REPORT

62nd ESA Parabolic Flight campaign

June 2015

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FOREWORD

Parabolic flight is an essential way of getting microgravity, along with drop towers, sounding rockets, recoverable capsules, space shuttles and orbiting stations. Initially used for training astronauts, parabolic flights are now exclusively dedicated to scientific experiments and technological tests of space equipment. Simplicity of preparation and operations, reduced cost, repetition of microgravity phases and opportunity for researchers, present on board, to work directly on the experiments are advantages that can not be found in any other means.

The 62nd ESA parabolic flight campaign had been conducted from Mérignac-Bordeaux airport from June 1st to 12th, 2015. Three flights had been performed for 13 experiments selected by ESA scientific committees.

The aircraft is the Airbus A310 ZERO-G owned by Novespace, which is in charge of the program, the organization of the parabolic flight campaigns and the flight and ground operations. CNES (French space agency), ESA (European space agency) and DLR (German space agency) are the promoters and sponsors of the program.

CAMPAIGN SUMMARY

Flight reports

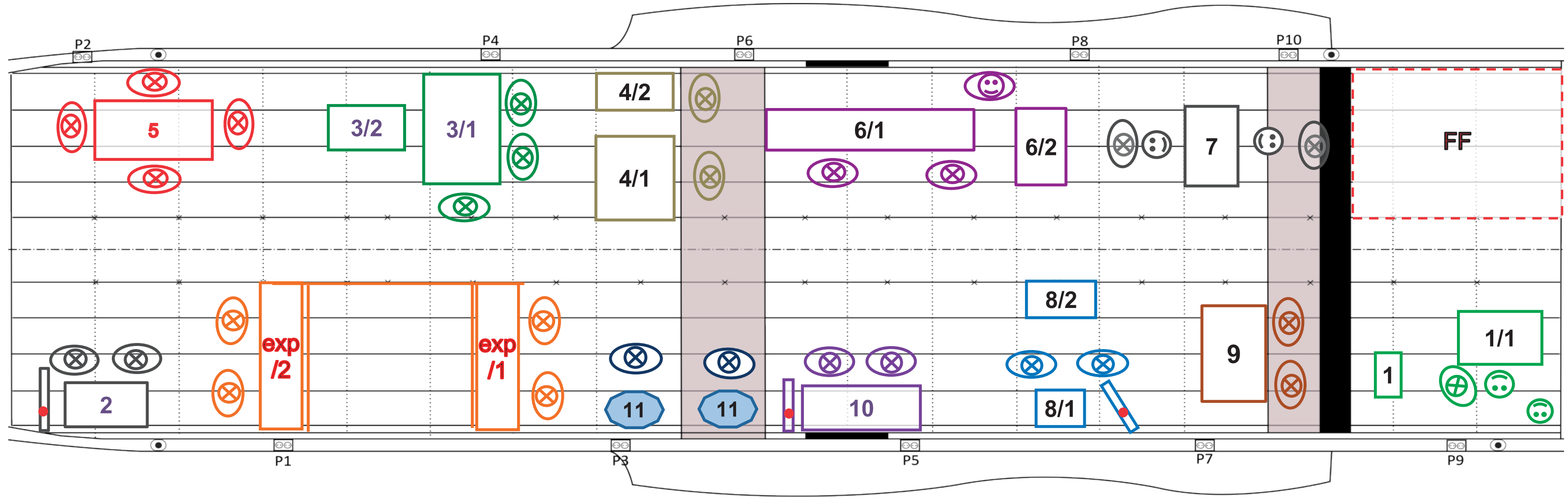
Flight n° 1 was performed on June 9th, 2015
Take-off at 9:30 a.m.
Landing at 12:30 p.m.
The A310 ZERO-G flew over Brittany and performed 31 parabolas.

Flight n° 2 was performed on June 10th, 2015
Take-off at 9:40 a.m.
Landing at 12:50 p.m.
The A310 ZERO-G flew over Brittany and performed 31 parabolas.

Flight n° 3 was performed on June 11th, 2015
Take-off at 9:25 a.m.
Landing at 12:55 p.m.
The A310 ZERO-G flew over Mediterranean Sea and performed 31 parabolas.

