) repository for Omics data as part of the Analysis Working Groups (AWG's). On the Genelab AWG symposium in 2019 they organized bilateral talks between each other to coordinate actions on our side of the Atlantic Ocean (Deane et al., 2022). Later we integrated our efforts with those of the International Standards for Space Omics Processing (ISSOP), a consortium of scientists who develop, share, and encourage sample processing standardization and metadata normalization of spaceflight "omics" experiments (Rutter et al., 2020).

Results:

Discovering the adaptation mechanisms of plants to the space environment is essential for supporting human space exploration. Transcriptomic analyses allow the identification of adaptation response pathways by detecting changes in gene
expression at the global genome level caused by the main factors of the space environment, namely altered gravity and cosmic radiation. A number of transcriptomic studies carried out from plants grown in spaceflights and in different ground-based microgravity simulators is shown (Figure 1). Despite differences in plant growth conditions, these studies have shown that cell wall remodeling, oxidative stress, defense response, and photosynthesis are common altered processes in plants grown under spaceflight conditions. European scientists have significantly contributed to the acquisition of this knowledge, e.g., by showing the role of red light in the adaptation response of plants (EMCS experiments) and the mechanisms of cellular response and adaptation mostly affecting cell cycle regulation, using cell cultures in microgravity simulators (Kamal et al., 2019a; Kamal et al., 2019b).

Conclusions:

Here we will disclose our final recommendations (Manzano et al., 2023) with a particular emphasis in the Plant relates experimentation including the development of payloads to replace EMCS.

Role of composition-dependent cross-diffusion on emergence of instabilities in ternary mixtures

Prof. Valentina Shevtsova[1,2], Dr. Berin Seta[3], Prof Mounir M. Bou-ALi[1]
[1]Mondragon University, [2]Basque Foundation for Science, [3]Technical University of Denmark
1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Valentina Shevtsova began the study of microgravity related subjects working in Bremen University. Her career has developed at Brussels University, Belgium, where she worked as a head of the research group for over twenty years. In 2020, she won a prestigious grant of Ikerbasque, and she works as a Research Professor at Mondragon University, Spain. Her research interests includes physics of fluid interfaces, vibrational phenomena in fluids, transport with diffusion & Soret effect, and others. Dr. Shevtsova served as the president of ELGRA (2011-2015). Since 2015, she has been the Editor-in-Chief of the Microgravity Science and Technology journal.

In ternary mixtures, three species interact through cross-diffusion, where each species is transported not only by its own concentration gradient but also by the gradient of the other two species. The focus of our research is on the toluene-methanol-cyclohexane ternary mixture, studied both on-board the ISS (DCMIX2 mixture) and in ground laboratories. The integral studies reveal that depending on composition, the cross-diffusion coefficients can be as large as the main ones. This mixture also exhibits the Soret effect and the studies showed that the Soret coefficients of the denser components are negative in a wide range of compositions that result in the hydrodynamic instability in non-isothermal gravity field. Our attention lies on the state point, which is located on the boarder of stability and its surroundings. Such point is characterized by nearly zero the net separation ratio, while individual separation ratios are typical.

We explore the behaviour of the system under three different conditions. The systems with thermal gradient when the Soret effect comes into play: a thermogravitational column (TGC) and a Soret cell. In isothermal conditions, we observe the diffusion of two layers of mixture with slightly varying compositions. In each of these cases, the emerging instability exhibits intriguingly distinct behaviour.

In TGC small variations of cross-diffusion lead to emergence distinctive patterns, ranging from oscillatory to monotonically standing Turing-like patterns [1, 2]. In contrast, the Soret cell shows the prevailing effect of the small net separation ratio over cross-diffusion. The behaviour of the system depends on initial conditions or external perturbations, revealing meta–stable behaviour. In the case of minor perturbations, the mixture remains motionless, facilitating the measurement of transport coefficients, while strong perturbations lead to the development of convective flow [3]. Under isothermal conditions, the composition-dependent cross-diffusion may induce the simultaneous development of double diffusion [4] (DD) and diffusive-layer convection (DLC) on two different sides of an initial contact line

References:
[1] B. Seta, A. Errarte, I. I. Ryzhkov, M. M. Bou-Ali, V. Shevtsova, Phys. Fluids 35 (2) (2023) 021702.
[2] B. Seta, A. Errarte, A. Mialdun, I. I. Ryzhkov, M. M. Bou-Ali, , V. Shevtsova, Phys. Chem. Chem. Phys. 25 (2023) 15715–15728.
[3] S. Prokopev, T. Lyubimova, A. Mialdun, V. Shevtsova,Phys. Chem. Chem.Phys. 23 (2021) 8466–8477.
[4] B. Šeta, A. Errarte, D. Dubert, Jo. Gavaldà, M. M. Bou-Ali, X. Ruiz, Acta Astronautica, 160, 2019, 442-450

Rooted in space: advancements and open questions in plant gravity perception and early gravitropic signaling

Prof. Dr. Maik Böhmer[1]
[1]Goethe University Frankfurt

ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics, Space Seven & Eight, September 5, 2024, 12:00 PM - 12:55 PM

Biography:
Maik Böhmer is a Professor of Plant Physiology at Goethe University Frankfurt, Germany. He specializes in plant environment interactions and gravitropism. He completed his degree in biology at the University of Marburg and his Ph.D. at the Max-Planck Institute for Max Planck Institute for Plant Breeding Research in Cologne. Before joining Frankfurt University, he held positions at UCSD in San Diego and the University of Münster. He served as the Principal Investigator in two sounding rocket campaigns and five parabolic flight campaigns. Currently, he is leading the preparations for an ISS campaign that will use the FLUMIAS-SIM microscope.

Insights from plant research in space and ground-based facilities advance our understanding of fundamental biological processes and inform future space exploration and colonization efforts. This presentation covers recent advancements and lingering inquiries in plant gravitropism research in altered gravity environments.
Gravitropism is the ability of plants to sense and respond to gravitational forces, which is fundamental to their growth and development. However, its precise molecular mechanisms and the proteins involved are still unclear. International Space Station (ISS) experiments have provided new insights into plant gravity perception. Furthermore, studies involving drop towers, parabolic flights and sounding rocket campaigns have signified the role of short-term microgravity exposures on plant gravitropic responses, providing valuable data for future long-duration space missions.
Moreover, emerging technologies such as advanced imaging techniques, a wide variety of omics approaches and high-throughput phenotyping platforms promise to unveil novel insights into the intricacies of plant gravitropism in space and on the ground. Leveraging microgravity platforms such as the FLUMIAS microscopes aboard the ISS or on TEXUS rockets and optogenetic systems like CaMPARI enable real-time visualization of cellular processes, facilitating the exploration of gravitropic signaling pathways with unprecedented detail and throughput.
Despite recent advancements, several questions persist regarding the molecular mechanisms underlying plant gravitropism. Key areas of investigation include deciphering how altered gravity affects amyloplast dynamics, calcium signaling, and gene expression patterns in plant cells. Additionally, understanding how plants adapt long-term growth strategies in response to varying gravitational conditions remains a critical challenge. Continued interdisciplinary collaborations and innovative research endeavors are essential to address these open questions and pave the way for the successful cultivation of plants in extraterrestrial environments.

Rotations and translations in cooling granular gases of spheres

Prof. Dr. Rer. Nat. Kirsten Harth[1,2], Dr. Mahdieh Mohammadi[1], Dr. rer. nat. Torsten Trittel[1,2], Dr. rer. nat. Dmitry Puzyrev[2], Prof. Dr. Raul Cruz Hidalgo[3], Prof. Dr. rer. nat. habil. Ralf Stannarius[1,2]
[1]Department of Engineering, Brandenburg University of Applied Sciences, [2]Department of Microgravity and Translational Regenerative Medicine and MARS, Medical Faculty, Otto von Guericke University, [3]Department of Physics and Applied Mathematics, University of Navarra
4.2 - Physical Sciences: Granular Media and Emulsions, Space Two, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
K. Harth studied physics and mathematics at the University of Magdeburg, and obtained a Dr. rer. nat. in the Institute of Physics, there. After a Postdoc at the University of Twente, she returend to Magdeburg with an own research project. Since 2022, she is Professor of Applied Mathematics at the Brandenburg University of Applied Sciences. Her research interests lie in the fields of granular materials, fluid mechanics and pattern formation. She has led and been involved in several microgravity experiments, mainly on granular gases and hydrodynamics in thin free-standing membrandes since 2009.

Introduction:
Intuitively, granular gases are rather simple multi-particle systems, where grains only interact by dissipative collisions. However, this subtle difference to atomic gases causes large physical effects, many of them predicted in theory or simulation. One of them is the continuous loss of energy, when particles in an initially excited state are left without external energy supply, the “granular cooling”, first described by P. Haff [1]. Experimental confirmation of its scaling law followed recently for rods [2,3], translational motion of spheres [4] and ellipsoids [5], with significant deviations from the predicted time scales. A second striking effect is the absence of equipartition of kinetic energy between translational and rotational degrees of motion, experimentally proven for rods [2], and between different components in a granular gas mixture [3]. The detection of rotations of spheres is more complicated and requires, e.g., patterning of the particles in optical measurements, see Fig. 1. We present 3D experiments accompanied by simulations, both analyzing the rotations and translations during granular cooling.

Methods:
We analyze the statistics of velocities, rotational velocities, positions and energy in a granular gas of spheres. We performed experiments with centimeter-sized elastic, rough rubber balls in the ZARM drop tower. The granular gas is first excited by vibrating walls of the container, and consecutively, the excitation is switched off and the actual measurement period starts. Rotations of the spheres can be tracked using specific coloring and patterns. We employ custom AI-aided software for particle detection, adapted from [6]. DEM simulations of granular gases of rough spheres are performed on GPUs.

Results:
As expected, the distributions of the velocity components at the beginning of, but also during later stages of cooling are non-Gaussian with fast grains overrepresented. The initial excess in energy in excitation direction decays after few collisions. Thereafter, the granular cooling follows Haff’s predictions. Angular velocities possess a non-Maxwell distribution. Equipartition of energy is violated. In simulations, we observe similar behavior. There, however, we can compare the cooling from a truly homogeneous random initial state to a mimicked experiment.

Conclusion:
Granular gases in 3D, even for simple particle types, are still an under-researched field of experiments. AI aided solutions are important for data evaluation. Open questions in particular related to experiments remain, e.g., regarding realistic contact models or the time scales of cooling. We present a first experimental / simulation study considering all degrees of freedom in 3D granular gases of spheres.

Sloshing mitigation in microgravity using baffles and thermocapillary flow

Dr. Pablo Salgado Sánchez[1], Mr. Dan Gligor[1], Mr. Carlos Peromingo[1], Mr. Pedro Marques[2,3], Dr. Miguel Mendez[2], Prof. Jeff Porter[1], Prof. Ignacio Tinao[1]

[1]E-USOC, Universidad Politécnica de Madrid, [2]von Karman Institute for Fluid Dynamics, [3]Université Libre de Bruxelles

5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

Pablo Salgado Sánchez is associate professor at E.T.S.I. Aeronáutica y del Espacio. He investigates phenomena associated with fluid and phase-changing systems subjected to vibrations and thermal excitation in microgravity, combining experiments and simulations. Since 2016, he has been a member of the Spanish Users Support and Operations Centre (E-USOC) as an ISS payload operator certified by ESA and NASA.

Introduction:

The behavior of liquids during transport and use is a subject of fundamental interest in numerous applications. Industrial and energy networks require natural gas transport in ships, for example, while the space industry must manage propellant in spacecraft, launchers, and rockets. One of the primary concerns in such applications is liquid sloshing, a type of motion that can appear in any system with a partially filled container as a result of transient or low-frequency excitations. Here, we summarize recent microgravity results on sloshing mitigation in microgravity, including the use of fixed baffles (Peromingo et al., 2023a), thermocapillary flows (Peromingo et al., 2023b) and a novel type of moving spring-mass baffles (Gligor et al., 2024).

Method:

We consider an open rectangular container, holding L x H = 30 x 15 mm² of liquid in weightless conditions. The container is subjected to a pulse-like perturbation that excites sloshing. A fixed baffle, or a movable one attached by a spring, is placed within the liquid bulk to reduce sloshing. The motion of the free surface is tracked using standard level-set moving mesh schemes. Results are obtained for a liquid with properties similar to 5 cSt silicone oil and with a static contact angle of 70°. The dependence of thermo-physical properties on temperature is neglected except for surface tension, which is the driving mechanism of thermocapillary flow. The problem is simplified by considering only 2D dynamics since previous 2D models of interfacial dynamics showed excellent agreement with microgravity experiments on immiscible liquids (Salgado Sánchez et al., 2019).

