# Minerva Mission - ESA Experiments Overview

# INC67 RESEARCH COMPLEMENT OVERVIEW

esa

**HUMAN RESEARCH**
Brain-DTI (G)
Cervical in Space (G)
DNA-mAge (G)
Epigenetic Adaptation (G)
GRIP / GRASP
Immuno-2 (R)
~~SMASH (R)~~
Lumbar Pain in Space (G)
Myotones
Sarcolab-3 (G)
CSA Vascular Aging

**EDUCATION**
EPO Astro-Pi European challenge
EPO Cristoforetti
EPO Task List

**FACILITY**
Bartolomeo
Biolab Maint
Echo SW Update
ESA Powerbank
EPM
PLDR
PPFS

**TECH DEMONSTRATIONS (1/2)**
ACLS (Life Support Rack, LSR)
Anita-2
ASI Acoustic Diagnostics
ASI EVOO
ASI NutrISS
ASI Prometeo
CNES Bioprint FirstAid
CNES Dreams
CNES Food Processor
CNES Lumina
CNES MatISS-3
CNES Ultrasonic Tweezers
DLR Calliope Mini in Space (Education)
DLR Children's Chain
DLR Cimon
DLR Concrete Hardening
DLR Metabolic Space
DLR Touching Surfaces
DLR Retinal Diagnostics
DLR VR-OBT
DLR Wireless Compose-2
Everywear
ICE Cubes

**TECH DEMONSTRATIONS (2/2)**
~~Laplace~~
Surface Avatar

**BIOLOGY**
Biofilms #2
Suture in Space

**MATERIAL SCIENCES**
EML Batch 3.2
MSL Batch 3a
Transparent Alloys
PK-4 (R)

**ENVIRONMENTAL SCIENCE & RADIATION PHYSICS**
ASIM (Ext. Payload)
DOSIS-3D

**FLUID PHYSICS**
CNES Fluidics
FOAM Coarsening 2-3
PASTA

G: Ground experiment
R: Russian crew

# MINERVA RESEARCH COMPLEMENT OVERVIEW*

*upload/downloads only not included

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Lumbar Pain in Space (G)

**EDUCATION**
EPO Astro-Pi European challenge
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EPO Task List

**FACILITY**
Bartolomeo
Biolab Maint
Echo SW Update
ESA Powerbank
EPM
PLDR
PPFS

**TECH DEMONSTRATIONS**
ACLS (Life Support Rack, LSR)
Anita-2
ASI Acoustic Diagnostics
ASI EVOO
ASI NutrISS
ASI Prometeo (aka Antioxidant Protection)
CNES Food Processor
CNES Lumina
CNES MatISS-3
DLR Calliope Mini in Space (Education)
DLR Cimon
DLR VR-OBT
DLR Wireless Compose-2
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# Human Research

**HUMAN RESEARCH**
Brain-DTI (G)
DNA-mAge (G)
Epigenetic Adaptation (G)
Immuno-2 ~~& SMASH~~ (R)
Lumbar Pain in Space (G)

# Brain-DTI - Ground

## SCIENTIFIC BACKGROUND

- A recently developed MR technique called Diffusion tensor imaging (DTI) allows investigating brain tissue microstructure and connectivity, particularly in white matter.
- This non-invasive imaging method probes the diffusion characteristics of water molecules in biological tissue, like the human brain. This allows determining the neuro-anatomy of the brain since water molecules are subject to random thermal motion ('Brownian motion'). This process causes these molecules to move in a translational matter and thus 'to diffuse'.
- However, in biological tissue, such as the human brain, free motion of the water molecules is restricted due to natural barriers, so in this case, water will move more easily in one direction than the other, corresponding with the underlying organization of the tissue.
- Based on neuro-anatomical data and previous work from PET and fMRI studies, DTI can be used to find biomarkers of neuroplasticity.

## SCIENTIFIC OBJECTIVES

1. To obtain knowledge on how astronauts adapt to microgravity at the level of the brain.
2. To use the model of microgravity to gain insight in which specific regions of interest are involved in space motion sickness (SMS), spatial disorientation, vertigo, and convergence of otolith and semicircular canal signals.
3. To link biomarkers of brain plasticity with clinical outcomes that are obtained by motion sickness questionnaires.
4. To use the obtained knowledge on this adaptation of the astronaut brain to microgravity as a starting point to optimize countermeasures against space motion sickness, spatial disorientation, vertigo and convergence of otolith and semicircular canal signals.
5. To use this knowledge as a starting point in the treatment of specific groups of vertigo patients (e.g. visual vertigo syndrome, mal de debarquement, uncompensated peripheral lesions).

## NEED OF SPACE

- Space flight is a model where a 'controlled' and reversal stimulus is given to the human body. Almost no other ethically approvable situation provides such a clear but also immense stimulus to the human body as several months of microgravity.
- It is crucial to understand the adaptation and plasticity of the brain to tackle the countermeasure problems that currently still exist in human spaceflight. Fundamental knowledge of how and where microgravity-induced neuroplasticity takes place may provide key solutions towards countermeasures against the deleterious effects of microgravity.
- Next, it opens a huge domain of research that benefits the general public. Indeed, it is not possible, due to ethical reasons, to study the effect of vestibular disorders pre and post disease for example. Indeed, we can't impose in healthy subjects such a dramatic effect on the vestibular system as obtained by microgravity. Space flight serves as a unique model to gain fundamental insight in neuroplasticity.

# DNA-mAge - Ground

## SCIENTIFIC **BACKGROUND**

- Ageing is the single biggest risk factor for almost all human pathologies other than those caused by infections or due to congenital defects. Presently, the best understood cause of ageing is senescent cells. There are compelling evidence to suggest the existence of another force that drives ageing. This insight comes from careful analyses of modifications that occur on DNA that concluded that DNA methylation ageing is indeed an innate property of cells and tissues.
- It is proposed that this innate aging process is driven by a yet-to-be characterised "epigenetic maintenance machinery" that is thought to be augmented to counteract potential genomic instability that may be instigated by DNA damage.
- It is however a significant challenge to test the effect of DNA damage on epigenetic ageing in humans on Earth. It is an unrivalled opportunity to analyses the epigenetic ages of astronauts who are exposed to greater DNA-damaging cosmic radiation during prolonged space flight.

## SCIENTIFIC **OBJECTIVES**

1. Obtain genome-wide DNA methylation data from humans pre- and post-spaceflight.
2. Gain insight into the relationship between DNA damage caused by low earth orbit radiation and age-related epigenetic changes in humans including the epigenetic clock (Horvath, 2013).
3. Characterize DNA methylation changes associated with spaceflight.
4. Describe genome-wide epigenetic changes associated with spaceflight in humans that can contribute to explain DNAm changes.

The project aims to gain insight into how an epigenetic biomarker of aging is affected by the radiation exposure during prolonged spaceflight and test the hypothesis that DNA methylation age progression is associated with DNA damage. This will help to unravel the relationship between epigenetic changes and the aging process in humans.

## **NEED** OF SPACE

- During spaceflight at ISS, astronauts are exposed to increased levels of radiation (approximately 80 mSV of which approximately half are constituted by protons, which are much more damaging to DNA than terrestrial ionising radiation, which has negligible fraction of proton and are also at very much lower doses (~3mGy/year).
- Thus, astronauts are predictably exposed to increased DNA damage during spaceflight, making this setting unique for investigating the role of DNA damage in the progression of ageing as measured by the "epigenetic clock" and therefore DNAm age.
- This knowledge will be employed to exclude or corroborate potential effectors and variables. As such, the hypothesis that cosmic radiation can perturb epigenetic ageing can be securely tested and concluded but it can only be done as part of a space experiment with the participation of astronauts. The testing of this hypothesis is not only important as a genuine scientific question but also potentially useful for future manned space industries and programmes.

# Epigenetic Adaptation - Ground

## SCIENTIFIC **BACKGROUND**

- The immune system is responsible for sensing pathogens and initiating immune responses against infections. Besides that, it is involved in the bidirectional interaction between the gut microbiota and the brain, and impacts tumour fate in different stages of the disease. Immune cells have complex signalling pathways which are tightly regulated at different levels by epigenetic factors.
- It is largely unknown how long-term space-flight influences changes in the epigenome. It is proposed to identify genome-wide changes of epigenetic modifications associated with enhancers1 acquired during flight in a defined subset of immune cells.
- The epigenomic changes induced by prolonged exposure to microgravity and cosmic irradiation will be compared to alterations occurring under normal gravity in control subjects. This approach will identify pathways involved in altered immune response during long-duration orbital space-flights and establish specific hypotheses concerning potential targets for therapeutic intervention.

## SCIENTIFIC **OBJECTIVES**

It is proposed to investigate global changes in the enhancers responsible for coordinating intrinsic and extrinsic differentiation signals of immune cells after a long-term orbital space-flight.

The objectives are:

1. A mapping of the enhancer landscape pre- and post-flight in specific cell types of the immune system.
2. A correlation of the alterations in the enhancer landscape to changes in the transcriptome.
3. A comparative analysis of enhancer signatures identified across different subjects, which differs in the control subjects comparing crew’s data to a control group.
4. A meta-analysis of space-flight associated enhancer signatures to a large cohort of publicly available dataset, aiming to identify commonalities of the space flight associated signatures to other known diseases.

## **NEED** OF SPACE

- Epigenetic mechanisms allow an organism to respond rapidly to the environment through changes in gene expression. The extent to which environmental effects, especially extended orbital space-flights, can provoke epigenetic responses of immune cells represents a promising area of research for space exploration.
- The results of this project will further extrapolate to other cell types besides the immune system and will inform future studies aiming to prevent or control these epigenetic alterations. It will allow to develop countermeasures that help preventing disruption in the immune system and therapies to help treat diseases during spaceflight.
- Ultimately, by comparing the identified signatures to known diseases it might be possible to identify known and approved drugs, which could represent potential treatment options to counteract space flight associated aberrations of the immune system.