Conclusion

Despite weather conditions that were not good for the parabolic maneuvers, this parabolic Flight Campaign was successful. Thanks to the co-operative working spirit of all experimenters, experiments have been successfully conducted on board. Only minor problems were encountered but solved during the flight week.



Electrical panel

VentLine port

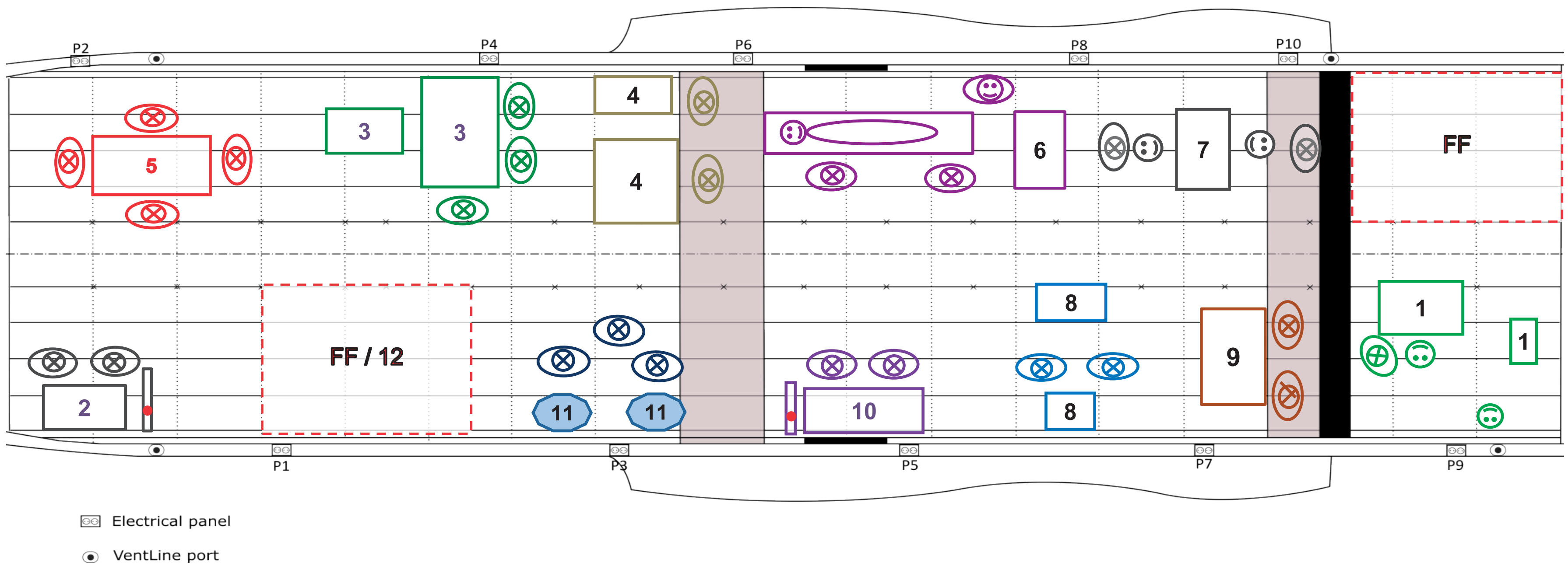
Free floating area

Experimental rack

Experimenter

Test subject

N°	Name of the PI	N°	Name of the PI	N°	Name of the PI
1	Tagliabue	6	Albracht	11	Cockell
2	Marengo	7	Schneider	EXP	Patender
3	Queekers	8	Kohn		
4	Fahrat	9	Renard		
5	Shevtsova	10	Bossis		



Free floating area

Experimental rack

Experimenter

Test subject

N°	Name	N°	Name	N°	Name
1	Tagliabue	6	Albracht	11	Cockell
2	Marengo	7	Schneider	12	Wuyts
3	Buffone	8	Kohn		
4	Fahrat	9	Renard		
5	Shevtsova	10	Bossis		