Results:

A summary of the obtained results is provided in the figure, which illustrates different baffle designs of increasing complexity (left panel) and their associated performance (right panel). Square markers denote the sloshing frequency and decay time relative to a no-baffle container and the associated performance envelope is shown (in selected cases) when combined with thermocapillary control (solid lines and circular markers) and when converted into spring-mass elements (shaded regions). Overall, the results indicate a potential reduction in decay time by up to 90%.

Conclusions:

Several sloshing mitigation strategies are explored. The effectiveness of fixed baffles is evident, as is the trade-off between design simplicity and performance. Combining these with thermocapillary control or substituting for a spring-mass baffle system allows an additional 50-60% performance improvement, for a total sloshing reduction of approximately 90%.

Soret and thermodiffusion coefficients of C60|THN|Tol ternary nanofluid mixture: Evaluation of the DCMIX4 experiment

Dr. Ane Errarte[1], Daniel Sommermann[2], Dr. Marcel Schraml[2], Dr. Aliaksandr Mialdun[3], Prof. Dr. Valentina Shevtsova[1,4], Prof. Dr. Werner Köhler[2], Prof. Dr. M. Mounir Bou-Ali[1]
[1]Mondragon Unibertsitatea (Mondragon Goi Eskola Politeknikoa), [2]Physikalisches Institut, Universität Bayreuth, [3]Université libre de Bruxelles, [4]Ikerbasque, Basque Foundation for Science
1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
PhD in applied engineering (Mondragon Unibertsitatea). She joined the fluid mechanics group in 2014, where she has carried out her research activity studying the transport mechanisms (thermodiffusion phenomenon, Soret effect and Marangoni effect) of liquid mixtures by means of laboratory techniques and numerical simulation. It is worth mentioning her participation in the DCMIX-4 project of the European Space Agency, where transport properties of multicomponent mixtures under microgravity conditions were determined. She has registered a utility model and has published 11 papers in indexed scientific journals (h-6 index). She is currently a lecturer in thermodynamics and fluid mechanics at Mondragon Unibertsitatea.

Convective instabilities on Earth hinder the study of the phenomenon of thermodiffusion in multicomponent liquid mixtures. Orbital laboratories, on the contrary, provide an ideal environment for the measurements, due to the absence of the destabilizing buoyancy driven convection. Several years ago, the DCMIX project was promoted, sponsored by the European Space Agency. The project, completed in four campaigns, aimed to establish a reliable set of guaranteed convection free reference data for the validation and calibration of present and future ground-based measurements and prediction models [1].
Experiments on the ternary system C60 (0.0007 gg-1) | THN (0.6000 gg-1) | Tol (0.3993 gg-1) flown during the DCMIX4 microgravity campaign are presented [2]. The fullerene-based ternary mixture has been investigated by means of the Selectable Optical Diagnostics Instrument at four mean temperatures of 20 ºC, 25 ºC, 30 ºC and 35 ºC. As Soret experiments were developed in microgravity, the mixture was tested in three terrestrial laboratories. The Optical Beam Defection (Universität Bayreuth) and the Optical Digital Interferometry (Université libre de Bruxelles) were used for direct determination of the Soret coefficient of each component, while thermodiffusion coefficients of each constituent were measured by the Thermogravitational Column Technique (Mondragon Unibertsitatea).
Reasonable agreement was obtained between convective and non-convective techniques on the ground, together with those analysed under microgravity conditions in the ISS, where thermal dependency of both Soret and thermodiffusion coefficients is observed. All experiments revealed that the mixture behaves as a quasi-binary system, where the Soret and thermodiffusion coefficients of the solute are small and the ones corresponding to the solvents are consistent with the associated binary subsystem THN (0.60 gg-1) | Tol (0.40 gg-1) [3]. Thus, experiments performed in SODI allowed validating the experiments on nanofluids in earth laboratories.

Space Crop Production Gaps and Challenges

Dr. Gioia Massa[1], Dr. Raymond Wheeler[1], Dr. Matthew Mickens[1], Mr. Trent Smith[1]
[1]NASA Kennedy Space Center
ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space, Space Seven & Eight, September 5, 2024, 9:00 AM - 10:40 AM

Biography:
Gioia Massa is a NASA scientist at Kennedy Space Center working on space crop production for the International Space Station and future exploration endeavors. She led the science team for the Veggie validation and she heads interdisciplinary teams to study nutrition, flavor, and microbial composition of space-grown crops. She has a BS in Plant Science from Cornell, a PhD in Plant Biology from Penn State, and conducted postdoctoral research at Purdue University and Kennedy Space Center. She has worked in the areas of plant space biology and bioregenerative life support.

As astronauts venture farther from Earth, and stay for longer periods, the space food system will increase in importance. Crop production can supplement a pre-packaged space diet to provide nutrition and dietary variety for space crews. In future missions, bioregenerative approaches may be used to generate a larger percentage of the diet, as well as help to reduce life support system burdens and resupply from Earth. Plants may also provide behavioral health benefits to crew members living in the isolated, confined environment of a space habitat. A number of unique challenges exist for growth of plants in microgravity and on other reduced gravity surfaces like the moon and Mars. Testing plant growth inside the Veggie and Advanced Plant Habitat (APH) chambers on the International Space Station is allowing us to understand the impacts of gravity and spaceflight on crop growth, nutritional content, acceptability, and the importance of plants to astronauts living and working away from Earth. We are also gaining a better understanding of food safety concerns and the behavior of space plant microbiomes and plant pathogens, but major gaps in knowledge remain. As we move from research towards operational space crop production to enable exploration, there are numerous gaps in technology, knowledge, and practice related to space crop growth that must be addressed. Research and development in key focus areas such as effective water and nutrient delivery at variable gravity levels, autonomous plant health monitoring, growth system cleaning and disinfection, and selection of ideal space crops are needed to fill these gaps. Breeding or engineering custom space crops may impact areas including plant growth and development, plant physiology, produce nutrition, organoleptic acceptability, and post-harvest characteristics, and these may further enable space crop production scenarios. Space crop challenges are multifaceted and require diverse interdisciplinary teams working together to develop effective solutions. Solving these requires an array of skill sets from across the biological and physical sciences, engineering, and human social sciences. Solutions to help ensure food security off-Earth may also translate to more sustainable terrestrial crop production approaches, and regular dialog between industry, academia, and government organizations working in related fields benefit all. Additional help can come from engagement with student researchers at various levels through courses, participatory science projects, and open science activities which can provide useful data. Global coordination and integration between space agencies and partners will be essential.

Spatial Orientation Perception Following a Centrifugation-Induced Gravity Transition

Ms. Caroline Austin[1], Dr. Torin Clark[1]
[1]University Of Colorado Boulder
5.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Caroline Austin received a B.S. in Aerospace Engineering Mechanics from the University of Alabama in 2022. She is currently pursuing a Ph.D. in Aerospace Engineering Sciences with a focus in Bioastronautics at the University of Colorado, Boulder. Caroline is also a Pathways intern at NASA Glenn Research Center. Her research has focused on spatial orientation perception during gravity transition analogs, developing sensorimotor countermeasures and training tools, and quantifying sensorimotor risk.

Introduction and Background:
Astronauts experience spatial disorientation during and after gravity transitions. Such spatial disorientation poses a risk for mission critical tasks such as emergency egress and space craft manual control. With upcoming lunar missions, astronauts will be exposed to microgravity before transitioning to lunar gravity and may be required to take control of spacecraft landings (indeed all Apollo landings utilized manual control despite automated capabilities [1]). Thus, we need to better understand spatial disorientation during crewed lunar landing and develop countermeasures to mitigate the risk. A common analog used to study sensorimotor impairment for gravity transitions is Sickness Induced by Centrifugation (SIC), where participants are exposed to 2G through the chest (2Gx) for an hour. This analog has been used to study motion sickness, vestibular reflexes, and functional performance [2,3,4], but changes to spatial orientation perception following SIC have not yet been quantified. A detailed understanding of perceptual changes following SIC will allow for better predictions of spatial orientation, countermeasure development, and extensibility of knowledge to gravity transitions to and from hypo-gravity.
Experimental Methods:
This experiment utilized CU Boulder's centrifuge to produce the SIC paradigm (2Gx for 1hr) and the Tilt Translation Sled (TTS) to provide roll tilts up to +/- 20 degrees. Participants completed two counterbalanced testing sessions at least a week apart. In one testing session they were exposed to the 2Gx SIC paradigm for an hour and in the other where they were exposed to 1Gx by lying supine for an hour. Following each gravitational exposure participants were seated in the TTS in the dark with their heads restrained and exposed to pseudorandom sum of sines roll tilt profiles. While being tilted, participants reported their orientation perception via a subject haptic horizontal (SHH) task. Here participants attempted to keep a bar connected to a potentiometer level with their perceived gravitational horizontal. SHH reports were compared following the 1Gx and 2Gx exposures.
Results:
Initial pilot testing suggests that there is substantial variability in perceptual reporting between participants regardless of the gravitational exposure, but that participants are less certain of their reports following the gravity transition. Through further testing we expect this to translate to decreased accuracy in perceptual reports.
Conclusion:
Gravity transitions, whether between hypo or hyper gravity, induce changes in orientation perception that can result in spatial disorientation. Perceptual changes measured during this experiment improve our understanding of spatial disorientation development following gravity transitions.

Strain-Dependent Microgravity's Effect on Mouse Kidney Genes Expression

MSc Rebecca Finch[1], Dr Geraldine Vitry[2], Dr Keith Siew[3], Prof Stephen Walsh[3], Dr Afshin Behesti[4], Prof Gary Hardiman[5], Dr Willian da Silveira[1]

[1]Staffordshire University, [2]International Space University, [3]University College London, [4]Blue Marble Space Institute of Science, [5]Queen's University Belfast

1.1 - Life Sciences: Cell Biology, Genetics and omics, Space One, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Dr. da Silveira is currently a Lecturer in Molecular Genetics and Genomics at the Staffordshire University and adjunct lecturer at the International Space University. He was also co-head of the Space Omics Topical Team funded by ESA.

He was the first-author of the November 2020 cover of CELL that featured the article "Comprehensive Multi-omics Analysis Reveals Mitochondrial Stress as a Central Biological Hub for Spaceflight Impact".

His research is in the field of Network Biology applied to Health Ageing and Spaceflight with the objective of developing Personalized Medicine treatments for the consequences of ageing and space travel on human health.

TTo explore new worlds we must ensure humans can survive and thrive in the space environment. Incidence of kidney stones in astronauts is a major risk factor associated with long-term missions, caused by increased blood calcium levels due to bone demineralisation triggered by microgravity and space radiation. Transcriptomic changes have been observed in other tissues during spaceflight, including the kidney. We analysed kidney transcriptome patterns in two different strains of mice flown on the International Space Station, C57BL/6J and BALB/c. Transcriptomic data related to kidney tissue obtained in the missions Rodent Research-1 (RR-1), Rodent Research-3 (RR-3), and Rodent Research-7 (RR-7) were obtained from NASA's GeneLab Platform from dataset identifiers OSDR-102, OSDR-163 and OSDR-253. R Studio and the package DESeq2 were used to perform differential gene expression analysis comparing Flight to Ground Control. Overrepresentation analysis was done using WebGestalt and Gene set enrichment analysis was performed using the program GSEA. The set of non-synonymous genetic differences between C57BL/6J and BALB/c was taken from Timmermans and collaborators, 2017. We found that the expression of genes involved in lipid metabolism, extracellular matrix and TGF- β signalling are affected in the kidney by spaceflight and the overrepresentation analysis showed that spaceflight is associated with positive enrichment of cholesterol metabolic pathways and negative enrichment of ECM pathways in the kidney. Interestingly we found diverging patterns of lipid synthesis, protein synthesis and circadian rhythm in response to spaceflight in C57BL/6J and BALB/c mice determined by overrepresentation analysis and that C57BL/6J (RR-1) and BALB/c (RR-3) mice present genetic background differences in lipid and extracellular matrix metabolism was reflected in the transcriptomics difference encountered. Overall, we found a stronger response was seen in C57BL/6J mice than BALB/c. Genetic differences in hyaluronan metabolism between strains may confer protection against extracellular matrix remodelling through the downregulation of epithelial-mesenchymal transition. We intend for our findings to contribute to the development of new countermeasures against kidney disease in astronauts and people here on Earth. We would expect that mice exposed to the same length of spaceflight would have similar responses to the stress, nonetheless, we encountered a very different response between strains. Their different genetic background is potentially a factor in explaining this difference.