# Lumbar Pain in Space - Ground

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## SCIENTIFIC BACKGROUND

- Exposing humans to microgravity has severe implications on their health. Low back pain emerges in flight and impairs the performance of the astronauts substantially.
- It is assumed that microgravity induces a swelling of the lumbar intervertebral discs (IVD), which causes the low back pain. New reports are claiming, however, that mechanisms involved in stabilizing the spinal cord might be the main reason for the pain, rather than the disc swelling.
- Additionally, astronauts suffer motor control challenged when exposed to different spine loading/unloading. For maintaining the balance of the upright body and the ability to adapt to changes in gravity and/or additional loading, a healthy motor control of the spine is essential). Gravity plays a key role in this spinal motor control system
- Last but not least, it has been shown that movement kinematics change in response to decrease of microgravity but more research is needed to explain the processes behind those changes.

## SCIENTIFIC OBJECTIVES

The objectives of this study are to elucidate the microgravity induced origin of low back pain in astronauts holistically. More specifically, this project aims at:

1. monitoring motion patterns of astronauts and determine the motor control of the spine under various loading conditions pre- and post-flight.
2. revealing the impact of microgravity exposure to the IVDs of the astronauts by conducting experiments on isolated bovine IVDs that have been exposed to similar conditions as the IVDs of the astronauts (Ground Reference Experiment)..

This project will investigate the microgravity-induced changes on the human spine to understand in more detail the above-mentioned knowledge gaps. Measurements of lumbar spinal motor control (stiffness and motion patterns) and ultrasonic examination of the discs (with and without load) of astronauts will be performed before and after mission.

## NEED OF SPACE LAB

- It is anticipated that investigating the effects of changing gravity conditions and axial load on astronaut IVDs and spinal motor control will lead to an improved understanding of the stabilization mechanisms of the spine in general. Furthermore, by investigating isolated IVDs that experienced similar microgravity exposure like the ones of the astronauts (as part of the ground reference experiment), a more profound knowledge on potential degenerative processes on tissue as well as cell level can be obtained.
- The knowledge gained could help to control spinal stability during future space exploration endeavours, thereby potentially reducing the incidence of low back pain and IVD herniation of astronauts.
- New prevention and therapy programs can be developed for astronauts on long-term space missions. These new programs could also help astronauts in unexpected loading situations and improve spinal robustness.

# Immuno-2 – Melfi samples (RSA)

esa

## SCIENTIFIC **BACKGROUND**

- Space flight conditions affect human health due to complex environmental challenges (“stressors”). Stress is a constellation of events, beginning with a stimulus (stressor) that precipitates a reaction in the biological system that subsequently activates physiologic subsystems in the body (stress responses). Stress has long been suspected of playing a role in the etiology of many diseases, and numerous studies have shown that stress can be immunosuppressive and hence may be detrimental to health. Stressful conditions of psychological or physical nature can activate and/or paralyze human innate or specific immunity, respectively.
- Because the immune system is crucial for the humans body homeostasis and the capability to cope with infectious challenges, immune dysfunction may endanger successful mission accomplishment and is considered to be a space mission relevant topic.

## SCIENTIFIC **OBJECTIVES**

1. Assessment of the consequences of stress due to life in Space at μG with increased radiation, including sleep alterations, back pain, moderate sleep hypoxia, mood and psychic stress on immunity and the autonomic nervous system (ANS), glucocorticoids (GC), the endocannabinoid (ECS) and the purinergic (PS) stress-response systems.
2. Association between a) alterations in immunity and b) changes in the ANS, GC, ECS and PS stress-response systems and due to stress in space with alterations in cognitive and emotional functions, (epi)genetic influence and brain morphology.

## **NEED** OF SPACE LAB

- The outcome of this study, due to its multidisciplinary and holistic approach, will provide the basement to suggest suitable countermeasures for the prevention of the unwanted immunological effects of stressful conditions during space mission as well as on earth.
- This integrative study protocol studies the complex physiological adaptation of humans during long-term space missions. Adequate function of humans in space is challenged by psychological/biological (e.g., confinement, sleep, pain) and physical stress factors (e.g., μG, variable oxygenation status, radiation). As a result, the immune system is targeted by a multitude of hormones, hormone-like substances as well as radiation effects, leading altogether to an imbalance of immune functions, which can result in diseases. Further, confinement and other stressors can affect cognitive and emotional functions and may even cause affective problems, which, in turn, can negatively impact immunity. Moreover, in a multi- directional way, also infections and inflammation are stress events that interfere with other physiological systems.

# Education

**EDUCATION**
EPO Astro-Pi European challenge
DLR Calliope Mini in Space

# EPO AstroPi – Columbus/Nadir Window/Mission Space Lab

## SCIENTIFIC **BACKGROUND**

- The Raspberry Pi Foundation is a British charity whose mission is to promote the uptake of computer programming skills in young people and adults. Over 39 million Raspberry Pis have been sold between 2012 and 2021 making it the 3rd most popular personal computer in history after the PC and the Apple Macintosh.
- The education and didactic support for the European AstroPi Challenge involves ESA Education procuring a set of Astro Pi kits which are shipped to registering schools. These kits contain equivalent hardware to the Astro Pi computers onboard the ISS and are used by the participating student teams to develop and test the software for their experiments.
- ESA Education has decided to upload new/improved replacement hardware to ensure ongoing Astro Pi operations, mitigate student software performance issues and add new science capabilities. An annual education program, utilizing the new hardware, has been developed and will run during the 2021/22 school year (September 2021 – June 2022).

## SCIENTIFIC **OBJECTIVES**

Mission Zero will be a non-judged simple coding activity where all teams that submit valid entries will have their code uplinked and run on the ISS. Students are asked to write a simple program which firstly displays a greeting in their own language and secondly measures and displays the ambient humidity onboard the ISS. For this phase, the Astro Pi mark II units will be deployed in Columbus.

Mission Space Lab comprises two thematic missions, with one assigned to each Astro Pi mark II unit:

- Life in Space: Astro Pi mark II unit deployed in COL. Student teams are asked to write programs which can make use of all Astro Pi Mark II sensors. Example topics include Earth's magnetic field, environmental monitoring, life support and microgravity.
- Life on Earth: AstroPi mark II unit deployed in front of an Earth-facing (ex. Node 1 or 2 or WORF) window. Student teams asked to write programs to take pictures of Earth using a camera type of their choice (Visible spectrum or Near IR). Example topics include vegetation analysis, light pollution, and climate change.

## **NEED** OF SPACE LAB

- The European Astro Pi Challenge provides opportunities for students to engage with coding activities in the context of space. The project uses computer coding as a means to do science investigations, and through this, stimulate the curiosity of students, nurture their skills and scientific competences, and motivate them towards further study of STEM subjects.
- The Agency is conscious that it can play a significant role in contributing to a scientifically literate and aware society, and that it has both a responsibility and a vested interest in doing so. The International Space Station (ISS) Education Programme makes use of human spaceflight and the ISS, as a means to capture the attention and the interest of students, to attract them to study, in particular, scientific and technical disciplines, and to appreciate and understand the benefits, challenges, and importance of space for Europe and as a member of a global economy.

# Calliope Mini – use of Astro Pi, ICE Cubes

## SCIENTIFIC BACKGROUND

- The Calliope mini microcontroller on board of the ISS will function as demonstrator for an educational call to German Schools for pupils in the age of 10. Many pupils lack programming skills after completing their school education, even though, in the course of digitalization, skills in the fields of engineering and information technology are becoming increasingly important.
- The star-shaped microcontroller Calliope mini enables playful access to computer science, even at primary school age. This microcontroller contains a number of sensors (e.g. light sensor), LEDs and buttons that pupils can programme via a graphical interface. In this interface, pupils can create programming in the form of blocks, whereby the programme sequences are conveyed without complicated syntax. Due to the different levels of difficulty and good documentation, pupils can learn individually. So far, over 100,000 of these small computers are in use in German schools.

## SCIENTIFIC OBJECTIVES

Running of the following experiments using computer programmes written by RUB/Calliope (use of Astro Pi, SCB, USOC, and SWCB) and listed in descending order according to priority):

1. "Colours of the Earth": Measuring the light spectra and colour intensities of the Earth adding the Grove colour sensor.
2. "UV measuring" with sun light Sensor: Comparing spectrum in orbit vs on ground
3. "Light Sensor": Measuring the ISS orbit from Night to night with the integrated brightness sensor.
4. "ISS acceleration": Measuring ISS acceleration with the integrated acceleration sensor.
5. "Rotation of the ISS": Calliope mini microcontroller's gyroscope is used and while the ISS keeps rotating the angular momentum is tried to be measured.
6. "Environment Monitoring": Measuring temperature, humidity, and CO2 concentration with the added Grove – CO2 & Temperature & Humidity Sensor

## NEED OF SPACE LAB

- While similar in nature to ESA's Astro Pi Challenge, the rational for the CalliopEO activity is twofold: 1) The Calliope mini computer is much more widely used in German schools than the Raspberry Pi, and 2) the Calliope mini coding language is targeted to a more primary age group.
- We can rely on an amount of 100,000 Calliope mini microcontrollers in German Schools and educational institutions all across the country. This is because the Calliope mini microcontroller is much cheaper than a Raspberry Pi and focuses on another target group; primary students (age 9-12). A Raspberry Pi (the computer used in Astro Pi) is without doubt a more powerful device.
- Improving future employment market conditions for STEM roles primarily for the European space industry but also for European society as a whole. Additionally, coupled with Calliope Mini, ESA'S Astro Pi IR Mk2 (referred to Astro Pi IR within this document) will have an added a multi-measurement tool which is accessible for very young students.