FLIGHT PARTICIPANTS

EXP Number	Name of the PI	Flight participants		
		Flight 1	Flight 2	Flight 3
1	Tagliabue	3	3	3
2	Marengo	2	2	2
3	Queekers	3	3	4
4	Fahrat	2	3	3
5	Shevtsova	3	4	3
6	Albracht	4	4	5
7	Schneider	4	4	4
8	Kohn	2	2	1
9	Renard	2	2	2
10	Bossis	2	2	2
11	Cockell	2	2	2
12	Wuyts	0	4	5
	CUSTOMER	4	3	2
	GUESTS	2	0	0
	MEDIAS	1	2	2
	EXP Medina	4	0	0
	TOTAL	40	40	40

DIMENSIONS

EXP Number	Name of the PI	Dimensions	X	Y	Z
1	Tagliabue	Rack 1	1020	700	1200
		Rack 2	660	450	20
2	Marengo	Rack 1	560	1100	1000
3	Queekers	Rack 1	800	1500	500
		Rack 2	700	500	720
4	Fahrat	Rack 1	1050	1045	470
		Rack 2	1080	545	600
5	Shevtsova	Rack 1	1500	710	850
6	Albracht	Rack 1	2450	0	1000
		Rack 2	585	925	500
7	Schneider	Rack 1	635	1146	458
8	Kohn	Rack 1	1000	550	0
9	Renard	Rack 1	800	1400	700
10	Bossis	Rack 1	1500	600	350
11	Cockell	Rack 1	2000	2000	2000
12	Wuyts	Rack 1	No rack		
EXP	Patender	Rack 1	500	2000	810
		Rack 2	500	2000	810

MICROGRAVITY EFFECT ON THE HAPTIC PERCEPTION OF GEOMETRIC SHAPES

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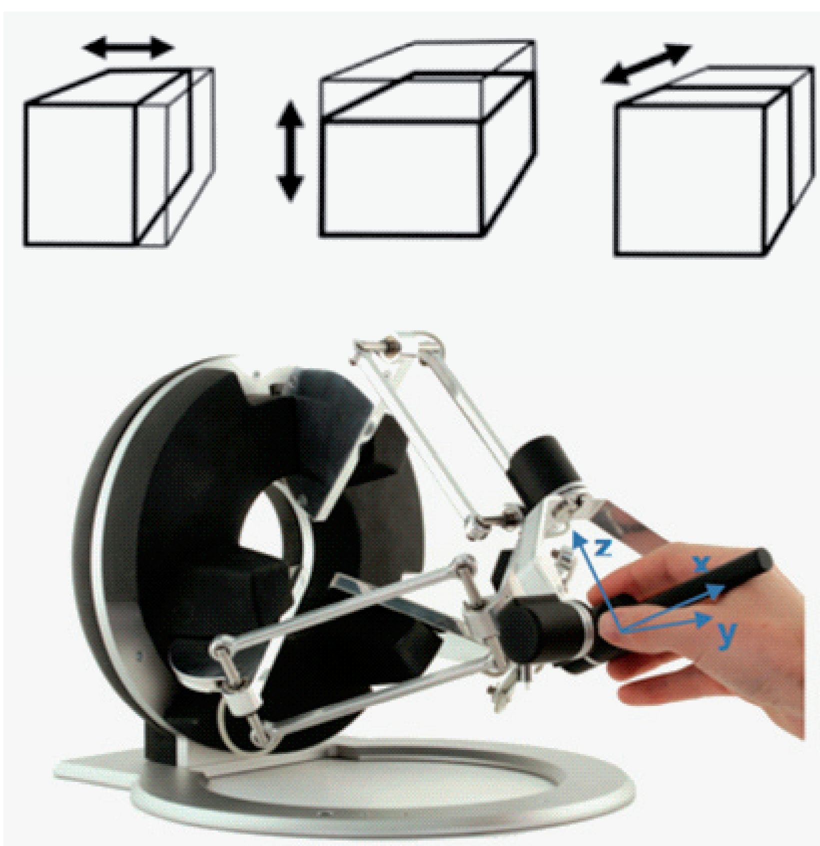
The aim of the experiment is to understand how gravitational signals, such as vestibular information, affect the haptic perception of shapes and dimensions. In particular, we want to test whether the perceptive distortions observed for the visual perception of 3D objects in microgravity affect also the perception of 3D objects through haptic (tactile) system. If similar distortions occur for both visual and haptic perceptions, this would mean that the visual distortions previously observed are not due to a direct effect of the gravitational signals on the visual system, but more likely to an interaction between gravity and the brain areas involved in the elaboration of the spatial information independently to the sensory modality trough which they have been acquired.