Successes, Challenges, and Delicious Surprises: Lessons Learned from Plants Grown in EDEN ISS in Antarctica

Jess Bunchek[1], Paul Zabel[1], Matthew Romeyn[2], Vincent Vrakking[1], Daniel Schubert[1]
[1]German Aerospace Center (DLR), [2]NASA Kennedy Space Center

ISLSWG Plants in Space Workshop - Theme 2: Plants for Life Support Systems (ECLSS) in Space, Space Seven & Eight, September 5, 2024, 9:00 AM - 10:40 AM

Biography:

Jess Bunchek is a botanist (B.S., Purdue University), agronomist (M.S., The Pennsylvania State University), and current PhD candidate in Space Systems Engineering at the University of Bremen (Germany) and the German Aerospace Center (DLR). While at NASA's Kennedy Space Center, she supported space crop production on the International Space Station, primarily with the Veggie plant growth chambers. From late 2020 to early 2022, Jess overwintered in Antarctica at Neumayer Station III as the EDEN ISS greenhouse operator, a collaboration between DLR, NASA, and the Alfred Wegener Institute. Her research interests include crop integration, nutrient composition, crew operations, and human factors.

EDEN ISS was a plant production facility located near Germany's Neumayer Station III (NM-III) in Antarctica from 2018 until 2022. During this project, four overwintering teams, each comprised of 9 to 10 crew members, spent 14 to 15 months at NM-III, of which 9 to 11 months were in total isolation. The overwintering crews tested more than 60 cultivars of fruits, vegetables, and herbs in EDEN ISS, producing a grand total of over 1 metric ton of fresh edible biomass. EDEN ISS served as the sole source of fresh produce in this extreme and isolated environment, and the crops supplemented both the crew's diet and psychological health. Many of the cultivars grown in EDEN ISS were selected because they had been previously grown in crop production hardware on the International Space Station, but EDEN ISS also provided the novel opportunity to test cultivars and plant families that have not yet been tested in existing space hardware, particularly crops with larger volume requirements such as cucumber and kohlrabi. Crops were also grown concurrently and continuously in EDEN ISS during the isolation periods. In this paper, we report on the successes of these crops, horticultural and system challenges, and approaches to maintain crew interest in the plants and resulting produce throughout the mission. It is our hope that the data, crew feedback, and lessons learned from EDEN ISS can be used to make better informed decisions on the design and operations of a large-scale crop production facility for missions on the Moon and Mars.

Supporting the Next Generation's Pathway to STEM & Space, from Asia to the World

Dr Anna Sabate Garcia[1]
[1]Space Faculty
3.1 - ELGRA, SELGRA and buildings collaboration with ESA & partners to Drive Space Education, Space One & Two, September 5, 2024, 9:00 AM - 9:45 AM

Biography:
Anna Sabaté Garcia is Tehcnical Head and Business Development Manager at Space Faculty Pte Ltd (Singapore). Anna is an aerospace engineer and holds a PhD in Computational and Applied Physics from UPC BarcelonaTech. She has been involved in microgravity research for over 14 years, participating in drop tower, centrifuge and sounding rocket campaigns in the frame of ESA, NASA, SNSB and DLR programs. Her research interest ranges from fluid dynamics to bioengineering, with an engineering aspect always present. Anna was president and co-founder of SELGRA in September 2013 and she is currently a management committee member of ELGRA.

Space Faculty aims to create opportunities for experimentation, learning and leadership through space. Owing to its strategic global network of partners across the private and public sectors, Space Faculty enables organisations and governments to unlock opportunities in the fast-growing space economy by building their talent, R&D, and industry development roadmaps. Space Faculty has helped to advance the space agenda in Asia in a myriad of ways including developing national-level STEM2.0 learning roadmaps for youths and professionals, enabling the private sector to tap into space-based and deep tech innovations or working with governments to create expand and leverage the space industry ecosystem.

In this presentation we will share some of the programmes we have developed specifically for emerging space-faring nations, to build the talent pipeline in their countries. The range of programmes covers levels from pre-schools to professionals, and each one touches on different areas such as satellite building, space data, life sciences or entrepreneurship, to name a few. We will focus particularly on our flagship programme, the International Space Challenge, and our upcoming international youth event Expand Space.

Synthesis of catalyst nanomaterials for photoelectrochemical water-splitting in microgravity

Dr. Camilla Tossi[1,2,3], Prof. Katharina Brinkert[1,4]
[1]Zarm, University Of Bremen, [2]Istituto Italiano di Tecnologia, [3]Aalto University, [4]University of Warwick
2.2 - Physical Sciences: Material Science, Space Two, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Dr. Katharina Brinkert is an Associate Professor at the University of Warwick/ UK, and a Group Leader at ZARM, University of Bremen/ Germany, where her research interests comprise artificial photosynthetic systems for application in solar-to-chemical energy conversion devices and (photo-)electrocatalytic synthesis in terrestrial and space environments. Previously, she was a Leopoldina Postdoctoral Scholar with Prof. Harry B. Gray at Caltech/USA and a Research Fellow at the ESTEC/The Netherlands. Katharina received her PhD from Imperial College London in 2015 and is a recipient of the Zeldovich Medal for the foundation of the research field "Photoelectrocatalysis and Solar Fuels in Space".

An uttermost priority of human space exploration is the sustainable fabrication and recycling of materials, mitigating the consequences of an impossible resupply of resources from Earth. Moreover, the long-term missions to Moon and Mars will require in-situ resource utilization (ISRU) technologies to synthesise materials in harsh environments and reduced gravitation. This opens a path for research on the fabrication and synthesis of materials that have potential for being utilised in energy conversion technologies in these environments.
Photoelectrochemical (PEC) energy conversion is currently investigated for space applications, due to its potential in converting water and carbon dioxide using sunlight into oxygen, hydrogen, and useful carbon compounds. Further, the monolithic design of PEC devices, which include integrated semiconductor-electrocatalyst systems, offers significant advantages for long-term space missions, such as a compact and lightweight payload. Particularly important is hereby the choice of electrocatalyst material (metals or metal oxides) for the respective anticipated redox reaction to minimize activation polarization overpotentials of the device.
Since microgravity is known to affect the synthesis of nanomaterials by inducing increased crystallinity and increased porosity - which are attractive qualities in a catalyst material - the present study investigates the effect of this environment on the synthesis of metal and metal oxide nanoelectrocatalysts via photoelectrodeposition. Further on, the performance of the synthesized catalyst materials is assessed in photoelectrochemical water splitting in the Bremen Drop Tower, Germany, as well as terrestrially. The starting metals are chosen with respect to their availability in extraterrestrial environments for future ISRU (e.g. ruthenium).

The Autonomic Response to 60 Minutes of Head-Down Tilt Exposure

Syeda Yasmin Zaman[1], Dr. Matteo Fois[2], Dr. Stefania Scarsoglio[2], Dr. Luca Ridolfi[3], Dr. Ana Diaz-Artiles[1]
[1]Department of Aerospace Engineering, Texas A&M University, [2]Department of Mechanical and Aerospace Engineering, Politecnico di Torino, [3]Department of Environmental, Land and Infrastructure Engineering, Politecnico di Torino
2.1 - Life Sciences: Cardiovascular Physiology, Space One, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Yasmin Zaman is a Master of Science student in Aerospace Engineering, researching in the Bioastronautics and Human Performance Laboratory at Texas A&M University. Her research focuses on the effect of short-term head-down tilt on cardiovascular and ocular physiology. Prior to Texas A&M, Yasmin was a Space Technology Officer at the Australian Space Agency. She received her Bachelor of Engineering (Honours) in Aerospace Engineering and her Bachelor of Science in Neuroscience from the University of New South Wales. She is a 2022 Fulbright Scholar from Sydney, Australia.

Introduction: Microgravity exposure alters the hydrostatic pressure gradient in the body, inducing a headward fluid shift. This affects cardiovascular autonomic function, leading to an increased risk of orthostatic intolerance [1][2]. Short-term exposures to weightlessness are becoming more prevalent with the growth of commercial spaceflight. Therefore, this study aims to investigate the initial autonomic response during the first 60 minutes of exposure to a simulated microgravity environment using 6º head-down tilt (HDT).

Method: Eleven subjects (6F/5M, mean age ± standard deviation: 25.4 ± 3.9 years old) were exposed to 60 minutes of 6º HDT. Several autonomic and hemodynamic indices were collected every 10 minutes during the 60-minute 6º HDT exposure. Data collected include standard deviation of all NN intervals (SDNN), root mean square of adjacent NN interval differences (RMSDD), heart rate variability triangular index (HRVTi), low frequency power (LF), high frequency power (HF), normalized low frequency power (LFn), normalized high frequency power (HFn), normalized low frequency-high frequency ratio (LF-HFn), baroreceptor sensitivity (BRS), mean arterial pressure (MAP) and heart rate (HR), all of which were collected with a Finapres NOVA. In addition, cardiac output (CO) and stroke volume (SV) were collected using an Innocor device. Measurements at the beginning and end of exposure were analyzed using paired t-tests or the Wilcoxon Signed Rank test when parametric assumptions were not met. Results are presented as mean ± standard error.

Results: Preliminary results suggest that there were no significant changes in autonomic variables during 60 minutes of 6º HDT (SDNN = 66.8±6.3 to 63.7±4.8 (p=0.437), RMSDD = 42.1±7.2 to 41.5±6.3 (p=0.783), HRVTi = 14.7±1.5 to 15.0±0.7 (p=0.798), LFn = 64.8±4.7 to 70.5±3.5 Hz (p=0.081), HFn = 35.2±4.7 to 29.5±3.5 Hz (p=0.081), LF-HFn = 2.5±0.5 to 3.0±0.6 (p=0.054), and BRS = 13.7±3.5 to 15.3±1.9 (p=0.413)). MAP significantly increased from 71.9±2.8 to 79.3±2.2 mmHg (p=0.002) and SV significantly increased from 64.7±5.8 to 71.7±4.8 mL (p=0.018). No significant changes were observed in HR (73.4±4.2 to 72.5±3.1 BPM, p=0.669).

Discussion: The autonomic response does not seem to evolve during the first 60 minutes of headward fluid shift exposure. However, significant increases were observed in the associated hemodynamic responses (i.e., MAP and SV). These results contribute to the understanding of the physiological responses elicited by short microgravity exposures and inform the development of human countermeasures for future human spaceflight missions.

The emergence of angle dependence in gravity sensing columella cells

Dr. Marta Del Bianco[1], Dr. Suruchi Roychoudhry[2], Dr. Katelyn Sageman-Furnas[5], Dr. Iftekhar Showpnil[3], Prof. Chris Wolverton[3], Prof Jiri Friml[4], Prof Stefan Kepinski[2]
[1]Italian Space Agency (ASI), [2]University of Leeds, [3]Ohio Wesleyan University, [4]Institute of Science and Technology Austria, [5]Duke University

ISLSWG Plants in Space Workshop - Theme 3: Advances in Plant Gravitational Biology and Space Genomics Continued..., Space Seven & Eight, September 5, 2024, 2:15 PM - 4:10 PM

Research on gravitropism has been dominated by two main ideas: that gravity is perceived through the sedimentation of starch-rich plastids within specialised gravity-sensing cells (Starch-statolith hypothesis), and that tropic growth is driven by auxin asymmetry across the graviresponding organ (Cholodny-Went hypothesis). Our recent work on gravity-dependent, non-vertical growth in lateral organs in Arabidopsis, has highlighted the importance of a third, even older concept in gravitropism: angle dependence. However, the mechanistic basis of how statolith sedimentation, and eventually Cholodny-Went driven auxin asymmetry, translates into angle dependent gravitropic behaviour remains unexplored. Here, using a combination of cutting edge vertical confocal imaging with time lapse tracking software, we characterize for the first time the dynamics of gra visensing in the columella of the Arabidopsis primary roots. We observed that statolith sedimentation across individual tiers of columella cells occurs according to the angle of displacement from the vertical axis. We also demonstrate how statolith sedimentation leads to angle dependent PIN3/7 polarization in specific columella domains. This detail analysis shows that different PINs/columella tiers play distinct roles in establishing the asymmetric auxin gradient at different angles. Our findings provide a fundamental framework to further explore the mechanisms that regulate angle dependent gravitropic responses in both primary and lateral organs, with major implications for crop improvement.