# Tech Demo

**TECH DEMONSTRATIONS**

ACLS (Life Support Rack, LSR)
Anita-2
ASI Acoustic Diagnostics
ASI EVOO
ASI NutrISS
ASI Prometeo
CNES Food Processor
CNES Lumina
CNES MatISS-3
DLR Cimon
DLR VR-OBT
DLR Wireless Compose-2
ICE Cubes
~~Laplace~~
Surface Avatar

# Life Support Rack (LSR) – Move to Node 3

## SCIENTIFIC BACKGROUND

- ACLS stands for Advanced Closed Loop System and includes a regenerative physico-chemical life support system which:
  - provides breathable oxygen for a crew of 3
  - reduces carbon dioxide (CO2) from the ISS atmosphere in concurrence with ISS ECLS and
  - converts hydrogen (H2) with CO2 to methane (CH4) and water (H2O)
  - is able to provide the CO2 removal function and the O2 generations function independently from each other in so called stand-alone operational modes.

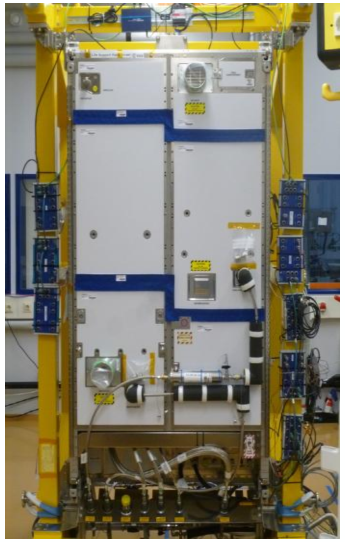
## SCIENTIFIC OBJECTIVES

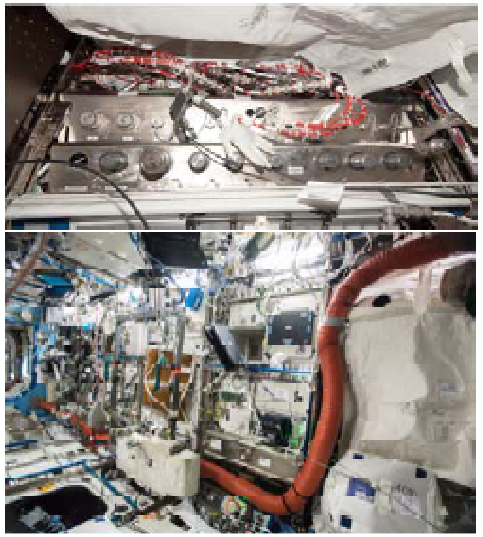
The Advanced Closed Loop System (ACLS) rack is a European Space Agency (ESA) designed life support rack that will demonstrate technology in CO2 removal, O2 production, and H2O production. ACLS will be installed at the LAB1P1 location. After installation, the ACLS rack will undergo a 1 month commissioning phase to verify on-orbit performance of each subsystem.

After the commissioning phase, the goal set by the ESA and the ECLS SMT is to achieve 1 year of cumulative operations in the first 2 years ACLS is installed. This run-time is desired to prove the reliability of the technology for potential use in future exploration missions.

Upon successful demonstration of the ACLS technology, all hardware is expected to remain on-orbit for the duration of the ISS available to provide an operational function in agreement with the ISS Vehicle Office.

ESA is responsible to manage procurement & upload of spare parts and the disposal of consumables, and it will be under system allocation.





# Anita-2 – ER-11B, LAB1P4

## TECHNICAL **BACKGROUND**

- ANITA-2 (ANalyzing InTerferometer for ambient Air) is a FTIR (Fourier Transform InfraRed) spectrometer that has the capability to monitor simultaneously 32 gaseous compounds, with a high time resolution (i.e. one sample every 5 minutes).
- ANITA flew on ISS as a technology demonstrator in summer 2007 with successful measurements and operations the mission lasted 11 months in total.

## SCIENTIFIC **OBJECTIVES**

Monitor the concentration of a series of compounds for a minimum period of three months. The lifetime of ANITA-2 is at least 8000h, i.e. one year continuous operation.

The long-term perspectives for ANITA2 are:

- Demonstrate the robustness of the improved technology at the ISS in a representative operational environment: ISS as a test bed for technologies for future exploration.
- Develop small European niches in the area of life support based on state of the art technology.
- Reiterate the NASA interest in the European technology for air contamination monitoring (no match in the US).
- For ESA to include ANITA2 technology in future cooperation with the IPs for long duration human exploration activities either as recurring items or improved ones

## **NEED** OF SPACE

- Demonstrate the air monitoring capabilities under realistic conditions in a space habitat, including the dynamic variation of air contaminants caused by astronaut activities, scientific experiments, degradation of space hardware over time, microbial activity etc.
- ANITA is a highly sensitive FTIR air contaminant analyser which in future evolution will allow automatic monitoring of air quality in open atmosphere and closed habitats.
- Autonomous, automatic air monitoring is a must for long term space missions. ANITA-2 is advantageous for long term exploration missions as it does not require any consumables.

# ASI Acoustic Diagnostics – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Some astronauts reported mild hearing damage in the past. Occupational health studies, performed on a very large number of industrial workers exposed to different levels of noise suggest that the noise levels that are actually measured on board the ISS (60-70 dBA) can hardly be responsible for any significant hearing loss. Therefore, it would be interesting to assess any adverse effect on hearing, which would be associated with peculiar mechanisms related to micro-gravity and/or its synergistic interaction with exposure to the moderate noise levels of the ISS.
- This experiment is the first aiming at monitoring the hearing function on board the ISS, exploiting the diagnostic potential of otoacoustic emissions (OAEs), which are particularly sensitive for the early detection of mild hearing loss.
- The PI has developed in the last decades advanced OAE acquisition and analysis systems, based on analytical and numerical solutions of nonlinear cochlear models, which significantly enhance the sensitivity of OAE-based diagnostic techniques.

## SCIENTIFIC **OBJECTIVES**

The main goal for this experiment is:

1. Pre-, post-, and in-flight assessment of the hearing functionality of astronauts, as a function of the time spent in the micro-gravity noisy environment of the ISS.

Secondary goals are also:

1. Optimization of a portable OAE measurement device, capable of accurate objective diagnostics of hearing in any other noisy environment.
2. Development of new data analysis algorithms to improve the sensitivity and specificity of the OAE-based hearing tests.

## **NEED** OF SPACE

- Monitoring the effect of the micro-gravity and noisy space environment as a function of time spent on board the ISS is important to detect and quantify early symptoms of mild hearing impairment, either temporary or permanent, which could lead to more significant impairment in the case of longer term missions.
- Therefore, the results of this study should help understanding whether hearing safety is a critical issue for the design of longer term missions in the future, and what countermeasures could be adopted, if necessary. Due to the noisy ISS environment, advanced OAE-based tests are the only practical available option for accurate in-flight diagnostics of hearing since it uses high level stimuli (65-55 dB), which are not perturbed by ambient noise.
- OAE diagnostics are objective while psychoacoustic audiometric techniques use pure tone signals around 0dB, which need to be perceived by the astronaut without disturbance from external noise, impossible on the ISS.

# ASI EVOO – Stand-alone

## SCIENTIFIC **BACKGROUND**

- The Extra Virgin Olive Oil (EVOO) in Space investigation studies the effects of exposure to the extra-terrestrial environment on extra virgin olive oil. The physicochemical, sensorial and nutritional characteristics of veiled and filtered extra virgin olive oils are compared to those on the ground.
- The nutritional value and the health promoting effects of olive oil rely on its favourable nutrient composition, including oleic acid (OA), as the most abundant fatty acid, fat-soluble vitamins, and phenolic compounds. The latter are recognized as contributing to the positive health effects related to the consumption of EVOO. The European Food Safety Authority says that “a daily intake of 20 g of olive oil, which contains at least 5 mg of hydroxytyrosol and its derivatives provides the expected beneficial effects”.
- Recently, new research has shown that olive-derived phenols can exert pharmacological effects in the prevention of inflammation and oxidative stress.

## SCIENTIFIC **OBJECTIVES**

The objective of EVOO in Space is to study the impact of exposure to microgravity and radiation conditions aboard the International Space Station (ISS) on extra virgin olive oil physicochemical, sensorial, nutritional and microbiological characteristics, to observe the composition of olive oil secondary metabolites, such as phenols and tocopherols (vitamin E) as affected to microgravity conditions, and to gather new information concerning olive oil composition and shelf-life to new environmental conditions.

## **NEED** OF SPACE

- The consumption of EVO oil is certainly beneficial for astronauts’ health during long term space missions. It would therefore be important to understand whether EVO oils would retain their properties when stored into spacecraft exposed the space environment for long period of time. This is even more important when considering the future long duration mission for extra-terrestrial exploration.
- The consumption of EVO oil could certainly be beneficial for astronauts’ health during long term space missions, if we can assess whether EVO oils would retain their properties when stored into spacecraft exposed the space environment for long period of time. Crews on future long-duration space missions need to eat foods rich in antioxidants and anti-inflammatory compounds such as olive phenols and olive fatty acids and tocopherols. These investigations add to a growing body of research on how the Space environment affects food and, in particular, extra virgin olive oils.

# ASI NutrISS – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Long term space-flight induces relevant changes in body composition and almost invariably leads to a 1-to-5 % loss of body mass. Results from bed rest research, a model simulating the microgravity condition in space, and from a few studies during human spaceflight, showed the importance and the efficacy of nutritional intervention to counteract or limit the detrimental effect of microgravity on metabolism and skeletal muscle. Changes in fat mass (either loss or deposition) can accelerate muscle atrophy in microgravity.
- A diet maintaining a near-neutral energy balance and/or increasing protein intake can limit microgravity-induced bone and muscle loss and insulin resist ance.
- The bioimpedance analysis was never used to monitor and prescribe countermeasures during spaceflight. Optimal monitoring and feedback tuning of nutrition would allow a sustainable metabolic control of microgravity drawbacks on musculoskeletal systems in astronauts.