THERMO-HYDRAULICS CHARACTERIZATION OF A SEMI-TRANSPARENT FLAT-PLATE PULSATING HEAT PIPE IN A VARIABLE GRAVITY REGIME

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SCIENTIFIC OBJECTIVE

The Pulsating Heat Pipe (PHP, Figure 1) is a thermally driven two-phase passive device mainly based on phase change phenomena (film evaporation, flow boiling and film condensation) and capillary forces, even if also gravity may play a role. The present research is indeed focused on investigating the effect of the gravity level on the hydraulic behaviour and thermal performance of such a device.

Results from ground experiments and from previous Parabolic Flight Campaigns on different meandering tube heat-pipes confirmed that the thermal performance of a PHP with capillary tubes operating in ground conditions and horizontal position is equal to the microgravity operation at any orientation, and that the optimal liquid filling ratio is different on ground and under microgravity. A short transparent tube section allowed visualizing the liquid flow pattern in a limited path of the cold region. In parallel, a Flat-Plate PHP was tested under microgravity: it was built with a single channel, replacing the tubes, engraved inside a massive copper plate (see figure 2).

During the coming 62th Parabolic Flight Campaign a new Semi-Transparent Flat-Plate-PHP will be tested. For this new device, one side of the plate will be fully transparent, allowing observation and video recording of the liquid, with its boiling and condensing structures and flow pattern. The copper side of the PHP will keep the thermal properties of the device.

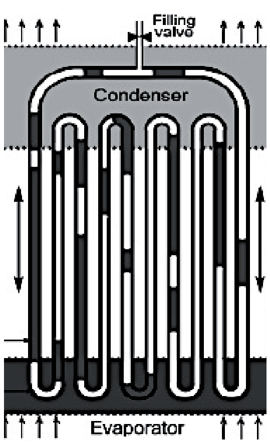
The channel dimension is larger than the capillary limit on ground, so that liquid and vapour phases tend to stratify with normal gravity, but, during microgravity, the capillary forces will be sufficient to re-establish classical slug an plug flows. We will thus be able to measure the effect of slug flows under microgravity on the thermal performances of the flat PHP. The results will give fundamental and original information on many aspects of PHP basic physics

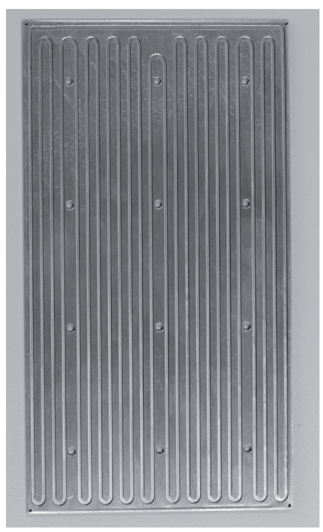
TECHNICAL DESCRIPTION OF THE EXPERIMENT

The experiment consists in measuring the performances of the Flat PHP in absence of gravity with different power loads, while recording the fluid behaviours. Figure 2 shows the engraved part of the PHP, with the square channel engraved in a metal plate, where the liquid will evaporate on the lower side (red dashed rectangle), flow to and condensate on the upper side (blue dashed rectangle), thus transferring the thermal energy. Figure 3 shows the PHP after assembling: the fluid channels are beyond the glass plate. On the right hand side one can distinguish the pressure sensor and the filling valve in connection with the interior of the PHP. Figure 4 shows the rack that includes the PHP with all the necessary instruments to operate it and save the experiment recordings. An electric heater will heat-up one side of the PHP, while the other will be cooled by an air flow (fins + fans). The temperature and pressure of the PHP and its heating and cooling system are monitored; the results allow measuring the thermal conductivity of the PHP during microgravity, and comparing it with the ground performance in different orientations.