The Impact of Microgravity on Dental Procedures: A Parabolic Flight Study

Mr. Tine Šefic[1], Mrs. Hana Prtenjak[2], Mr. Simon Oman[2], Mr. Aleš Fidler[1]
[1]Faculty of Medicine, University of Ljubljana, [2]Faculty of Mechanical Engineering, University of Ljubljana

1.3 - Life Sciences: Human Physiology and Performance, Space Nine, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

Tine Šefic, a senior dentistry student, is the project leader, researcher and principal coordinator of SpaceDent, an interdisciplinary student project under the ESA Academy Experiments programme from Slovenia, where he performed dental procedures in microgravity conditions during parabolic flights. Certified in project management by Google, Tine is also a member of the Association of Professional Futurists. His goal is to advance dentistry for space exploration, adapt dental technologies for terrestrial applications, and establish a universal, multi-planetary oral healthcare system that serves Earth, the Moon, and Mars.

Background: As humanity advances towards long-duration spaceflight and the establishment of extraterrestrial habitation, the prolonged impact of microgravity on various physiological systems, including the oral cavity, emerges as a critical area of concern. To mitigate this risk, effective countermeasures need to be developed. The study presented here aimed to develop a dental operatory, test the operator's position and hand stability, and conduct dental procedures in simulated microgravity. This research contributes to the broader goal of investigating the feasibility of oral countermeasures to ensure the oral health and well-being of astronauts during long-duration space missions.

Methods: During three parabolic flights enabled by the Air Zero G plane by Novespace, a total of 90 microgravity intervals, each with a duration of 22 seconds, were provided. Two senior dentistry students performed simulated caries preparations and composite restorations on artificial teeth attached to a phantom head. The experimental procedures were executed under microgravity conditions, while control procedures were conducted during steady flight and under normogravity on the ground. The dental operatory, designed to simulate a simplified dental practice environment, incorporated an isolation chamber, a turbulence synchronization system, and an adjustable illumination system. The operatory was adjusted for the kneeling position, ensuring unimpeded practitioner mobility in microgravity. The final evaluation of the results was conducted using computer-aided assessment of 2-dimensional and 3-dimensional imagery, and a two-way ANOVA statistical analysis was employed.

Results: The constructed dental operatory facilitates performance of dental procedures without statistically significant accuracy differences. The accuracy (mean [CI]) for O1 and O2 were 12.58%, 95% CI [9.81, 15.35] and 16.79%, 95% CI [14.02, 19.56], respectively. The interaction effect between environment and operator on restoration accuracy was not statistically significant.

Conclusion: The conducted study provides valuable insights towards the possibility of performing dental and potentially surgical procedures under microgravity conditions. Within the limitations of this study, it has been demonstrated that our simulated dental operatory can accommodate the execution of dental procedures across a range of environments. With appropriate training, medical instruments can be utilized safely and effectively, thereby expanding the scope of medical interventions possible in space.

The need for Space Biology Education: A case for Space Omics.

Dr Willian da Silveira[1], Prof Virginia Wotring[2]
[1]Staffordshire University, [2]International Space University
5.3 - Life Sciences: Gravity Related platforms, ageing and biology research, Space Nine, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Dr. da Silveira is currently a Lecturer in Molecular Genetics and Genomics at the Staffordshire University and adjunct lecturer at the International Space University. He was also co-head of the Space Omics Topical Team funded by ESA.

He was the first-author of the November 2020 cover of CELL that featured the article "Comprehensive Multi-omics Analysis Reveals Mitochondrial Stress as a Central Biological Hub for Spaceflight Impact".

His research is in the field of Network Biology applied to Health Ageing and Spaceflight with the objective of developing Personalized Medicine treatments for the consequences of ageing and space travel on human health.

The teaching of space biology is essential to prepare future generations of scientists to tackle the challenges of space exploration and to understand the effects of space on living organisms. Yet, the opportunity to study space biology in an organized curriculum is very limited in Europe and overseas. The United Nations Office for Outer Space Affairs (UNOOSA) program "Access to Space 4 all" has a webinar series on the subject in its Education Component, but Space Biology is only 1 topic of seven in one of the 5 major fields on UNOOSA's Education Curricula. In 2022 the European Space Policy Institute (ESPI) published a report on Space Education that although cited "Astrobiology" 3 times in its 40 pages but failed to cite "Space Biology". This suggests the authors were not aware of the differences between the terms or that there was no dedicated Space Biology training at the time in the region. The European Space Agency (ESA) declared the intention to increase the number of students in STEM by 20%, to offer talents with attractive opportunities and have put "Life Sciences" as one of its major disciplines. But Space Biology training made accessible via ESA Academy has been limited and a majority of students in space fields report difficulty finding a job in the area.
But since 2021 the International Space University (ISU) have pioneered the teaching of Space Omics in Europe. Space Omics is the application of large-scale biological data acquisition and analysis – e.g. Genomics, Transcriptomics and others – to Space Education. ISU maintains, so far, the only dedicated education initiative in this field in the whole continent. This initiative comprises a module of the Master of Studies Program, and workshops have been taught in France, Portugal, Spain, Norway and online. The training is interdisciplinary, making sure the topics covered are of relevance for students from diverse backgrounds (engineering, physics, business, humanities and life sciences). This interdisciplinarity puts this course in a strong position to contribute to the Focus Areas of the ESA Life Science Industry Accelerator program, being strategic for ESA to fulfil it intentions in STEM Education and the creation of opportunities. We look forward to engaging a larger portion of the community to make this possible.

The SubOrbital Express 3 and 4 Rideshare Missions in 2022 and 2024 for Microgravity Research

Mr. Gunnar Florin[1], Mr. Stefan Krämer[1], Christian Lockowandt
[1]Swedish Space Corporation, SSC
2.3 - Gravity Related platforms and Launch Services, Space One, September 4, 2024, 4:30 PM - 6:15 PM

Biography:
Christian Lockowandt studied physics and mathematics at Stockholm University. He has been working in the space sector since 1989. Primarily involved in development of microgravity experiment hardware for drop towers, parabolic flights, sounding rockets, the Space Shuttle and ISS. Focus have been in the development of the core experiment hardware in close collaboration with the responsible scientists. He has also been involved in scientific stratospheric balloon projects as system engineer and project manager. Actively involved in ELGRA since 2015 with different positions in the management committee.

SSC runs the Suborbital Express programme, providing 6 minutes of high-quality microgravity conditions on-board a sounding rocket of 280 kg scientific payload capacity. The launch takes place at Esrange Space Center in the northern hemisphere. The payload is recovered within three hours after launch.

The SubOrbital Express 3 - M15 Rideshare Mission was carried out in November 2022. It accommodated payloads of ten different organisations within total twelve different experiment systems in various sizes. For the first time, the rideshare concept included the dedicated Shared Module enabling the access to the microgravity environment, even for smaller payloads of CubeSat size or similar.
Three of the payloads were accommodated and flown under ESA contract, eight small 300 gram to ~10 kg payloads of different customers were accommodated in a dedicated rideshare system and finally one re-entry experiment capsule by CIRA / Italy with ESA-funded flight ticket was ejected during the flight. The research disciplines related to the flown experiments covered life science, fluid science, cosmology, biology.
The Lab on Paper experiment by student teams from Portugal, selected by ELGRA for the grant covering the flight ticket, was part of the payload.

The Shared Module was again flown in 2024 on the DLR MAPHEUS 14 mission with seven research experiments from DLR and from Australian and Swedish organisations, covering space radiation shielding, life science, technology demonstration for future satellite missions and 3D printing in space.

The SubOrbital Express 4 - M16 Rideshare Mission is scheduled for Q4 2024.
It accommodates scientific payloads of four different organisations within total six different experiment systems in various sizes. Three of the payloads (JACKS, micACTin, LiFiCo) are flown under ESA contract, and one payload (DUST-II) developed by JAXA is flown under DLR funding.
In addition, there a small payload from Stockholm University and one student developed experiment from Linköping (SE) and Colorado Springs (US) universities.

While the forthcoming SubOrbital Express 4 mission is fully booked, the work for filling up the subsequent SubOrbital Express mission scheduled for 2025 is currently on-going. The payload will this time consist of the Shared Module with room for up to 8 small 1U-sized payloads and by ESA funded experiments.

This presentation will provide additional information on the payload configurations, the mission performance as well as details on the experiments with their requirements on the mission.

The SubOrbital Express Shared Module for Cubesat-sized payloads for research in microgravity

Mr. Gunnar Florin[1], Mr. Stefan Krämer[1], Christian Lockowandt
[1]Swedish Space Corporation, SSC
2.3 - Gravity Related platforms and Launch Services, Space One, September 4, 2024, 4:30 PM - 6:15 PM

Biography:
Christian Lockowandt studied physics and mathematics at Stockholm University. He has been working in the space sector since 1989. Primarily involved in development of microgravity experiment hardware for drop towers, parabolic flights, sounding rockets, the Space Shuttle and ISS. Focus have been in the development of the core experiment hardware in close collaboration with the responsible scientists. He has also been involved in scientific stratospheric balloon projects as system engineer and project manager. Actively involved in ELGRA since 2015 with different positions in the management committee.

Introduction:
SSC runs the Suborbital Express programme, providing 6 minutes of high-quality microgravity conditions on-board a sounding rocket of 280 kg scientific payload capacity. The launch takes place at Esrange Space Center in the northern hemisphere. The payload is recovered within three hours after launch. The rideshare service is a complement to the flight implementation of the larger microgravity experiments of ESA and other customers, which constitutes the basis for the 280 kg scientific payload mission.
Shared Module for multiple small-sized experiments
In 2022 SSC introduced the multi-payload platform “Shared Module” with the capacity of hosting eight 1U Cubesat-sized payloads in a joint rideshare compartment in pressurized environment.
The main objective of the Shared Module is to provide flight opportunity to a broader audience. This benefits customers with small-sized, self-contained payloads, designed to fit into the Shared Module payload format. The introduced concept immediately became a success, with six scientific payloads experiencing the maiden flight in November 2022, being part of the SubOrbital Express rideshare mission. In February 2024 the Shared Module flew again as rideshare on the DLR MAPHEUS-14 mission, hosting six small payloads.

Concept:
The basic concept – directed towards customers, scientific groups and even teams of young engineers – is a shared, pressurized compartment housing several small-sized experiments, close to CubeSat form factor. Standard interface solutions for power, communication and mechanical implementation are provided. Each experiment is individually powered by the platform’s support electronics (1A/28 V) and can hence be individually switched on/off during test and launch campaign. One TM/TC communication line is available for each payload. On-site support for biological and life science experiments including late access on launch pad and fast recovery is optional.
Rideshare experiments on recent flights
The scientific and technical validation payloads flown on the first two rideshare missions were

- LabOnPaper by Polytechnical Institute of Porto, University of Coimbra and NOVA University of Lisbon (flight ticket funded by ELGRA);
- MUSA by Orbital Space Technology, Costa Rica;
- RADICALS by RMIT, Australia;
- ADI-Alpha by ResearchSat, Australia;
- ADI-Echo by ResearchSat, Australia
  ANT61 by ANT61, Australia
- Cambrian Executive, Australia;
- FORTIS by FORTIS Watches, Switzerland;
- CeMIR by Karolinska Institutet, Sweden;
- Aurore-I and -II by the Swedish Astronomical Youth Association;
- DEIMOS by DLR;
- MiniPLAX by DLR

Conclusions:
This talk will further present the technical Shared Module approach and the first missions.

The ZBOT-NC Experiment - Effects of Non-Condensable Gases on Propellant Tank Pressurization and Pressure Control

Dr Mohammad Kassemi[1], Ms Sonya Hylton[1], Dr Olga Kartuzova[1]
[1]Case Western Reserve University
5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
Dr. Mohammad Kassemi is a Professor & Director of the National Center for Space Exploration Research at Case Western Reserve University and NASA Glenn Research Center in Cleveland, Ohio. He is the Principal Investigator of the Zero-Boil-Off Tank (ZBOT) experiment series performed aboard the ISS. He is a member of the National Academy of Sciences Committee on Biological and Physical Sciences in Space. He is an AIAA Associate Fellow and a member of the AIAA Liquid Propulsion Technical Committee. He is also the recipient of the 2015 NASA Exceptional Public Achievement Award and the 2019 NASA Silver Snoopy Award.