## SCIENTIFIC **OBJECTIVES**

The present proposal is a proof of concept aimed at:

1. Defining programs to implement timely nutritional suggestions during the long-term spaceflights, based on body composition values
2. The time course of in-flight musculoskeletal changes will allow an evaluation of the effectiveness of such feedback
3. Optimization of astronauts' performance and quality of life
4. Speed-up and improve the astronaut re-conditioning phase.

## **NEED** OF SPACE

- This scientific and operational proof of concept aims to shed light on pathophysiology of changes in body composition during long-term spaceflight. These achievements will improve physical performance and quality of life of the astronaut during spaceflight and optimize the astronaut recovery-phases on Earth after landing. Moreover, the obtained experimental data could implement clinical management of malnourished and/or obese immobilized patients, therefore improving quality of human life on Earth.

# ASI Prometeo (Antioxidant Protection) – Kubik

## SCIENTIFIC **BACKGROUND**

- Oxidative stress (OS) is the mechanism at the base of many deleterious effects of spaceflight, involving exposure to microgravity (MG) and cosmic radiation (CR), and it is inherent to the genesis of several pathological conditions on Earth (among which Crohn's and Parkinson's diseases). The central nervous system (CNS) is the most vulnerable target of OS.
- This project focus is on neuronal cells involved in cognitive and motor functions both in space, where any behavioural impairments pose significant risks to manned expeditions, and on Earth, where dopaminergic neuron loss underlying Parkinson's disease (PD) progression still requires effective contrast. This project in particular aims at exploring the connection between spaceflight and OS, by discriminating the effects of MG from those of CR, and at providing nanotechnology countermeasures to short- and potentially long-term alterations of the CNS due to spaceflight-induced reduction/oxidation (redox) reaction imbalance.

## SCIENTIFIC **OBJECTIVES**

1. The primary objective of this research project consists in the achievement of an innovative nanotechnology countermeasure based on polydopamine against degeneration of neurons induced by OS, both associated to MG and CR during spaceflight and to neurodegenerative disease onset/progression on Earth. This project therefore aims at elaborating effective, safe and controllable therapeutic tools for preservation /maintenance/promotion of architectural and functional integrity of the nervous tissue.
2. Strictly related to the primary one, the secondary objective lies in the achievement of multifunctional tools able to compensate dopaminergic depletion. This objective will be pursued through several coordinated and possibly iterative steps of preparation, validation, and analysis, implying actions that will mainly be conducted in the IIT laboratory.

The project represents an attempt at providing innovative nanotechnological countermeasures to those degenerative processes sustained by OS, involving crucial neurons responsible for cognition and behaviour.

## **NEED** OF SPACE

- A large gap still exists in the comprehension and distinction of the effects of real microgravity from those of simulated microgravity (SMG) and of cosmic radiation on the CNS. A short literature review clearly evidenced limitations of the currently adopted methods to simulate MG and CR on Earth, supporting the need of corroborating investigations on ground with spaceflight experimentations.
- These studies evidence the stringent need to perform experiments implying exposure of nervous models to both real MG and CR, as only achievable by permanence on board spaceflight vessels, in order to complement studies performed on ground and elaborate suitable countermeasures to motor and cognition deficits due to OS-associated neurodegeneration in space.

# CNES Food Processor – Stand-alone

esa

## SCIENTIFIC BACKGROUND

- One of the objectives of the Advanced System for Space Food (ASSF) project, part of the CNES roadmap "Nutrition for Exploration" is to develop an equipment (i.e. the Food Processor) allowing astronauts:
  - to cook meals in adequation with their gustative preferences and their nutritional needs,
  - to give the astronauts the pleasure to eat them.
- The objective is to have the first operational model of the Food Processor ready for exploration flights, the final systems will be able to manage food stock, prepare recipes for the crew in a secured way.
- With Food Processor, the intent is to perform a technological demonstration: the first prototype will be able to make one recipe: i.e. a chocolate mousse.

## SCIENTIFIC OBJECTIVES

The objective of the present experiment is to test the equipment (demonstrator) with one specific recipe using cooking basic functions for Alpha mission (beating egg whites, mixing products); then the fully functional equipment (weigh, mix, knead, heat, dry, cook, colour, rehydrate) will be developed and available for exploration flights.

Data will be collected thanks to:

- A questionnaire provided to the crew (using the EveryWear application) to get their feedback about the quality of the produced recipe (taste, colour, texture…).
- Pictures taken by the crew, of the produced recipe. Pictures can be taken using the EveryWear Application (preferred) or the ISS camera (TBC).

## NEED OF SPACE

- This equipment is developed to help astronauts to cook meals adapted to their nutritional needs and give them some pleasure with eating time. This equipment will cook for them in a secure way respecting space/microgravity related restrictions.
- This equipment will cook for them in a secure way to respect special restrictions of in space area. This equipment and related activities (cooking) may also improve and reinforce social interactions and the crew team spirit within exploration long duration flights.

# CNES Lumina – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Optical Fiber Dosimenter experiment is an active dosimeter based on optical measurements on different types of optical fibers.
- The Lumina sensor includes two optical fiber coils of several hundred meters which are used as an active dosimeter. These fiber coils are cylindrical and conduct light with minimum internal attenuation, allowing the signal of incident particles to easily reach the sensor (photo diode). When exposed to space radiative environment, optical fibers experience Radiation Induced Attenuation. Measurement of this attenuation (comparison between two optical path from a laser diode used as a source and a photodiode as a light receiver) is directly linked to the total ionizing dose.
- Dose monitoring is active as the light source remains permanently ON. For a given set-up, sensitivity of the apparatus is governed by the length of the fiber coil. The longer the fiber, the more sensitive the dosimeter.

## SCIENTIFIC **OBJECTIVES**

1. The main objective is to consolidate the concept of RIA measurement as a TID indicator in realistic space conditions: particle spectrum (in terms of type, flux, energy), volume constraints, mechanical levels, remote operation (reliability, low band width required), power consumption, interface.
2. The second objective is to increase scientific knowledge on fiber behaviour when exposed to low dose rate for a long time in space.

ISS measurements will provide precise indication on the performance of fibers in space. The first information is the actual sensitivity of fibers to the space radiation spectrum, compared to laboratory models. Another output of the mission is the stability of the RIA response over time. As the experiment will remain onboard for a relatively long duration at a low dose rate, measurements will give a feedback on the dosimeter performance evolution. This might be useful to prepare instruments dedicated to interplanetary exploration missions.

## **NEED** OF SPACE

- A thorough understanding of radiation exposure is a key issue for space exploration. The principle of RIA measurement on optical fibers as an indication of the total ionizing dose (TID) has been validated many times on particle accelerators and radioactive sources on Ground.
- The method was proven to be very reliable and sensitive to all sources of particles (electrons, protons, photon X and Gamma, neutrons) at various energies. Yet the environment encountered in space is unique. It is very dependent on the orbit, the solar activity, the spacecraft shielding etc. These conditions cannot be reproduced on earth, hence the need for a flight proven RIA dosimeter concept is needed.
- Fiber dosimeters are destined to monitor and detect dose variations on various types of satellites. The experiment on the space station will be exposed to a real radiative environment providing data in space conditions.

# CNES Matiss-3 – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Matiss (Microbial Aerosol Tethering on Innovative Surfaces in the international Space Station) is a family of experiments that started in 2015, in the context of the first space mission of Thomas Pesquet, Proxima. Matiss initial versions aimed to demonstrate that surfaces with hydrophobic properties could be a possible answer applicable at spacecraft scale by reducing the contact area of water droplets with surfaces.
- Matiss-3 aims to test new surface treatments using new technologies and analytical tools, as the current sample holder only allows morphological analysis of the contamination using light microscopy techniques.
- At this stage, modifications of the sample holder used until now are proposed to allow more in-depth analyzes of the contamination of the exposed surfaces and, in particular, the identification of the particles by the use of Raman spectroscopy techniques, in a first phase, and then by the use of X fluorescence in a second phase.

## SCIENTIFIC **OBJECTIVES**

- Strategy on Matiss-3 is to focus on microorganisms over different contamination sources by testing new antimicrobial coatings in the ISS. Using hydrophobic coatings will help to target microorganisms via their water droplets.
- Selected new coatings will precisely target microorganisms rather than bigger particles, in order to define and design new control systems of biological contamination for the exploration.
- Matiss-3 will use a modified sample holder from the versions used for the previous parts of the project. The new sample holders constitute a notable evolution by allowing identification of contamination via Raman spectroscopy and X-ray fluorescence methods. Flight sample holders will integrate innovative surfaces supplied by CEA-Leti.
- Post-flight analysis of the sample holder will be conducted by Raman and X spectroscopy in order to validate the instrumental concept and the associated analysis.

## **NEED** OF SPACE

- Antimicrobial surfaces are currently used on Earth in a number of sectors, such as healthcare, food industry, water industry, textiles. Consequently, numerous tests and standards exist for evaluating antimicrobial surfaces for terrestrial applications. However, they are not being adequate for closed habitats environment, and do not take into account parameters specific to manned spaceflights such as environmental conditions including radiation effects and impact of microgravity on the attachment mechanisms of contaminants on modified surfaces.
- Studies are currently being conducted to derive standard requirements for the evaluation of antimicrobial surfaces in the very specific context of manned spacecraft, but the complexity of the environment need to be derived in precise test parameters. In particular, the concentration and content of test inoculum lead to complex and hardly reproducible tests conditions, calling for in-situ data collection to support theoretical studies.

# DLR Cimon – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Key features of a successful interplanetary mission will critically depend on individual adaptation and performance, crew interactions and method of psychological countermeasures (Manzey, 2004). Because of that, new examination methods or innovations are needed, which autonomously detect stress or other negative attributes.
- The designed Crew Interactive MObile companioN (Cimon) was proposed as the first intelligent artificial companion in space. By operating as a link between Space and Earth, Cimon shall improve the relation between the crew and ground control.
- Cimon provides the possibility of clever conversation and provision of information to the crew by accessing the internet which is one of the main keys to be accepted by the astronaut. This will assure the technology readiness of Cimon to serve as a tool for psychological countermeasures.