APPLICATIONS OF THE RESEARCH

The Pulsating Heat Pipe represents an efficient device to cool down electronic equipment in space and ground applications. The knowledge of its working characteristics in absence of gravity will allow its use on satellite and on interplanetary missions where the heat produced by electronic component must be drawn away, with continuous increasing performances and thermal requirements. The advantages with respect to the actual thermal management techniques are linked to the building simplicity (it is a wickless system), the weight, the ability to dissipate high heat powers, and the possibility to build up flexible or movable systems.





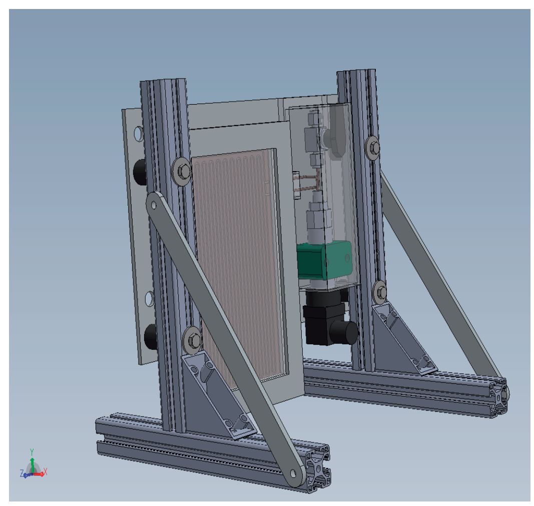


Figure 1. PHP working principle. The serpentine is partially filled by a liquid; its evaporation and condensation and the bubble chaotic movement are the engine of the heat exchange.

Figure 2. The channel engraved in the PHP internal part, the core of the experiment

Figure 3. The PHP installed on its support: the internal channels are visible trough the transparent side

Figure 4. The experiment rack in the ZERO-G aircraft during the 58th Parabolic Flight Campaign. All components are enclosed by safety cages.movement are the engine of the heat exchange.

STUDY OF IN-TUBE CONVECTIVE CONDENSATION IN MICROGRAVITY

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SCIENTIFIC OBJECTIVE

Condensation is used in many engineering fields (e.g. energy conversion, chemical, pharmaceutical and food industries) including space applications. Future space missions are expected to greatly increase in complexity and duration leading to higher power requirements and to a growing heat dissipation demand. Among the various types of thermal management systems that have been proposed in the recent years, two-phase loops can guarantee high heat dissipation rates together with a reduced weight of the cooling system. In a two-phase cooling system, the heat is removed in the evaporator and then it is rejected to the space in the condenser, where the working fluid passes from the vapor state to the liquid state. While evaporation is already studied in microgravity conditions, much less investigation has been performed during convective condensation. The In-Tube Convective Condensation experiment will focus on the condensation phenomenon starting from this context. The main goal of this experiment is to better understand convective condensation inside channels during reduced gravity, when surface tension and shear stress at liquid-vapour interface are expected to control the heat transfer process. One objective of the experiment is to obtain quasi-local heat transfer coefficient data and to perform visual observations of the two-phase flow patterns using a high speed camera. This experiment is the result of the effort of three research groups, MRC in Brussels (Belgium), LAPLACE in Toulouse (France) and DII at University of Padova (Italy).

TECHNICAL DESCRIPTION OF THE EXPERIMENT

Condensation tests will be performed in a dedicated test section with an internal diameter of 3.38 mm, using HFE7000 as working fluid. This test section is composed of two copper heat exchangers designed for the measurements of quasi-local values of the heat transfer coefficient. A glass tube is also installed between the two heat exchangers to allow the visualization of the flow pattern during convective condensation inside the channel. The test rig and the test section are instrumented with thermocouples, thermopiles, mass flow meters, and pressure transducers. The experimental apparatus also includes a stirring evaporator, a post-condenser and a Peltier cell system to cool down the water which is used as coolant secondary fluid.