Introduction:
Integral to all phases of NASA's projected planetary expeditions is affordable and reliable cryogenic fluid storage for use in propellant or life support systems [1]. It is greatly advantageous to develop innovative vent-less pressure control designs based on cooling/mixing of the bulk tank fluid to allow storage of the cryogenic fluid with zero or reduced boil-off. The presence of noncondensable gases can interfere with condensation at the interface impacting tank pressure control during subcooled jet mixing, especially, in microgravity.
The Zero-Boil-Off Tank (ZBOT) Experiments are a series of small-scale experiments aboard the International Space Station (ISS) that use a transparent volatile simulant fluid in a transparent sealed tank to delineate various fundamental fluid flow, heat, and mass transport, and phase change phenomena associated with storage tank pressurization and pressure control in microgravity [2, 3]. The ZBOT-1 experiment was performed on the ISS in the 2017-2018 timeframe and collected data to validate a state-of-the-art CFD model for tank pressurization and pressure control for a pure system. The ZBOT-NC Experiment is the second experiment, in the series, to be performed on the ISS in 2025. Its goal is to investigate the effects of noncondensable gases on interfacial evaporation and condensation during self -pressurization and jet-mixing pressure control in microgravity for a two-component system.

Materials & Methods:
In this work, we will describe the detailed features of the ZBOT-NC experimental hardware and Diagnostics that include a nonintrusive Quantum Dot Thermometry (QDT) technique for whole field temperature measurement. All microgravity pressurization and pressure control tests will be performed for both the pure and the two-component systems with Xenon and Neon as the two noncondensable gases spanning the small and the large molecular weights and sizes. The two-phase CFD model that is developed as part of the project will be also presented and discussed.

Results:
Ground-based pressurization and jet mixing experiments and CFD simulation results are compared to each other to validate both the fidelity of the CFD model predictions and the accuracy of the QDT measurements (Fig 1). Model simulations for noncondensable gas effects will also be compared against large Cryogenic LH2-GHe experiments to indicate the noncondensable gas effects on tank pressure control during jet mixing in 1G (Fig 2). Finally, CFD results will be presented to predict the effects of the noncondensable gas during subcooled jet mixing in the ZBOT-NC tank in advance of the microgravity experiment in 2015 (Fig 3).

Theoretical Foundations of Neuroeconomics in Enhancing Astronaut Well-being and Decision-Making in Space

Miss Kavya Murali Parthasarathy, Dr Shaijumon C.S
[1]University Of Stirling

1.3 - Life Sciences: Human Physiology and Performance, Space Nine, September 4, 2024, 11:00 AM - 1:00 PM

Biography:

As a postgraduate researcher at the University of Stirling, Kavya is pioneering the integration of neuroscience, psychology, and economics to understand the complexities of human decision-making. With an impressive academic background bolstered by three master's degrees, Kavya specialises in the confluence of human behaviour, decision analytics, and the burgeoning space economy. Her research studies the decision-making processes within high-stakes environments, particularly space exploration, exploring the influence of cross-modal sensory inputs on human choices. Driven by diversity, curiosity, and a relentless pursuit of excellence, Kavya aspires to forge new pathways and offer profound insights into the space economy and beyond.

As humans advances towards greater space exploration, driven by significant technological progress and the commercialization of space efforts, we encounter unique challenges in expanding human presence beyond Earth. Notable initiatives such as India's Gaganyaan mission, NASA's Artemis program, and the European Space Agency's Mars explorations highlight the urgent need to address the multifaceted impacts of microgravity on astronaut health and performance. This pursuit necessitates an interdisciplinary approach to ensure the well-being of crew members during long-duration space exploration (LDSE) missions.

This paper introduces Neuroeconomics—a combination of neuroscience, psychology, and economics—as an innovative framework to investigate the physiological and psychological effects of space travel. By employing a mixed-methods study design, our research utilises neuroimaging techniques and economic decision-making tasks under simulated microgravity conditions. These methods aim to measure and analyze neurobehavioral changes in astronauts, providing crucial insights into their cognitive and emotional adaptations.

Estimated results from our theoretical simulations suggest that neuroeconomic interventions can potentially alleviate the negative consequences associated with space travel, enhancing team cohesion, resilience, and decision-making capabilities. These estimated outcomes highlight the importance of Neuroeconomics in navigating the complexities of deep space travel and aiding to successful human adaptation beyond Low Earth Orbit (LEO). This study not only outlines potential strategies but also emphasises the pivotal role of Neuroeconomics in advancing the frontier of human space exploration (Sterling & Eyer, 1988; De Dreu et al., 2010).

Thermal Characterization of Deployable Pulsating Heat Pipe in Variable Gravity conditions

Ms Erin Saltmarsh[1], Mr Alessandro Billi, Ms Silvia Picchi, Mr Vittorio Rosellini, Mr Michele Bocelli, Mr Nicola Ricci, Mr Nicolas Miche, Mr Fabio Bozzoli, Mr Mauro Mameli, Mr Sauro Filippeschi
[1]Advanced Engineering Centre, University Of Brighton, [2]Department of industrial engineering, University of Pisa, [3] Department of Energy, Systems Land and Construction Engineering, University of Pisa, [4]Department of information engineering, University of Pisa, [5]Department of Engineering and Architecture, University of Parma, [6]Department of Energy, Systems Land and Construction Engineering, University of Pisa, [7]School of architecture, technology and engineering, University of Brighton, [8]Department of Engineering and Architecture, University of Parma, [9]Department of Energy, Systems Land and Construction Engineering, University of Pisa, [10] Department of Energy, Systems Land and Construction Engineering, University of Pisa
5.2 - Physical Sciences: Multiphase Flows, Space Two, September 5, 2024, 2:15 PM - 3:45 PM

Biography:
I am an enthusiastic Aeronautical Engineering master's student, with an interest, and experience in the experimental and investigation, and modelling of thermofluidic devices.

I am passionate about applying my knowledge to solve complex problems in thermal management and aerospace propulsion and am eager to contribute to research and development efforts that improve the efficiency and performance of thermofluidic systems.

This study investigates the thermal properties of a deployable Pulsating Heat Pipe (PHP) during the 83rd ESA Parabolic Flight campaign within the "DEPLOY!" student project funded by ESA. The PHP, a passive thermal control device utilizing self-sustained oscillatory fluid motion driven by phase change, is subjected to diverse gravity conditions during parabolic flights. Our focus is on characterizing the thermal behavior of the deployable PHP under static conditions at different folding angles and dynamic conditions during folding/unfolding maneuvers, all while gravity varies.

The device comprises an aluminum capillary tube (ID 1.6 mm) folded into an 11 U-turn serpentine of 800 mm length, featuring an adiabatic section designed as a torsional spring with 3.5 convolutions and a 65 mm coil diameter. The PHP is vacuum-sealed and filled with 40g of HFE-7000 fluid (FR = 70% vol.). In a flight-proof experimental setup, the PHP's mechanical configuration is altered using a remotely controlled stepper motor. Temperature and pressure within the PHP are monitored with 16 thermocouples, two pressure transducers, and an infrared camera.

Through three parabolic flight tests, the PHP's behavior is examined in various static unfolding configurations (0° - 45° - 90° - 135° - 180°) and folding/unfolding dynamics (0° to 180° and 180° to 0°). Different thermal conditions, including heating powers of 34W and 56W and condenser temperatures of 20°C and 25°C, are explored. Results indicate the device reaches a pseudo steady state within 15 to 25 minutes, maintaining stable operation in all tested configurations with occasional local stop-overs during microgravity.

Crucially, the device sustains functionality throughout unfolding configuration variations, exhibiting different parameter values. Gravity variations influence tube temperature and fluid pressure, yet neither hypergravity nor microgravity intervals disrupt the device's operational regime. These findings underscore the potential of the deployable PHP design for future utilization in space thermal control applications.

Thermally controlled space habitats using phase change materials

Mr. Andriy Borshchak Kachalov[1], Mr. Tusher Mollah[2], Dr. Berin Seta[2], Mrs. Claudia Ongil[1], Dr. Pablo Salgado Sánchez[1], Dr. Úrsula Martínez[1], Dr. José Miguel Ezquerro[1], Dr. Jon Spangenberg[2]
[1]E-USOC, Universidad Politécnica De Madrid, [2]TU Denmark
2.2 - Physical Sciences: Material Science, Space Two, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Meet Andriy, a Ukrainian researcher and PhD student in Aerospace Engineering at the Technical University of Madrid, specialized in heat transport in phase change materials. His research focuses on the phase change with convective flows, i.e. thermocapillary convection, and the application of phase change materials as passive thermal control devices. Also, he works as an ISS payload operator at the Spanish Users Support and Operations Centre (E-USOC).

Introduction:
Motivated by emerging environmental awareness, the use of PCMs as thermal control and energy storage devices has notably increased in recent years. Thermal control in buildings is arguably one of the most widespread applications, where PCMs are incorporated into building walls to absorb/release energy in the form of latent heat and compensate for energy imbalances.

This concept is explored in space habitats, where extreme temperatures fluctuations are a common issue. PCM performance is analyzed considering only conduction, a scenario with practical interest in reduced gravity environments.

Method:
As sketched in the figure, the habitat consists of a semi-spherical construction. The PCM is placed within the habitat wall — between its exterior and interior boundaries — and acts isolating the internal habitat environment from the cyclic variation of the external solar flux. Such habitat design can be obtained by co-axial 3D printing, where the inner and outer nozzles print PCM and regolith geopolymer, respectively. The wall, of thickness L, displays absorptivity (α) and emissivity (ε) values on its exterior boundary. Note that the selection of (α,ε) can be done by design, using appropriate paintings or coatings.
The system dynamics are explored numerically for a wide range of parameters, including L, (α,ε), and eclipse/illumination fractions, among others.

Result:
Balancing the heat absorbed and released by the PCM during illumination and eclipse, one can estimate the optimal (α/ε) and the minimum PCM thickness, which depend on the solar flux, the melting temperature, the mission period and illumination fraction, and the density and latent heat of the PCM. From a design perspective, simple expressions can be used to select the external painting of the wall, given a PCM and mission environment.
In the figure, the optimal system response is shown, demonstrating that, under repeated cycles of illumination and eclipse, the PCM can maintain the internal temperature of the habitat at the melting point.

Conclusions:
Nowadays, PCMs are widely used in different applications. Here, we have examined their capability to thermally control a space habitat: the design integrates the PCM within the habitat walls, reducing the fluctuations of the interior temperature that result from cyclic variations in solar radiation. We find that the ratio α/ε play a key role and largely define the optimal design of the habitat.

Thin liquid film coating and drying under microgravity conditions. Sounding rocket experiments: Wet chemistry deposition

Professor Jan van Stam[1], Dr. Leif Ericsson[1], Dr. Ishita Jalan[1]
[1]Karlstad University
2.2 - Physical Sciences: Material Science, Space Two, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
My research is fundamental and of applied relevance and treats interactions in complex systems; polymer-polymer, polymer-solvent, and interactions during concentration gradient under Earth and microgravity conditions. I collaborate with scientists at Materials Research at Karlstad University on systems for organic photovoltaics. I collaborate with scientists at Chalmers and Université Libre de Bruxelles. My research gets financial support from SNSA. My PhD is from Uppsala University, and I spent six years at De Schryver's lab at KU Leuven, Belgium, before moving to Karlstad University in 1998. Since 2011 I am a full professor in physical chemistry. I have published 70+ articles.

The LiFiCo project is part of a multi-disciplinary research programme, within the prioritised research area Materials Research at Karlstad University. Scientists from different fields, e.g., chemistry, materials physics, and modelling, investigate molecular interactions under normal and microgravity conditions. LiFiCo aims at a better fundamental understanding and control of the molecular interactions yielding the structures found in the molecular blend thin films of the active layer in an organic solar cell. For an organic solar cell, the coating solution contains donor, acceptor, and sometimes additional compounds. The evaporation of the solvent causes a concentration gradient, leading to an evolving phase separation. Due to the fast evaporation, the phase separation is arrested before it reaches completion. This partial phase separation results in a film structure, the morphology, decisive for the device performance. It is of fundamental and applied interest to control and manipulate the film morphology, as well as developing means of performing wet chemistry preparations under microgravity conditions.