## SCIENTIFIC **OBJECTIVES**

Technology Demonstration of free flying unit:

1. baseline setup of Free flying unit is successful under µg conditions
2. orientation towards the crew is achieved with the use of verbal commands by the crew
3. translational movement by command of crew
4. evasive movements are initiated under µg with the ideal goal to avoid an unintentional collision.

Cimon shall also demonstrate the feasibility - how and to which extent a "mobile companion" can:

1. support the crew in their daily tasks (Assisted crew activity/Maintenance)
2. perform mobile video documentation and assist during complex science tasks (Science support)
3. facilitate training of specific motor skills (Skill Training)
4. promote educational outreach programs.

## **NEED** OF SPACE

- Cimon is one of the first attempts on the way to achieve an intelligent mobile crew assistant. Which might have manipulating capabilities in the future. To test each of the technologies that are implemented in Cimon, a space experiment may not seem necessary. Nevertheless, Cimon should be regarded as an integrated technology demonstrator that shall be tested in the real space environment under microgravity conditions directly interacting with crew to assess acceptance by the astronaut corps. Although interaction with the soft- and hardware per se would be possible on Earth, Cimon is designed to specifically work as a free flyer in the unique situation in Space.
- During the first spaceflight of Cimon, the efficiency of assistance as well as the user friendliness and convenience need to be assessed to make a statement about feasibility, applicability and worthiness of future technological development of such a free – flying device. As a first step after commissioning a board, the free-flying capabilities of Cimon shall be demonstrated and investigated on the ISS.

# DLR VR OBT – Stand-alone

## SCIENTIFIC **BACKGROUND**

- On-board training (OBT) materials can take many forms and can often include renders and animations of complex hardware or crew tasks. As the exploration programme focuses on destinations beyond low earth orbit, training time on ground remains a scarce resource and the need for short notice effective training persists despite new constraints. As such, the need to deliver effective and efficient training on-board is growing both in relevance and significance.
- Unlike other media, virtual reality enables users to interact with and observe complex three-dimensional objects, phenomena and data. In this regards, virtual reality may be a crucial technology supporting future training needs.
- The VR-OBT technology demonstration aims to deliver on-board training via Virtual Reality. Specialized training content shall be developed for and delivered via a Virtual Reality Head Mounted Display (HMD). VR-OBT seeks to determine the efficacy and efficiency of delivering such content.

## SCIENTIFIC **OBJECTIVES**

1. Evaluate the efficacy of OBT delivered via a VR HMD in terms of the capacity of the crew member to carry out the trained tasks.
2. Evaluate the efficiency of OBT delivered via a VR HMD in terms of the time required to carry out the OBT and the time and resources required to develop the VR OBT content relative to 'standard' OBT content.

## **NEED** OF SPACE

- The efficacy of Virtual Reality as a medium for on-board training has yet to be established. On ground, VR as a tool for training is entering mainstream utilization with multiple large organisation integrating the technology as part of their standard business.
- Parabolic flights are not suitable due to the limited period of micro-gravity, which would be insufficient to deliver suitable training. The on-board environment poses a number of unique logistical and technical challenges. These challenges include, but are not limited to: user motion tracking and localization in micro-gravity, safe use of immersive VR, and accurate training appropriate representation of the on-board environment utilizing VR HMDs.
- Virtual Reality, utilized in the space environments, may represent a crucial tool allowing crew members to understand intricate three-dimensional information central to important tasks. Unlike the two-dimensional screens of mobile devices and laptops, modern VR HMDs are capable of displaying the third dimension of depth with exceptional fidelity.

# DLR Wireless Compose 2 – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Wireless sensor networks (WSN) are already well established in industrial and safety-relevant applications to ensure a simple and reliable communication, even across long distances. The Wireless Compose-2 technology demonstrator is based on the technology used for the Wireless Compose experiment in 2018. Wireless Compose-2 consists of a technology demonstration of a wireless network, analyzing energy harvesting capabilities, localization and a sensor equipped shirt for a ballistocardiography experiment.
- The focus lies on the scientific experiment BEAT (Ballistocardiography for Extraterrestrial Applications and long-Term missions), which is a demonstration of novel ballistocardiography (BCG) sensors monitoring important cardiovascular parameters in a microgravity environment.
- The sensors are implemented into SmartTex, which is a Smart-Shirt with integrated sensors, wiring and a communication module to transmit the scientific data via the wireless link to the base station.

## SCIENTIFIC **OBJECTIVES**

1. The main scientific goal of the experiment is provision of a flexible and adaptable wireless network infrastructure to conduct and execute low-power, low-weight and wireless experiments on the ISS. For the demonstration, Wireless Compose-2 will operate several experiments whereas the focus lies on the scientific and medical BEAT experiment, which evaluates and demonstrates the BCG sensing and the impact of the space environment on the cardiovascular system. Here, also a newly developed Smart-Shirt “SmartTex” will be used comfortably to integrate the sensors onto the body conveniently.
2. Additionally, Wireless Compose-2 will also demonstrate a newly developed IR-UWB hardware to enable precise localization applications and it will analyse the energy harvesting potential on the ISS. Since Wireless Compose failed to send data in energy harvesting mode, Wireless Compose-2 will provide several sensors to gather more information of the internal light sources and its energy harvesting potential

## **NEED** OF SPACE

- The ISS is chosen specifically as a testbed to demonstrate the capabilities of a WSN for the future and post-ISS activities. The evaluation of the experiment will help to analyse potential uses of the technology for unmanned and manned space flight and to derive obstacles and limitations for the operations in very specific environments which are comparable to the ISS modules. It will enable new smart technologies for the monitoring of critical health parameters of an astronaut and it will provide a new concept to navigate free-flying objects with accurate resolutions of less than 1cm in an enclosed micro-gravity environment as expected in the ISS modules.
- The gathered data of the BEAT experiment are of high interest e.g. for further scientific examinations on ground for future health-monitoring systems in space and a possible technology transfer in terrestrial applications. The experiment will also acquire highly important physiological data about the cardio-vascular parameters of humans and its change during a long period in zero-g.

# ICE Cubes – Stand-alone

## SCIENTIFIC **BACKGROUND**

- **SpaceOMIX II.** Six tubes will contain dried blood spots with RNA preserving agent. The full RNA transcriptome will be analyzed before and after space flight on the dried blood spots cards and will be compared to fresh blood here on earth from the same patient .
- **AIM**. The concept of system that we have designed consists of a pump which simulates the human heart and attached to the output of the pump a model of the aorta. This model is composed of the ascending aorta, which is the output vessel from the heart. The aortic tract branches into three main vessels; the left subclavian artery, the left common carotid artery and the brachiocephalic artery. The aorta continues with the descending aorta and in addition to these vessels the brachiocephalic artery splits into two blood vessels: the right common carotid artery and right subclavian artery. From the aorta the fluid enters a reservoir where the fluid is collected and is then taken by the pump. The two sensors measure the mass flow in the two carotid arteries.
- **Gravitational Effects on the Faraday Interfacial Instability.** The experiment aims at studying the instability may arise when two immiscible liquids are subject to an oscillating acceleration field applied perpendicular to their common interface. This instability is manifested by the sudden generation of waves and fluid motion at the interface and is termed “the Faraday instability”. The view to be taken is that the bilayer is shaken at a set frequency, ω, and the amplitude of the motion, A, is incrementally increased until the instability occurs. The instability is a result of resonance between the imposed or parametric frequency of oscillation and the system’s natural frequency. Now the natural frequency and, therefore, the threshold amplitude are affected by gravity and so it is the aim of this project to investigate the effect of gravity on the threshold and nature of the Faraday instability.

## SCIENTIFIC **OBJECTIVES**

- **SpaceOMIX II.** The results can be a game changer for astronauts working in space - and conduct heel or finger prick testing stored on absorbable paper cards - and can be grounds of a life sciences biobank for the visiting Astronauts vs opposed having to take 3 ml of whole blood , freezing and storage space. The dried blood spots cards will ensure efficient space management and storage for a longer term.
- **AIM**. The data are stored and then retrieved every day using internet connection. The data will be also compared with the data from the test on the ground made before the launch. During the 4 months, we will change the parameters of the pump in order to perform the experiment under different conditions
- **Gravitational Effects on the Faraday Interfacial Instability.** A so called ”Faraday Cell”, containing two immiscible liquids, is first centrifugated, to de-mix the two liquids (preparatory step), and then exposed to “vertical” oscillations, at different frequencies and amplitudes, in the direction orthogonal to the separation surface of the two liquids.

# Surface Avatar – Stand-alone

## SCIENTIFIC **BACKGROUND**

- Robotic assets for exploration and infrastructure development on heavenly bodies avoid dangerous and time-consuming EVAs and lowers the barrier to entry to the planet surface. Effective command of these assets from orbit is essential: an operator should be able to supervisorily control semi-autonomous robot teams, but at the same time also be able to "dive inside" a particular robot and control them as an avatar. This is possible from orbit but not from earth, due to the time delay and hence stability/transparency issues.
- The concept of commanding on these different levels and seamlessly transitioning between them is called "Scalable Autonomy". From previous experiments we have seen the need for this in space teleoperation. Having reached the limits of the insights that can be gained on earth, many questions still need answering before we can deploy and control robots on a heavenly body from orbit.

## SCIENTIFIC **OBJECTIVES**

Multi-modal, holistic UI command of individual dissimilar robots at changing scales of autonomy.

- A UI used for commanding a variety of robots at various scales of autonomy should therefore be holistic: switching command between two robots, between different scales of autonomy, and between planning and commanding, should be easy and transparent.