The kinetics of the phase separation is slowed down under microgravity conditions, while the evaporation kinetics is thought to remain unchanged. Microgravity conditions, hence, facilitates to study the initial stages of the morphology formation. By applying microgravity conditions in preparations during parabolic flights, we have found differences in morphology related to the slower phase separation. Unfortunately, the short time-span of microgravity under parabolic flights is not enough to ensure complete drying maintaining microgravity conditions. To ensure that the complete drying process is performed under microgravity conditions, sounding rocket experiments are needed.

To realise the deposition of the coating solution, a new experimental unit was developed in collaboration with ESA and the Swedish Space Corporation. This equipment, relying on flow-coating onto a glass substrate, allows to create a gravitational field aligned with the experiment cell. This field is necessary during filling and retraction of the solution, in order to control the liquid flow. The new equipment's functionality was tested in October 2023 with drop-tower experiments at ZARM in Bremen. These experiments showed that the equipment works as predicted and yielded valuable information on flow-patterns and wetting.

The LiFiCo project is part of the sounding rocket mission Suborbital Express 4-M16, scheduled for launch at Esrange in April 2024. In this contribution we will summarise the results from the preceding parabolic flight campaigns (70th and 78th ESA PFC), the conclusions from the drop-tower experiments at ZARM, and the preliminary results from the sounding rocket experiments.

TICTOC (Targeting Improved Cotton Through Orbital Cultivation): stress resistance in cotton grown on the ISS

Dr Richard Barker, Dr Arkadipta Bakshi, Dr Sarah Swanson, Prof Simon Gilroy
[1]NASA GeneLab and Blue Marble Space Institute Of Science

2.4 - Life Sciences: Life Support systems, Agriculture and Life Support Systems, Space Seven & Eight, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Dr. Richard Barker is a plant scientist who focuses research on plant responses to spaceflight. During his PhD he developed tools for genetic engineering and plant imaging. During his post-doctoral research, he led student teams to create novel robots and co-founded the CoSe benefit corporation as a platform to enable simulated microgravity space biology research. He participated in multiple spaceflight projects designed to investigate genes involved in stress resistance. He actively shares data and protocols and received awards for his contributions. His research extends beyond plants, recently also studying the genetic response of human and mice responses to spaceflight conditions.

Introduction/Background:
Roots play roles in a host of plant functions that are critical to cotton yields, stress resilience and its impact on the environment, through their activity in processes such as water uptake, nutrient usage, and soil carbon sequestration. Previously, Zhang et al., (2011) created cotton plants that over-express the vacuolar proton pumping pyrophosphatase (AVP1-OX). These plants show increased salt and drought resistance with more than a 20% increased fiber yield under stressful conditions that normally severely limit cotton productivity. These plants also develop a larger root system that can explore a wider and deeper volume of soil for water and nutrients. Such exploration patterns are inextricably linked to gravity, which directs the growth of the main and lateral roots via modulation of e.g., auxin signalling.

Method/Experiment:
The ISS National Laboratory provided us with a unique opportunity to ask: (1) what are the drivers for cotton root system development and function in the absence of the confounding influence of gravity, and (2) does AVP1 overexpression lead to resistance to the stresses of the spaceflight environment.

Result:
Analysis of root system architecture and growth kinetics indicate that the AVP1-OX lines grew larger roots when compared to the wild type in flight and to all of the ground controls, including the AVP1-OX lines themselves. Biochemical analyses of these plants also suggest they experienced reduced oxidative stress and maintained photosynthetic pigment levels.

Current conclusions and future work:
AVP-OX can be used as a tool to engineer larger more stress-resistant plants for future astro-agroecosystems. RNAseq analysis of these plants is now being used to provide insight into possible cellular and molecular mechanisms regulating these physiological responses.

Supported by CASIS UA-2018-276.

Towards a ground-based partial-gravity platform and big scientific data with the GraviTower Bremen Pro

Dr. Merle Cornelius[1], Anna Becker[2], Marcel Bernauer[2], Dr. Thorben Könemann[1], Peter von Kampen[1], Prof. Dr. Marc Avila[1]
[1]ZARM FAB mbH, [2]ZARM, University of Bremen
2.3 - Gravity Related platforms and Launch Services, Space One, September 4, 2024, 4:30 PM - 6:15 PM

Biography:
Dr. Merle Cornelius is a physicist working as Deputy Head of Science and Operation at the ZARM Drop Tower Operation and Service Company (ZARM FAB mbH) in Bremen, Germany. At the ZARM research facility, where experiments in weightlessness are performed, she manages the drop tower operation and is the point of contact for the scientists. Before working at ZARM FAB mbH, she was a researcher and did her PhD in physics at the University of Bremen, where she conducted microgravity experiments at ZARM in the field of quantum optics.

Introduction/Background:
Drop Towers are the ideal platform for microgravity experiments on short time scales which demand high accessibility and flexibility. The request for increased repetition rates without losing microgravity quality leads to novel drop tower concepts. In particular guided platforms offer the additional advantage to provide partial gravity. Experiments and technology developments conducted under Lunar and Martian gravity conditions are becoming more important for human exploration, e.g. to our next destination – the Moon.

Method/Experiment:
Since the beginning of the year 2022, the GraviTower Bremen Pro represents ZARM's new next-generation drop tower system, which makes use of a rail-guided rope drive being able to perform 20 experiments per hour. Its technology is based on a commercial hydraulic winch system with more than 4000 hp of engine power that moves a rail-guided drag shield in a 16 m high tower, upwards and downwards. With its novel and sophisticated Release-Caging-Mechanism (RCM), the actively driven GraviTower located in the integration hall of the Bremen Drop Tower is capable of controlling heavy payloads of up to 500 kg in a very smooth and precise manner. The RCM developed and patented by ZARM also enables a fast and reliable decoupling as well as re-coupling of the experiment capsule inside the drag shield.

Result:
In this contribution, we will give an overview of ongoing development projects on the GraviTower. The first project is dedicated to the next version of the RCM aiming for precise partial gravity capabilities. First demonstrations of lunar gravity levels were performed with the current RCM design, demanding that the experiment stay connected to the drive. The resulting high vibration levels will be reduced with the novel RCMmm concept (RCM Moon / Mars), based on an active force control system. Since the RCMmm will ensure a decoupling in the vertical-translational direction, low residual acceleration levels are expected for partial gravity.
The second project concentrates on the automation of the facility and precise time-synchronization. In particular the implementation of machine learning (ML) algorithms for optimization purposes benefits from the high repetition rate of the GraviTower.

Conclusion:
With these novel aspects, the GraviTower facility becomes the ideal testbed for partial gravity experiments, while the high repetition rates can be exploited for future big scientific data handling. Thus, the easy excess and cost-efficient GraviTower platform will pave the way into space for a broad field of research.

Two-dimensional emulsions of islands in thin free-standing fluid films

Prof. Ralf Stannarius[1,2], Dr. Christoph Klopp[1], Dr. Torsten Trittel[1,2]
[1]Otto von Guericke University Magdeburg, [2]Brandenburg University of Applied Sciences
1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Professor of experimental physics (ret.) with interests in soft matter including granular materials and anisotropic fluids, spontaneous pattern formation, thin fluid films, experiments in microgravity

Introduction:

Some smectic liquid crystals are known for a unique feature: the can form thin, freely suspended films with extraordinarily large aspect ratios, widths may reach several centimeters at uniform thicknesses of only few nanometers. In the smectic A phase, for example, they show liquid-like behavior without long range positional order of the mesogenic molecules in the film plane. These films can be considered as excellent models for two-dimensional (2D) fluids. Rheology in 2D is often more complicated than in 3D, the Stokes paradox is an eminent example for that. We study the coalescence of inclusions in this quasi-2D liquid environment, and the aging dynamics of emulsions formed by islands (circular plateaus of larger film thickness) in the surrounding homogeneous films.

Methods:

Spherical smectic films (bubbles) with 15 mm diameter were prepared in microgravity on the ISS. The dynamics of inclusions in these films was recorded by optical imaging, including high-speed videos.

Results:

Merging of droplets of molten film material was recorded and analyzed. Droplet coalescence shows a crucial dependence on details of the droplet structures [1,2]. In biphasic droplets, the merging process is retarded by roughly three orders of magnitude. A thin nematic membrane forms between the isotropic droplet cores.
Arrays of islands were prepared as 2D emulsion to analyze their aging [3]. The patterns coarsen primarily by merging events, yet contributions of Ostwald ripening can clearly be found. The peculiarity is that the continuous and the dispersed phases consist of the same mesogenic material.

Conclusion:

Our experiments with droplets in free-standing films provided new insights into the merging of flat len¬ses in a 2D plane. In contrast to grease drops on water, the influence of a subphase is negligible. The studies of quasi-2D emulsions provided qualitative and quantitative data on aging processes in such a geometry. Long-term experiments are needed to establish the exponents for the growth dynamics.

UAS for reduced gravity testing - a comparison against traditional systems.

Mr Karol Wijacinski[1], Dr Ben Parslew[1], Dr Nicholas Crisp[1], Mr Khristopher Kabbabe[1]
[1]University Of Manchester

2.3 - Gravity Related platforms and Launch Services, Space One, September 4, 2024, 4:30 PM - 6:15 PM

Biography:

Karol is a PhD student working within the Aerospace Systems Laboratory and Space Systems Research Group at the University of Manchester. Karol's interests lie novel applications of UAVs and similar technologies. His project, 'Development of Reduced Gravity Testing Capabilities using Unmanned Aerial Systems' looks into the planning and requirements of using UAS as a reduced gravity platform. This project also looks into where UAS fits into the overall reduced gravity testing field.

Drones provide lower cost and improved accessibility access to reduced gravity (RG) conditions than traditional systems. Drones offer a lower cost solution and allow the possibility of partial gravity, at the cost of lower payload capacity. This shows that there are trade-offs when selecting RG systems for experiments. This study will evaluate existing comparison metrics of g-duration, g-level, and g-quantity, as well as discussing introduction of alternate metrics.

Current metrics of g-duration, g-level, and g-quality are used in understanding the operational characteristics of RG systems. However, the assessment of g-quality as a metric reveals limitations, particularly in accurately representing phenomena due to time-based variations in acceleration measurements.

G-level and g-duration refer to the acceleration that can be reached by an RG system, as well as the amount of time it is able to maintain it. G-quality refers to the error between target g-level and actual g-level measured during experiments and is usually presented as the maximum and minimum error. A series of acceleration datasets from AirZeroG flights were analysed by finding maximum and minimum accelerations and calculating standard deviations for each manoeuvre. The use of standard deviations has shown to provide a clearer distinction between the g-quality of sets of acceleration data as opposed to using purely minimum and maximum values, as it reduces the impact of singular peaks of accelerations on the quality. This is beneficial both when quantifying the performance of an individual system, but also for comparison against others.

Beyond performance parameters, cost and accessibility play pivotal roles in system selection. Accessibility encompasses the technical barrier to entry of conducting experiments and the availability of testing locations and services. This factor significantly influences the overall feasibility and practicality of utilizing RG systems. The cost of performing experiments on different systems will drive decision-making based on budget, as well as the expected addition of value to the experimental campaign of any project using such systems.

Moreover, payload capacity emerges as a crucial consideration, with historical data serving as a valuable resource for comparison. Understanding the payload mass and volume capabilities of RG providers will again impact decision-making, as these may not fit within limits of each RG system.

Work within this project will continue to quantify metrics where possible, as well as providing holistic comparisons of systems providing reduced gravity conditions.

Ultrasonic Cooling System in Microgravity

Alex Drago-González[1,2], Prof. Ricard González-Cinca[1]
[1]Space Exploration Lab, Department of Physics, Universitat Politècnica de Catalunya - BarcelonaTech.,
[2]Medical Ultrasonics Lab, Department of Neuroscience and Biomedical Engineering, Aalto University
1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Alex Drago-González, a doctoral candidate in Applied Physics at Aalto University, specializes in experimental and numerical research at the intersection of physics and aerospace engineering. Graduating in both disciplines, his expertise encompasses fluid dynamics, wetting, ultrasound, microgravity, heat transfer, and space situational awareness. Collaborating on projects with the European Space Agency (via DropYourThesis!) and ienai SPACE Inc., he focuses on enhancing satellite cooling and optimizing electric propulsion. Alex is dedicated to innovating satellite technology for a more sustainable and ethical use of space.