Extending multi-modal UI command to team(s) of dissimilar robots.

- Having multiple, dissimilar robots work together on a task increases the range of tasks that can be performed. Commanding multiple robots, however, should introduce as little additional complexity in the UI for the crew as possible. In order for telerobotic exploration, building and maintenance to be practical, a single human operator will need to manage a team of robots without excessive physical or mental workload.

## **NEED** OF SPACE

It was reached a barrier with respect to the insights that can be gained from terrestrial research. This is due to two main reasons:

- The first is the physical conditions in which the operator works. Not only does the communication channel between the robot and operator have high latency, low bandwidth and poor quality, but the astronaut must remain in a confined space with limited company. Their only communication is with the scientists and engineers responsible for the system, many of whom they have not met or only met briefly a long time prior.
- The second is the known fact that sensorimotor performance is degraded in microgravity even after long acclimatisation. This makes it imperative to investigate and draw insights for teleoperation with haptic feedback in microgravity, with operators who have had time to acclimatise themselves (i.e. not on a parabolic flight). In addition, the difference between gravity on earth and microgravity in space may create a cognitive dissonance.

# Biology

**BIOLOGY**
Biofilms #2
Suture in Space

# Biolfilms #2 – Kubik

## SCIENTIFIC **BACKGROUND**

- To guarantee the health of the astronauts, several prevention, monitoring and mitigation measures have been implemented to control microbial contamination in human-tended space stations. The microbial populations mostly come from the crew (skin, upper respiratory tract, mouth and gastrointestinal tract) but also from the surrounding on-board equipment.
- The hampered immune system of astronauts combined with limited treatment and isolation, and no immediate return to Earth, reinforces the requirement to stringently control microbial contamination.
- Antimicrobial metals like silver, copper and their alloys are currently the subject of investigation as antimicrobial surfaces. Such materials provide a long-lasting, intrinsic antimicrobial effect and do not require additional maintenance. These constraints render such types of materials ideal candidates for preventing microbial contamination on limited accessible research stations such as the ISS.

## SCIENTIFIC **OBJECTIVES**

The goal of Biofilms is to compare how biofilms are formed in low gravity in a liquid environment on inhibiting and non-inhibiting metal surfaces. Within a single experiment,

1. Different microbial species will be tested
2. Different metal surfaces will be cross-compared
3. The biofilms shall be growing on board of the ISS at three different glevels: 1g (for reference), zero-g and Martian-g.

After the flight, the biofilms as well as the surfaces they grew on will be subjected to an in-depth analysis comprising various microbiological, genetic, molecular biological, chemical and materials-science investigations. Expectedly, the data generated will be indispensable for the future selection of antimicrobial materials in support of astronaut-/robotic-associated activities in space exploration.

## **NEED** OF SPACE

The required low-gravity conditions cannot be created on ground. To provide microgravity and Martian gravity for a longer period of time the proposed experiment must be conducted in space.

# Suture in Space – Biolab

## SCIENTIFIC **BACKGROUND**

- Providing adequate medical care in space, close to the terrestrial standards, requires in depth studies and careful planning. Injury due to accidents, traumatic events or unexpected emergency surgery as a result of the growing number of high-risk activities could increase in future long-term space missions. Because evacuation times to Earth might be very long, the need for implementing trauma care/surgery in space increases and wound healing must be regarded as a major problem, since it is critical for survival.
- Wound healing is a multistep process that starts, after an injury, with an inflammatory phase followed by a remodeling phase and, in the case of healing by second intention, by wound contraction due to the presence of myofibroblasts. Although some studies have demonstrated that surgical procedures are feasible in μg, suture behavior of and the healing process in conditions of mechanical unloading are poorly known.

## SCIENTIFIC **OBJECTIVES**

The aim of the proposed experiment is to study the behaviour of sutures and wound healing in microgravity, in terms of ability of the wound's margins to merge, to restore the tensile strength in the tissues around the wound and to favour healing.

This is to better understand the role of mechanical stress in the healing of sutured wounds and to define requirements for suturing materials and techniques suitable to μg conditions.

The goal of the experiment is to gain information on:

1. the influence of gravity on the behaviour of suture and wound healing;
2. how the suturing materials and techniques can be adapted to the μg environment, thus developing strategies to favour wound healing in space;
3. how to improve suturing techniques on Earth in order to promote wound healing avoiding fibrotic scars.

## **NEED** OF SPACE

1. The team wants to verify in in vitro tissue models exposed to real μg some results obtained in simulated μg studying fibroblast and endothelial cell cultures.
2. Using ground facilities to simulate microgravity in tissue samples with dimensions of the order of centimetres may lead to errors and unreliable results.
3. The whole in flight experiment could hardly be implemented using facilities for simulating μg conditions, due to the experiment requirements: hardware volume, duration of the experiment, etc.
4. Experiments carried out using facilities to simulate microgravity can be affected by shear stress and other problems. Shear stress directly acting on the sutured wound could be an important bias for this experiment.
5. A simulation of μg conditions does not simulate space environment: in space not only unloading but also cosmic radiation can influence the wound healing process and affect the suture behaviour.

# Material Sciences

**MATERIAL SCIENCES**

EML Batch 3.2

MSL Batch 3a

Transparent Alloys

PK-4 (R) Science Campaign(s)

# EML Batch 3.2 – EML facility

## SCIENTIFIC **BACKGROUND**

- The EML electromagnetic levitator is a multi-user facility that provides containerless melting and solidification of electrically conductive, spherical samples, under ultra-high vacuum and/or high gas-purity conditions. Each sample container will fit 18 samples, defined as a 'Batch'.
- Heating and positioning of the sample is achieved by electromagnetic fields generated by a coil system. The EML supports research in the field of meta-stable states and phases and measurement of high-accurate thermophysical properties of liquid metallic alloys in the stable and undercooled state. The max processing temperature is 1,950 ° C. The former field covers investigations of nucleation and solidification kinetics in undercooled melts and developing microstructure. Thermophysical properties include surface tension, viscosity, melting range, fraction solid, specific heat, heat of fusion, mass density and thermal expansion, and thermal transport properties as the total hemispherical emissivity and effective thermal conductivity.

## SCIENTIFIC **OBJECTIVES**

The aims of the Batch 3 experiments covers 12 individual projects.

Topics are: morphology of chill-cooled industrial steel, thermophysical properties of supercooled Ti-Zr- Ni liquids of different composition, solidification, thermophysical properties and electrical conductivity in liquid of the eutectic system formed by the phases CoSi and CoSi2, metastable phase formation of magnetic alloys, study of nucleation, microstructure investigation and determination of the growth velocity of Al-Ni, Al-Fe, Al-Cu and Si-Ge samples, influence of melt convection on phase selection in technically important peritectic alloys, thermophysical properties and electrical conductivity of liquid Si-Ge semiconductor alloys, thermophysical property (specific heat, density, surface tension and viscosity, electrical conductivity) measurements of industrial alloys, influence of melt convection on phase selection in technically important eutectic and peritectic alloys, nucleation and supercooling of glass- and quasicrystal-forming alloys, thermofluid and magnetohydrodynamic effects in liquid metal samples.

## **NEED** OF SPACE

All sample systems have been tested in numerous Parabolic Flight Campaigns using the TEMPUS Parabolic Flight Facility of DLR in preparation for the EML missions.

# MSL Batch 3a – MSL facility

## SCIENTIFIC **BACKGROUND**

- The MICAST and CETSOL projects aim at directional solidification of metallic alloys to identify the gravity-induced solidification phenomena and to develop analytical and advanced numerical models.
- Using the comparison of ground-based and microgravity experiments will pinpoint the effect of gravity and increase the accuracy of these computer models. MICAST focusses on solidification of AlSi-based alloys with different compositions, studying dendritic growth and the formation of intermetallic phases, eutectic growth and primary Si-phases in diffusive conditions and with forced melt flow. Within CETSOL, the columnar growth and the columnar-to-equiaxed transition as well as fragmentation effects will be investigated in refined AlCu alloys applying diffusive boundary conditions in microgravity without melt flow and sedimentation.
- The experiments of Batch 3a will make use of the Low Gradient Furnace (LGF) and the Solidification and Quenching Furnace (SQF).

## SCIENTIFIC **OBJECTIVES**

1. MICAST. The project is dedicated to (1) systematic analysis of the effect of convection on the evolution of the microstructure in technical Al-alloys, (2) investigate flow effects on binary and ternary variants of technically important aluminium casting alloys, and (3) combine advanced theoretical and experimental research methods on ground and in space.
2. CETSOL. The project is dedicated to deepen the quantitative understanding of the physical principles that govern microstructure formation with particular attention paid to the columnar-to-equiaxed transition (CET) in technically relevant cast alloys by directional solidification experiments.

## **NEED** OF SPACE

1. In order to perform experiments in space, those projects will make use of the Materials Science Laboratory (MSL). The Materials Science Laboratory (MSL) is part of the Materials Science Research Rack 1 (MSRR-1), which is housed (since Aug 2009) in the US "Destiny" Module on the International Space Station to perform unique experiments in the field of high temperature materials research under significantly reduced gravity conditions.
2. The MSL consists primarily of a Process Chamber accommodating both the Furnace Insert (FI) and the individual experiment cartridge, hereafter referred as a Sample Cartridge Assembly (SCA). Various FIs and SCAs will allow different types of materials science experiments to be performed. These experiments will include research into alloy solidification, crystal growth and the measurement of thermophysical properties, over a wide range of temperatures and with different experimental profiles.

# Transparent Alloys – Transparent Alloys facility

## SCIENTIFIC BACKGROUND

- **SETA**. The aim of this experiment is to study the pattern formation during univariant eutectic reaction in directional solidification in transparent ternary alloys. This pattern formation process shall not be affected by wall effects or by convective contributions to the heat and mass transport during the phase formation.
- **SEBA**. The aim of this experiment is to study the morphological instabilities of directionally solidified, transparent binary eutectic alloys under purely diffusive conditions.
- **METCOMP**. The aim of the METCOMP project is the research on layered structures in peritectic systems by in-situ observation.
- **CETSOL**. the ultimate objective of the CETSOL research programme is to significantly contribute to the improvement of integrated modelling of grain (crystal) structure in industrially important castings.

## SCIENTIFIC OBJECTIVES

- **SETA**. Observation of the microstructure formation in univariant two-phase eutectic growth along the different eutectic grooves, study nucleation of eutectic phases on pre-existing phases in transient growth,o bservation of the origin of fault lines in eutectic structures and changes of the faultless eutectic structure
- **SEBA**. Study of the formation and the relaxation of topological defects in rod-like structures, the rod-to-lamellar transition of eutectic growth patterns, the forcing effects of the distortions of the thermal gradient
- **METCOMP**. Study of the influence of gravitational effects on the microstructure evolution by comparing 1g and µg, experiments to pinpoint the effect of gravity, determination of microstructure selection maps, correlated to particle size, growth dynamics and fluid flow process parameters
- **CETSOL**. The experiments have the objective of characterising the columnar and equiaxed solidification and columnar-to-equiaxed transition in transparent alloys.

## NEED OF SPACE

- **SETA**. The experiments under microgravity shall for the first time enable the observation of the dynamics of the pattern formation in an univariant two-phase eutectic alloy
- **SEBA**. Observations would be strongly sensitive to convective motions in the liquid, which, in ordinary conditions on Earth, entail a detrimental redistribution of the solute on a scale comparable to the container size. Such convective motions are suppressed in microgravity.
- **METCOMP**. The comparison of the experimental results, in space and on Earth, will allow evaluation of the influence of natural convection on the microstructure evolution.
- **CETSOL**. The major aim using transparent model alloys will be to identify growth regimes (columnar or equiaxed or mixed) and physical mechanisms in dependence of the experimental parameters (solidification velocity, temperature gradient) for diffusive heat and mass transport and without gravity effects.

# PK-4 – PK-4 facility (with Russian crew support)

## SCIENTIFIC BACKGROUND

- PK-4 is an experiment for investigating complex plasmas. Plasmas are ionized gases produced by high temperatures, like in the sun, or by electric fields, i.e., low temperature discharge plasmas like in neon tubes. In the latter case the degree of ionization is small and a large amount of neutral gas is present. Complex or dusty plasmas are plasmas which contain beside electrons, ions, and neutral gas in addition micro-particles, e.g., dust grains. Due to the high mobility of the electrons (compared to the ions) in low temperature discharge plasmas the micro-particles collect a large number of electrons on their surface.
- For a particle with a diameter of a few microns this charge can be of the order of 10.000 electron charges. Therefore the micro-particles interact strongly with each other, and complex plasmas are an example for strongly coupled plasma in which the interaction energy between the plasma particles (or at least of one component) is larger than the kinetic energy of the particles.

## SCIENTIFIC OBJECTIVES

The main interest lies in the investigation of the liquid phase and flow phenomena of complex plasmas for which PK-4 is especially suited.

1. Microscopic properties of complex plasmas: charging of the particles, the external forces on the particles (e.g. ion drag), the fundamental interactions between the particles, agglomeration, and particle growth.
2. Macroscopic properties of complex plasmas: hydrodynamics (e.g. viscosity), thermodynamics (e.g. equation of state), and non-equilibriums aspects (e.g. lane formation, self-organisation) of complex plasmas.
3. Generic properties of classical many-body systems: Complex plasmas are ideal model systems for studying various problems of strongly coupled many-body systems in solid state physics, fluid physics, plasma physics, nano-technology and even nuclear physics because complex plasmas can easily be produced and observed in real time on the microscopic and kinetic level.

## NEED OF SPACE

Due to the strong influence of gravity on the micro-particles, most experiments on complex plasmas are strongly distorted or even impossible on earth and require microgravity conditions. Hence dynamical processes can be investigated on the level of single particles which is not possible in most systems. Therefore new insights in the dynamics of those processes can be provided. Typical examples are crystallization and melting, phonons in plasma crystals, dust waves, Mach cones, nozzles, turbulence, and nano-fluidics.

# Material Environmental Science & Radiation Physics

**ENVIRONMENTAL SCIENCE &
RADIATION PHYSICS**
ASIM (Ext. Payload)
DOSIS-3D

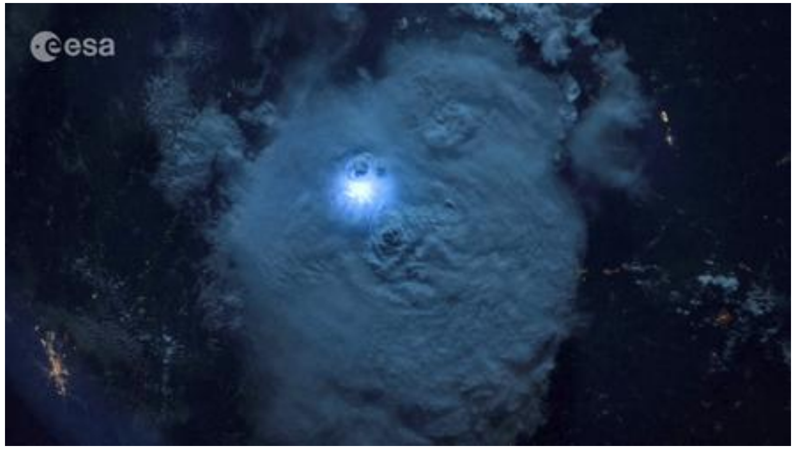
# ASIM – External Payload

## SCIENTIFIC **BACKGROUND**

- The Atmosphere-Space Interactions Monitor (ASIM) is an Earth observation facility located on the external payload platform on the Columbus module. The aim is the study of severe thunderstorms and their role in the Earth's atmosphere and climate. ASIM can measure high altitude electrical discharges in the stratosphere and mesosphere and intra-cloud lightening in the troposphere, gravity waves and the creation of high-altitude clouds. Also, the newly discovered "Transient Luminous Events" (TLEs) and "Terrestrial Gamma-ray Flashes" (TGFs). The observations of TLEs are of "sprites", a manifestation of electrical break-down in the mesosphere, the "blue jet", a discharge propagating upwards into the stratosphere from cloud tops, and the "elve", a concentric ring of emissions from neutrals excited by a lightning electromagnetic pulse at the bottom edge of ionosphere. TGFs are from the atmosphere above thunderstorms, generally of duration shorter than 1 msec with energies from ~100 keV to tens of MeV.

## SCIENTIFIC **OBJECTIVES**

1. Atmosphere and Climate: provide the most comprehensive global survey of TLEs and TGFs, study the physics of TLEs and TGFs, how TLEs and TGFs are related to lightening, quantify effects of gravity waves on the mesosphere, study high-altitude cloud formation, determine the characteristic of thunderstorms that make them effective in the perturbation of the high-altitude atmosphere.
2. Space Science: study effects of thunderstorms on the ionosphere and the radiation belts, determine the distribution of meteors in the Earth's environment and quantify their effect on the atmosphere, lightening-induced electron precipitation and relativistic electron precipitation, aurora borealis.
3. Earth Observation: dust storms and their effect on cloud formation and electrification, mega-cities and the effect of pollutants on cloud formation and electrification, forest fires and volcanoes and the relation to cloud formation and electrification, intensification of hurricanes and its relation to eye-wall lightning activity.



# DOSIS 3D – Stand alone

## SCIENTIFIC **BACKGROUND**

- Radiation is one of the main health detriment for long-duration human space missions. Radiation levels far exceed the ones encountered on Earth for occupational radiation workers. Accurate knowledge of the physical characteristics of the space radiation field in dependence of the solar activity, the orbit parameters and the different shielding configurations of the ISS is needed.
- The aim of the DOSIS 3D experiment is to measure radiation field parameters such as absorbed dose, particle fluence and LET spectra as well as dose equivalent at different locations inside the International Space Station ISS, using passive and active radiation measurement devices. The collected set of data will be used for the refinement of radiation transport calculations through realistic shielding distributions of the ISS and will provide baseline data for experiments conducted in the ISS, as well as (and in particular for) assessing the radiation exposure of the astronauts working on board.

## SCIENTIFIC **OBJECTIVES**

1. The main objective of the DOSIS 3D experiment is the determination of the absorbed dose and the dose equivalent using a variety of active and passive radiation detector devices distributed throughout the ISS. To achieve the dose distribution in three dimensions (3D), DOSIS 3D aims to combine data acquired by ESA with complementary data from radiation detectors operated by JAXA, NASA and ROSCOSMOS/IMBP. Based on the combined output from passive and active detectors, an interactive database is under construction to serve the scientific community, holding essential information for the application of radiation protection standards for manned spaceflight and for any radiationsensitive experiment in space. A first version of the database designed for educational purposes is available within the so-called 'DOSIS Data Viewer'.
2. An additional scientific objective of the DOSIS 3D experiment is to determine the impact of ionizing radiation in LEO on plant seeds.

## **NEED** OF SPACE

The radiation environment in space cannot faithfully be mimicked on ground, and definitely not including the complex shielding characteristics of the ISS. Due to its dynamics, is it not possible to make accurate predictions based on radiation data that have already been acquired on board of the ISS. The only approach to obtain reliable information is to permanently monitor the radiation environment in situ, on board of the ISS in different locations.