Introduction:
On Earth, electric circuits dissipate heat through convection flows driven by gravity, facilitating the transfer of energy from electronic devices to the surrounding environment. However, in microgravity, the absence of buoyancy disrupts this cooling mechanism, and heat accumulates around its sources. Recent works showed that acoustic streaming generated by ultrasound enhances heat transfer in gases in normal gravity [1,2]. In microgravity this effect has only been studied with liquids up until now [3]. We present an experimental study where ultrasound is used to enhance heat transfer in air in microgravity.

Method:
An experimental setup was designed and built to test the physical phenomenon in the ZARM drop tower. The setup consists of a test cell and systems for acoustic actuation and data acquisition. The test cell contains a heating element. Ultrasound is generated by means of a piezoelectric transducer attached to the cell. Temperature is measured at different positions near the heating element. Video images are acquired for Schlieren processing. The experiment run in five catapult launches at the tower, with 9.4 s of microgravity in each launch.

Results:
Figure 1 shows the temperature at a position near the heating element during the microgravity time of a drop. Red dots and line correspond to the case when no acoustic actuation is applied, while blue dots and line correspond to an acoustic actuation with a frequency of 43.7 kHz. Temperature increased approximately 2°C in the considered position when the acoustic actuation was applied, which shows the acoustic effects on heat transfer.

Figure 2 shows Schlieren-processed images of the air density in the test cell. Bottom row shows the evolution in time when no acoustic actuation is applied, while middle and top row show the time evolution when an acoustic actuation of 43.7 kHz and 60.2 kHz is applied, respectively. The strongest effects on the air density variation (i.e. on heat transfer) take place at the resonance frequency of the piezoelectric transducer (43.7 kHz).

This study highlights the feasibility of using ultrasound to enhance heat transfer in gases in microgravity. This result lays the foundation for potential new cooling technologies for electronic devices in satellites and manned spacecraft.

Unveiling Retronasal Aromas and Mouthfeel Perception in Space-Simulated Environments: Improving Palatability for Extended Missions

Dr Claudia Gonzalez Viejo[1], Ms Natalie Harris[1], Dr Sigfredo Fuentes[1,2]
[1]The University of Melbourne, [2]Tecnologico de Monterrey

6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
Dr Claudia Gonzalez Viejo is a Postdoctoral Research Fellow working on the development and establishment of novel digital techniques and protocols to assess astronauts' wellbeing and sensory perception and acceptability towards their interaction with plants for space (P4S) as a source of food and beverages. Her research interests lie on the development of emerging technologies based on artificial intelligence such as robotics, sensors, computer vision, biometrics and machine learning modelling and their application in the field of agricultural, food and beverage sciences and engineering.

Even though substantial research has revolved around developing food for Space to sustain astronauts in short- and mid-term missions, there are still concerns surrounding inadequate calorie consumption that leads to weight and bone loss due to menu fatigue and low palatability perception. Hence, it is important to investigate the perception of food senses in simulated space and microgravity environments, which will aid in developing palatable plants that may be produced in Space during long-term missions such as NASA-Artemis. Existing studies have focused on perception of orthonasal aromas and some basic tastes; however, these studies presented some flaws, and no or minimal research has been conducted to assess retronasal aromas and mouthfeel perception. This study focused on the assessment of retronasal aromas and trigeminal sensations (mouthfeel) intensity perception in two seating positions: (i) normal and (ii) simulated microgravity (reclined) and two simulated environments (i) neutral and (ii) immersive Space (rooms with 180° screens). Two sensory sessions for (i) retronasal aromas and (ii) mouthfeel were conducted with 12 trained panellists using the BioSensory© application (University of Melbourne, Parkville, VIC, Australia) to record participants self-reported (intensity) and subconscious (physiological and emotional) responses using non-invasive biometrics in different simulated environments and seating positions. Results were analysed using multivariate data analysis; therefore, four principal component analyses (PCA) were developed for each session/treatment PCAs 1 and 5 for neutral environment using samples in the two seating positions, PCAs 2 and 6 for simulated Space environment using samples from the two seating positions, PCAs 3 and 7 for normal seating position using samples tested in the two environments, and PCAs 4 and 8 for simulated microgravity seating position using samples tested in the two environments. Overall, results showed that retronasal aromas tested in simulated microgravity seating positions were associated with lower intensity in both environments (PCA 1 and 2); likewise, samples tested in both seating positions in the immersive Space environment were related to lower intensity (PCA 3 and 4). Mouthfeel samples were perceived with lower intensity in the simulated microgravity seating position in both environments (PCA 8) and the simulated space environment with the simulated microgravity position (PCA 6). However, mouthfeel samples tested in the neutral environment with normal seating position were associated with higher intensity (PCA 5). This evidence may be considered for developing plants suitable for Space environments, providing astronauts with tastier food options to address the challenges of altered taste perceptions in Space.

Using thermocapillary flow and vibrations to control a free surface in microgravity

Jeff Porter[1], Dan Gligor[1], Pablo Salgado[1], José Plaza[1], Úrsula Martinez[1], José Miguel Ezquerro[1], Karl Olfe[1]
[1]Universidad Politécnica de Madrid
4.3 - Physical Sciences: Marangoni convection, Space Nine, September 5, 2024, 11:00 AM - 1:00 PM

Biography:
Jeff Porter received his Ph.D. from the University of California at Berkeley in 2001 and has held a position of Profesor Contratado Doctor (I3) at the UPM since 2006. His research applies ideas from nonlinear dynamical systems, like bifurcation theory and pattern formation, to the study of fluid instabilities, particularly under microgravity conditions. He is interested in Faraday waves, cross-waves, frozen waves, vibroequilibria and, most recently, the effect of thermocapillary convection on Phase Change Materials.

Introduction:
Fluids, with all their complex behavior, are an essential part of space exploration. The reduced gravity environment of typical space missions alters how fluids interact with their surroundings and respond to external forces. Fluid manipulation and control in such conditions is both crucial and challenging.

The ''Thermocapillary-based control of a free surface in microgravity'' (ThermoSlosh) experiment aims to study the effectiveness of thermal and inertial forcing for fluid control in microgravity applications. ThermoSlosh was presented to the ISSSP competition and awarded 2nd place.

Experiment and method:
The heart of the experiment is a cylindrical cell, half filled with silicone oil and subjected to controlled temperatures and vibrations. The thermal system of the experiment is composed of two pairs of thermocouples and Peltier elements while the optical system includes a high-resolution camera, a fixed-focus lens, and an LED panel. The experiment cell and optical system are mounted on a base plate which is attached to a stepper motor that can impose controlled vibrations.

To understand and predict the experimental measurements, we numerically analyze the 2D dynamics of the fluid; see the left panel of the figure. The influence of the applied temperature difference, vibrational amplitude, fluid viscosity, and contact angle are explored, and the response of the free surface is characterized using the rise and stabilization times, and the overshoot of its motion.

Results:
The right panel of the figure shows examples of the temporal response of the (average) surface orientation under different scenarios. The applied ΔT and the thermocapillary flow it generates initially induce counterclockwise rotation of the interface. The rise time characterizes when the free surface first reaches an average orientation perpendicular to ΔT. The surface, however, continues to rotate because of inertia and overshoots. Subsequent cycles of clockwise and counterclockwise rotation with decreasing amplitude define the stabilization time for its approach to equilibrium.

Conclusions:
Simulations indicate that the thermocapillary effect can be used to control the orientation of a free surface in microgravity while supplemental vibrations can be added to increase responsiveness. This control can be further improved by using PID feedback to adjust the applied temperatures in real time. Controller gains can be selected to optimize the stabilization time, energy cost, and reduce steady-state errors. Overall, the results demonstrate the potential of thermal forcing and vibrations for fluid management in reduced gravity and support the types of experiments proposed in the frame of the ThermoSlosh project.

Venous Thrombosis during Spaceflight

Dr. Stuart Lee[1], Dr. James Pavela[2], Mr. David Martin[1], Dr. Scott Smith[2], Dr. Sara Zwart[3], Dr. Jason Lytle, Dr. Steven Laurie[1], Dr. Brandon Macias[2]
[1]KBR/NASA-Johnson Space Center, [2]NASA Johnson Space Center, [3]University of Texas Medical Branch
2.1 - Life Sciences: Cardiovascular Physiology, Space One, September 4, 2024, 2:15 PM - 4:00 PM

Biography:
Dr. Lee has worked at NASA's Johnson Space Center since 1992. During his first 16 years at Johnson, he supported research activities in the Exercise Physiology Laboratory and later served as a research scientist for the Cardiovascular and Vision Laboratory. His work focuses on understanding cardiovascular and musculoskeletal adaptations to spaceflight and developing countermeasures to protect astronaut health and performance during and after spaceflight missions. Dr. Lee supports research and medical operations directed toward the human health and performance of astronauts throughout all stages of flight. He joined the Human Health Countermeasures Element in 2023 as an Associate Element Scientist.

For the first time in more than 60 years of human spaceflight, a deep venous thrombus (DVT) was identified in an astronaut during an International Space Station mission. The incidental finding occurred during remotely-guided ultrasound imaging of the left internal jugular vein (IJV) by a research team studying hemodynamics in weightlessness and was confirmed by a second, medically-directed ultrasound examination with compression. The astronaut was successfully managed on-orbit using anti-coagulation and was safely returned to Earth without further complications. Although a postflight inherited thrombophilia evaluation was negative, a potential risk factor for the DVT that was identified was the use of estrogen-containing contraception. However, use of oral contraceptives to suppress menses is not a new practice in spaceflight and may not be the causative factor for this issue. Indeed, a suspected partially-occlusive DVT was identified in the left IJV of another astronaut who was not taking oral contraceptives, though diagnosis of DVT in this second individual was not confirmed with standard diagnostic practices because the identification was made during a retrospective review of research imaging. Several peer-reviewed publications have described factors that might contribute to venous thrombosis during spaceflight, but data from original research and medical surveillance are limited. Hypotheses regarding the mechanisms of venous thrombosis during spaceflight have included a strong emphasis on those factors described by Virchow's Triad: flow stasis, hypercoagulability, and endothelial dysfunction and/or vessel wall damage. Recent observations of left IJV flow stasis in brief periods of weightlessness during parabolic flight suggest that conditions that could contribute to thrombus development may occur early in spaceflight and may be directly related to headward fluid shift and movement of organs and vessels in the thoracic cavity and neck. To date, biomarkers of hemostasis have not clearly differentiated the definitive and potential IJV thrombus cases from 12 other astronauts in the same study, and stasis was observed >30% of all participants. Subsequently, a venous surveillance protocol was initiated by NASA Space Medicine, and no additional thrombus cases in NASA crewmembers have been observed to date. Given that the confirmed and suspected cases of IJV thrombus in 2 astronauts during spaceflight were asymptomatic, the actual incidence of DVT remains unknown in the 88 NASA astronauts who have flown on ISS for >30 days, and the etiology requires further investigation.

Ventricular volume changes across multiple spaceflights

Professor Floris Wuyts[1], Chloe Mohanadass[1], Lauren Church[1], Steven Jillings[1], Inna Nosikova[2], Elena Tomilovskaya[2], Ilya Rukavishnikov[2], Ekaterina Pechenkova[2], Peter Zu Eulenburg[3]
[1]LEIA - University Of Antwerp, [2]IBMP - Russian Academy of Sciences, [3]Ludwig Maximilians University
6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
I studied biomedical sciences with a master's in neuroscience at the University of Antwerp in Belgium. Interested in brain imaging and neuroplasticity, I pursued a PhD at prof. Wuyts' Lab for Equilibrium Investigations and Aerospace (LEIA), where I researched the effect of long-duration spaceflight on human brain structure and function. I did a joint-PhD between the University of Antwerp and University of Liège, and obtained my PhD in Science and Medical Science in 2021. Since then, I have continued the space related projects as a postdoc at LEIA.

Brain ventricular volume increases post long-duration International Space Station (ISS) missions, persisting up to a year after missions, suggesting potential carry-over effects [1-4]. This study explores ventricular volume changes across multiple ISS missions, aiming to elucidate long-term effects on cosmonauts.