# Fluid Physics

**FLUID PHYSICS**
CNES Fluidics
FOAM Coarsening 2-3
PASTA

# CNES Fluidics – Fluidics Facility (1/2)

## SCIENTIFIC **BACKGROUND**

- **Sloshing of fluid with different tanks**. One of the satellite perturbations results from the sloshing of fluids in the tanks during the maneuvers which generates forces and torques on the structure. The helium bubble used to pressurize the tank is free to move and also induces displacement of fluid center of mass. For high pointing resolution missions, one solution is to use a pre-stressed elastomeric membrane which contains the fluid in the lower part of the tank, and damped the fluids movements during the maneuvers. Thanks to FLUIDICS experimental data have been gained for simulating decoupled tanks with gas-liquid interface.
- **Wave turbulence** The previous runs studied weak turbulence. During phase 2, experiments are done with different excitation profiles involving smaller angular amplitudes and larger frequencies. This will keep the excitation at a high enough amplitude to achieve wave turbulence but will reduce the radial component of the acceleration with respect to the azimuthal one.

## SCIENTIFIC **OBJECTIVES**

- **Sloshing of fluid with different tanks.** To complement FLUIDICS results by exploring others excitations range, fill ratio & fluid behavior; to further characterize FLUIDICS step-up (i.e. more accurate determination of tank mass, inertia and center of mass, frequency perturbation); to use the same excitation profiles on two different experimental platforms, FLUIDICS and MICROSLOSH, which will enable the acquisition of long-duration independent data; to validate the design of the MICROSLOSH experiment whose design presents a number of additional technological challenges compared to FLUIDICS.
- **Wave turbulence.** Different excitation profiles with smaller angular amplitudes and larger frequencies will be studied in order to decrease the radial component of the acceleration with respect to the azimuthal one. Better signal quality is expected and this procedure will also allow to study the transition toward the turbulent regime. The regime characteristic of scales larger than the one of the excitations, for which statistical equilibrium is expected, will be studied.

## **NEED** OF SPACE

- **Sloshing of fluid with different tanks.** Sloshing results in micro-gravity under excitation profile representative of spacecraft maneuver are impossible to reproduce with a long duration (i.e. > 100s) during parabolic flight. For elastomeric membrane and coupled liquid propellant/solid spacecraft dynamics in open- and closed-loop control loop.
- **Wave turbulence.** Low gravity environment is needed to study capillary wave turbulence without the parasitic effect of the gravity regime which is dominant at large scales. In laboratory experiments studying the interface between two non-miscible iso-density the nonlinear interaction mechanism between the waves is modified becoming a four-wave interaction instead of the three-wave interaction of capillary waves. A second advantage is related to the spherical geometry of the experiment that of course cannot be achieved in the laboratory. The fluid layer inside the spherical boundaries has no lateral boundaries that reflect the waves. Two waves can thus propagate on long distances which make nonlinear interaction dominant.

# CNES Fluidics – Fluidics Facility (2/2)

## SCIENTIFIC **BACKGROUND**

- **Feedforward Control and Slosh4AOCS.** It is investigate a technique to spin-up a tank in such a way that the fluid permanently stays at the outer wall of the tank, based on input shaping shall be applied, which will result in minimal sloshing motion. With the proposed technique the fluid is always kept at one tank wall and spin-up is performed in a smooth way. The practical interest of such a technique is that a spacecraft could be spun-up while only a minimal amount of nutation is induced.
- **Capillary-driven fluid transport.** The unique capability to transport fluid in a preferred direction by capillary forces and under absence of other driving mechanisms, such as gravity, makes an appropriately structured surface predestined for the use of liquid handling in micro-gravity environments. Key aspect of the development is a bionic-based structured surface, on which directional capillary-driven fluid transport takes place. The natural surface structure has been optimized and transferred to an artificial surface.

## SCIENTIFIC **OBJECTIVES**

- **Feedforward Control and Slosh4AOCS.** The objective of Feedforward Control and Slosh4AOCS is to spin-up the centrifuge to 51 deg/sec in seven commands over 80 seconds. The main objectives of this activity are to investigate different stopping strategies (shapes and/or slopes) to minimize tranquilization time (well observable by cameras) and to identify the optimal stopping strategy, potentially depending on certain physical parameters.
- **Capillary-driven fluid transport.** To investigate the phenomena of directional capillary driven fluids transport across specific surfaces textured according to biological antetypes and transferred to technological samples. Determine fundamental characteristics of the surface texture by observation of macroscopic phenomena; establish a high-quality database for mathematical model and simulation tool development of the observed phenomena and capillary effects in general; expand the understanding of the working principle of the phenomena capillary-driven fluid transport across bionic-structured surfaces

## **NEED** OF SPACE

- **Feedforward Control and Slosh4AOCS.** Historically the issue of sloshing in space and especially in launchers has been limited to modeling and analysis of stability and performance degradation. This opens the question of actively influencing the propellant. For example, the capability of slewing maneuvers with less sloshing excitation than the existing one, are desirable. Excitation-less spin-up and spin-down are a further interesting improvement. A validation of the concept is of course needed in a zero g environment.
- **Capillary-driven fluid transport.** In order to achieve the targeted goals of fundamentally investigating capillary effects it is needed to have a closed volume to accommodate test liquid and samples of a bionic structure to be tested, an environment with varying g-levels (including µg), visual observation of the fluid transport, maintaining of constant g-levels (including µg) for long times (timescale of maximum 1h30min). The FLUIDICS experimental setup, provides the required features and is therefore seen as an ideal opportunity to perform the proposed experiments.

# Foam Coarsening 2-3 - FSL

## SCIENTIFIC BACKGROUND

- Foams are dispersions of gas into liquid or solid matrices. The behaviour of foams in micro-gravity and on earth are very different, because the process of drainage is absent in micro-gravity conditions. Drainage is the irreversible flow of liquid through the foam (leading to the accumulation of liquid at the foam bottom, and to a global liquid content decrease within the foam). Micro-gravity offers the opportunity to investigate the so-called "wet" foams, which cannot be stabilized on earth because of drainage (drainage gets faster as the foams gets wetter).
- The Hydrodynamics of Wet Foams (FOAM) project studies aqueous and non-aqueous foams in microgravity. The objective of FOAM coarsening is the study of the quiescent coarsening of foams as a function of the liquid fraction. It focuses on very wet foams which cannot be studied on ground, due to drainage effect. Conductimetry and multiple light scattering measurements provide measurements of the liquid fraction, of the bubble structure and dynamics of the material during coarsening.

## SCIENTIFIC OBJECTIVES

The role of gravity on quiescent wet foams can be captured in 2 key questions:

1. Is the growth law for average bubble size R~Sqrt[time], such that R dR/dt is a constant? If so, what is the liquid-fraction dependence of this rate?
2. How do the rate and the nature of the bubble rearrangement dynamics change as the liquid fraction is increased to the point of un-jamming?

Both questions require prolonged microgravity to capture the dramatic changes expected for the very wet foams. Answers to both represent baseline knowledge of structure/dynamics upon which flow and rheology must be interpreted. While this program can be usefully carried out for a single surfactant, it is also very interesting to examine different types of surfactants and different additives such as polymers and particulates.

## NEED OF SPACE

- Gravity plays an important role in the formation of foam and its subsequent evolution. Its primary effect is to cause excess liquid to drain rapidly away. When the foam is stable enough, it becomes dry and the gravitational force is balanced by a vertical pressure gradient in the liquid (and hence a vertical profile of liquid fraction). This restricts ground experiments to stable dry foams, and indeed the idealized theoretical models are largely confined to the dry foam limit. The present trend of the subject is therefore towards wet foams as well as dynamic effects.
- A micro- or zero-gravity study of wet foam hydrodynamics enables one to overcome the limits imposed by various instabilities experienced under normal gravity. This broader experimental characterization and corresponding insight will provide a scientifically valid alternative for the necessarily conservative empiricism currently employed to estimate the operational window and design for foam handling in industrial processes (such as gas/liquid contacting, flotation and pumping).

# PASTA - FSL

## SCIENTIFIC **BACKGROUND**

- Foams and emulsions can be formed and stabilized only in the presence of well selected additives, such as surfactants, polymers, proteins and their mixtures. By the addition of surfactants or polymers, the properties of the particles' surface can be modified, and in turn the free energy of their attachment to a liquid interface. This will allow us to tune the stabilizing or destabilizing action of a particle/surfactant system, depending on the demands of a respective application.
- The work proposed in the Particle STAbilised Emulsions and Foams (PASTA) project follows the line from characterizing the surface properties of particles via a complex analysis of the properties of layers at liquid/gas and liquid/liquid interfaces to studying the behaviour of liquid films and finally to model real foams and emulsions. The work comprises the application of available knowledge to the preparation and characterization of particle stabilized emulsions, produced by adapting to the SOFT MATTER DYNAMICS instrument.

## SCIENTIFIC **OBJECTIVES**

The scientific state of the art provides only general principles for the present subject and many questions are yet open. Understanding of special systems has been established but generic mechanisms do not exist yet. Therefore, taking advantage of the existing expertise of the participating teams significant progress will be achieved in this old and simultaneously very new scientific and technological field. This will also cover the further improvement of insight into the generic mechanisms of foam and emulsion stabilization.

The experiments will address the following topics:

1. Evaluate the characteristic time for the droplet coalescence as a function of the formulation
2. Identify and investigate specific dynamic regimes for droplets dynamics (for example Brownian vs. Capillarydriven) during emulsion destabilization.
3. Test and develop models for emulsion stability/destabilization prognosis.

## **NEED** OF SPACE

- Microgravity conditions provide a unique environment to investigate emulsion destabilization under the sole effect of coalescence. In fact, on ground conditions segregation (creaming) is coupled with coalescence in an intricate way.
- Coalescence is however the real process triggering the destabilization in low viscosity emulsions. In fact micrometric (or sub-micrometric) droplets in the absence of coalescence would remain uniformly dispersed under the effect of Brownian motions.
- Specific microgravity experiments are therefore able to provide evidences of the relations between the properties of the interfacial layers of droplets and their coalescence, allowing testing all existing models and develop innovative approaches.
- The latter will respond to the request of prognosis tools to help the formulation of emulsifiers and de-emulsifiers in a wide range of industrial applications.