Methods:

MRI scans from 24 cosmonauts over 10 years, part of ESA's BRAIN-DTI project, were analyzed. Six cosmonauts participated in consecutive missions, and nine control subjects underwent three measurements over 1.9 years. T1-weighted images were analyzed using cat12 toolbox, extracting CSF volumes from various ventricular regions. Linear mixed models in JMP Pro 16 and statistical analyses were employed.

Results:

Significant time effects on third (3V), right lateral (RLV), and left lateral ventricles (LLV) were observed (all $p<0.0001$). LLV exhibited increased volume 3 years post-mission compared to preflight. Linear increases in 3V, RLV, and LLV were noted when excluding immediate postflight data ($p<0.0001$). The fourth ventricle (4V) showed an impact of previous missions on pre- to postflight volume change. Control data exhibited time and age effects, with group-level increases influenced by two older subjects.

Discussion:

A trend towards accumulating ventricular volume increases in 3V, RLV, and LLV was observed. LLV maintained elevated volume three years post-mission. Although no significant difference in percentage volume change between missions was found, linear increases suggest cumulative effects. This study, analyzing the same cosmonauts across multiple missions, presents a unique framework. However, limited sample size and missing data constrain firm conclusions. Variability in ventricular volume dynamics and aging effects should be explored further. Despite limitations, these findings offer insights for future studies on how prior space experience impacts ventricular volume in space travelers.

Verification of root hydrotropism by spaceflight experiments and its application to agriculture

Prof. / Dr. Hideyuki Takahashi[1]
[1]Chiba University
ISLSWG Plants in Space Workshop - Theme 4: Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture, Space Seven & Eight, September 6, 2024, 9:00 AM - 10:25 AM

Biography:
Hideyuki Takahashi is currently a director of the Research Center for Space Agriculture and Horticulture, Graduate School of Horticulture, Chiba University. He was a PI of four spaceflight experiments aboard the space shuttle and the International Space Station. He served as a chair of F1 sub-commission of COSPAR (1998-2004), the president of the Japanese Society for Biological Sciences in Space (2013-2017), a representative of the Japanese Science Union for Human Planetary Habitation in Space (2016-2019), a member of the JAXA Advisory Committee for Space Utilization Sciences (2009-2015), and a chair of the JAXA Sub-committee for Space Utilization (2017-2019).

It has been demonstrated that plants display a genuine response to moisture gradients, root hydrotropism, for their better growth and survival under water-limited conditions. On Earth, gravitropic response interferes with hydrotropism in roots, although the degree of interference differs among plant species. Therefore, hydrotropism was first re-discovered with agravitropic roots of pea mutant ageotropum and thereafter via clinorotation experiments [1,2]. Based on a hypothesis obtained from these studies, we conducted spaceflight experiments to verify the interaction between gravitropism and hydrotropism in cucumber roots [3]. In the presence of moisture gradients, cucumber roots grew toward the side of higher-water potential in microgravity and along the gravity direction under artificial 1G conditions in space. These successful separation of the two tropisms led us to find unique mechanisms for root hydrotropism. Root hydrotropism occurs independently of the root cap, while columella cells in the root cap play a crucial role in the auxin-regulated gravitropism [4,5]. MIZU-KUSSEI1 (MIZ1) indispensable for hydrotropism in Arabidopsis roots functions in cortical cells of the root elongation zone [4,6]. Abscisic acid (ABA) also plays an important role in the cortex-regulated hydrotropism of Arabidopsis roots [4]. Interestingly, MIZ1-overexpressors showed more pronounced hydrotropic response than the wild type and better growth under drought conditions in Arabidopsis roots [7,8]. MIZ1 homologues are found in the genomes of various land plants, suggesting their roles in hydrotropism of crop roots as well. Currently, however, we do not know whether MIZ1 homologues in crop plants are functional in their hydrotropic response or not. It is therefore important to examine the MIZ1- and ABA-regulation of root hydrotropism in crop plants, which will lead to the development of useful technology to grow plants with a minimum amount of water in arid area on Earth or in some cultivation systems of space plant factory. This paper presents our approach for such purpose and an outline of newly established research center for space horticulture at Chiba University in Japan.

Vestibular integration in modified gravity and motion sickness

Tess Bonnard[1], DU Jean-René Cazalets, PU-PH Dominique Guehl, IR Etienne Guillaud
[1]Univ. Bordeaux, CNRS, INCIA, UMR 5287, F-33000 Bordeaux, France
5.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 5, 2024, 2:15 PM - 3:45 PM

Biography:

Tess Bonnard is a PhD student since October 2023 at the Institut des Neurosciences Cognitives et Intégratives d'Aquitaine (INCIA). She obtained a double bachelor degree in biology and chemistry at the Université Côte d'Azur. Fascinated by neurosciences, she continued with a master degree in molecular and cellular neurosciences at the Université Paris Cité (former Université Paris Descartes). During her master internships, she had the opportunity to work with cellular and animal models, in medical, fondamental and translational research topics. Her PhD now focuses on microgravity effects on vestibular system and motion sickness, using human as a model.

Introduction:

Space motion sickness (SMS) affects more than 50% of astronauts during the initial days of a mission (Davis et al., 1988b). The occurrence of SMS is hypothesized to be related to sensory mismatch within the vestibular system itself (Lackner and DiZio, 2006). In space, otolithic information, which provides cues about gravity direction on Earth, is absent, and the precise impact of gravity on vestibular capacities remains uncertain. SMS typically disappears after three to four days, following adaptation to microgravity. Evaluation of the gravitational influence on vestibular function primarily occurs in adaptated astronauts.

Aim:

In the experiments presented here, we focus on assessing vestibular capacities, with particular attention to the critical period preceding adaptation, during which SMS occurs. Additionally, we aim to investigate the impact of space motion sickness on visuo-vestibular integration.

Methods:

To examine how vestibular integration is affected, we conducted experiments during parabolic flights where participants were exposed to repeated short sessions of microgravity and hypergravity. Throughout these flights, we followed the evolution of motion sickness using both objective measurements and subjective feedbacks. For now, nine participants took part in the CNES parabolic flight campaign. Vestibular integration was evaluated through two investigations focusing on otoliths (Colebatch et al., 1994) and semicircular canals (Benson et al., 1986) respectively. The first assessment evaluated vestibular evoked myogenic potentials (VEMP) recordings, while the second measured the suppression of the vestibulo-ocular reflex (VOR). The impact of vestibular disturbance on visual integration was examined by assessing the optokinetic reflex (OKN) with virtual reality before and after the parabolic sessions. Motion sickness was continuously monitored through objective measurements such as skin conductance, temperature, heart rate, as well as through subjective information obtained from questionnaires and self-reports.

Discussion:

We will present the effects of short-term exposure to modified gravities on hard-wired vestibulo-spinal reflexes and concurrent integration. We wish to identify the most relevant physiological variables for motion sickness estimation and to discuss the relationship between physiological variables and vestibular responses over time. Furthermore, we aim to determine the differences between terrestrial motion sickness experienced in virtual environments and that encountered during parabolic flights, while evaluating their respective impacts on vestibular integration.

White matter changes after long-duration spaceflight – new insights

Professor Floris Wuyts[1], Ben Jeurissen[1], Steven Jillings[1], Angelique Van Ombergen[1], Elena Tomilovskaya[2], Ilya Rukavishnikov[2], Ekaterina Pechenkova[2], Peter Zu Eulenburg[3]
[1]LEIA - University Of Antwerp, [2]IBMP - Russian Academy of Sciences, [3]Ludwig Maximilians University
6.1 - Life Sciences: Brain & Nervous System, Psychology, Space One, September 6, 2024, 11:00 AM - 1:00 PM

Biography:
I studied biomedical sciences with a master's in neuroscience at the University of Antwerp in Belgium. Interested in brain imaging and neuroplasticity, I pursued a PhD at prof. Wuyts' Lab for Equilibrium Investigations and Aerospace (LEIA), where I researched the effect of long-duration spaceflight on human brain structure and function. I did a joint-PhD between the University of Antwerp and University of Liège, and obtained my PhD in Science and Medical Science in 2021. Since then, I have continued the space related projects as a postdoc at LEIA

Introduction:
The impact of spaceflight on the central nervous system, particularly the white matter (WM) of the brain, remains poorly understood. Previous studies using diffusion MRI and voxel-based analysis suggested an increase in WM in the cerebellum after spaceflight, potentially indicating neuroplasticity. However, questions persisted regarding whether these changes truly reflected alterations in connectivity or were a result of fluid and tissue displacements. To address these uncertainties, we conducted an advanced fixel-based analysis of diffusion MRI on 18 Roscosmos cosmonauts before and after extended space missions.

Material and Methods:
During the study, cosmonauts were scanned using diffusion-weighted MRI before (average 81 days) and shortly after (9 days) their missions to the International Space Station (ISS), which typically lasted 195 days. The diffusion MRI data were preprocessed, and the white matter fiber orientation distribution function (fODF) was estimated in each voxel using multi-tissue constrained spherical deconvolution. Fixel-specific metrics, including Fiber Density (FD), Fiber Cross-section (FC), and Fiber Density modulated with Cross-section (FDC), were calculated to assess microscopic and macroscopic changes in WM fibers.

Results:
Results from an omnibus F-test revealed widespread alterations in WM due to long-duration spaceflight, supporting previous findings. However, subsequent posthoc t-tests demonstrated that the majority of these changes were macroscopic (FC) rather than microscopic (FD). Further analysis, considering both FD and FC simultaneously (FDC), showed no net decreases in WM, indicating that most FD changes were likely due to macroscopic fluid shifts rather than true alterations in connectivity. Interestingly, FDC analysis identified a net increase in WM fibers in the left superior and left middle cerebellar peduncles, providing additional evidence for neuroplasticity induced by long-duration spaceflight.

Conclusion:
In conclusion, this fixel-based analysis of diffusion MRI data in cosmonauts revealed widespread macroscopic changes in WM after spaceflight, with no significant net decreases when considering both microscopic and macroscopic effects. The study also uncovered a net increase in WM fibers in specific cerebellar regions, supporting the notion of neuroplasticity induced by prolonged space missions.

ZBOT-FT: Investigation of liquid removal in microgravity using Screen Channel Liquid Acquisition Device

M.Sc. Prithvi Shukla[1], Professor Michael Dreyer[1]
[1]Zarm, University Of Bremen

1.2 - Physical Sciences: Soft Matter, Complex fluids and Vibration, Space Two, September 4, 2024, 11:00 AM - 1:00 PM

Biography:
Prithvi Shukla has been working as a research assistant at ZARM (Center of Applied Space Technology and Microgravity), University of Bremen, Germany, since October 2019. She completed her bachelor's degree in Mechanical Engineering in 2016 and her master's degree in Mechanical System Design in 2019, both in India. Currently, she is pursuing her doctoral degree at the University of Bremen. Her primary field of work involves phase separation and working with liquid acquisition devices, experimenting with them in normal gravity and microgravity environment.

The exploration of space is constrained by the capabilities of our heavy lift-off vehicles. To extend the boundaries of our exploration, the establishment of an in-orbit propellant depot is crucial. This is the main motivation behind our project, ZBOT-FT, whose primary objective is to investigate the complexities associated with the removal, filling, and transfer of liquids in a microgravity environment. A preliminary focus in this current piece of work is to achieve gas-free liquid removal under different initial conditions in microgravity. The Screen Channel Liquid Acquisition Device (SC-LAD) is identified in the literature as one of the most promising liquid acquisition devices for these propellant depot operations, effectively separating phases and ensuring the delivery of gas-free liquid.

In the presented work, we have focused on the process of liquid removal and the phase separation capability of a specially designed SC-LAD, aiming to provide gas-free liquid from an experimental tank in microgravity. Our experiments were conducted in the ZARM drop tower under different initial conditions. The test liquid was HFE-7500, and the working conditions were assumed to be isothermal. The observations from the drop tower experiments were analyzed and compared with analytical solutions, showing close agreement [1]. Additionally, various other phenomena, such as the reorientation of the free surface under microgravity, capillary rise of liquids between parallel plates, flow through screen pressure loss due to the applied removal flow rate, and bubble point breakthrough of the screen, were captured through a high-speed camera, presenting intriguing insights

These findings not only demonstrate the viability of SC-LAD for gas-free liquid removal in space but also contribute valuable insights into the complex fluid behaviour under reduced gravity conditions, propelling forward the capabilities for extended space exploration.