APPLICATIONS OF THE RESEARCH

In order to increase the performance of condensers, understanding convective condensation phenomena is necessary. In particular, since there are operating conditions when the condensing heat transfer is strongly affected by the gravity level, the In-Tube Convective Condensation experiment will provide condensation heat transfer data in such operating conditions. Results obtained with this experiment will give a more complete knowledge of the condensation process that is not possible to achieve with ground experiments. Measured heat transfer data and visualization results can give an important contribution to the developed of new tools for the design of compact heat exchangers, not only for space applications but also for ground applications.

THE DIRECT EFFECTS OF GRAVITY ON CAVITATION BUBBLE ENERGY

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SCIENTIFIC OBJECTIVE

Our parabolic flight experiment aims at generating the most spherical cavitation bubble ever created, in order to unravel the physical laws governing cavitation erosion in hydraulic systems on Earth.

Cavitation - the appearance of vapor bubbles in a liquid as the pressure drops – occurs naturally in many hydraulic systems as the liquid pressure varies in the flow. Such cavitation bubbles can implode violently (“collapse”) in the vicinity of surfaces and therefore engender serious erosion damage in propulsion systems, rocket propellers and energy-production turbines. This ‘erosive power’ has also recently found useful applications in water cleaning, medicine (tendinitis, lipid, cancer therapy).

Cavitation erosion is thought to be associated with energetic events occurring at the last instants of bubble collapse, in particular with liquid jets and high-pressure shock waves (reaching pressures of ~100 bars) emitted during the violent collapse of these bubbles. The cavity even concentrates its energy so as to reach high temperatures (several thousands of degrees), inducing the emission of light and, arguably, a few amount of atomic fusion. These high temperatures possibly represent an erosion path as well.

The magnitude of these phenomena and the energy released sensibly depend on the sphericity of the bubble, which is disturbed by any factor breaking the symmetry of the liquid such as accelerating flows and the gravity vector itself (inducing a vertical pressure stratification in the fluid). Investigating how bubble sphericity perturbations affect the aforementioned energetic events is thus the key towards understanding the physical origin of cavitation erosion. In this aim, our experiment creates the most spherical bubble and perturbs it in a precisely controlled way by altering the g-level (residual acceleration) inside the A310 aircraft.

To create the most spherical bubble, we minimize all other sources of asymmetry by focusing the energy of a high-power laser into a small point within a large water volume (see picture below). The ensuing bubble is then so spherical that the tiny gravity-induced pressure gradient is by far the remaining symmetry breaking factor. We demonstrated this in our participation to the ESA PFC in 2010, whereby spectacular high-speed visualizations disclosed bubble jets directed against the pressure gradient, with a magnitude that was ever greater as the gravity level increased (see Obreschkow et al., PRL 2011 http://prl.aps.org/toc/PRL/v107/i20 , movies can be watched here, http://arxiv.org/abs/1110.3135).

In this campaign, we will investigate the other potentially erosive energy channels of cavitation. By recording the weak electromagnetic radiation emitted at the bubble collapse, we will obtain information about the very last 'invisible' (using filming techniques) state of cavitation collapse, in particular the very high temperatures. The intense shock wave pressures will also be measured.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

To create an ideally spherical cavitation bubble (up to the gravity factor), we will use a large container with approx. 6 l. of water to avoid any perturbation of nearby surfaces on the bubble.

Second, we will focus the energy of a strong laser pulse into the water in the smallest possible volume in a short interval of time. This concentrated energy will locally create a hot plasma (riping off the electrons from the atoms), which will expand thermally into a cold bubble of water vapour, i.e. a cavitation bubble. By creating a close-to-point-like initial plasma, the ensuing bubble will by most spherical. We developed an innovative laser-focusing technique using a gold parabolic mirror for this purpose.

Such artificially-created bubbles are out of equilibrium and collapse under the surrounding water pressure in about 10 ms. To record this phenomena, we will use a very fast camera with about 180'000 images per second, i.e. twice more images per s. than there are seconds in a day. The movies will allow us to observe the gravity-induced deformation of the bubble, the emission of shock waves (complemented by pressure sensors in the water), and the emission of light following the bubble collapse. By using a spectrometer, we hope to measure the spectrum of the light emission and hence to obtain the temperature reached by the bubble at the last instants of its collapse.

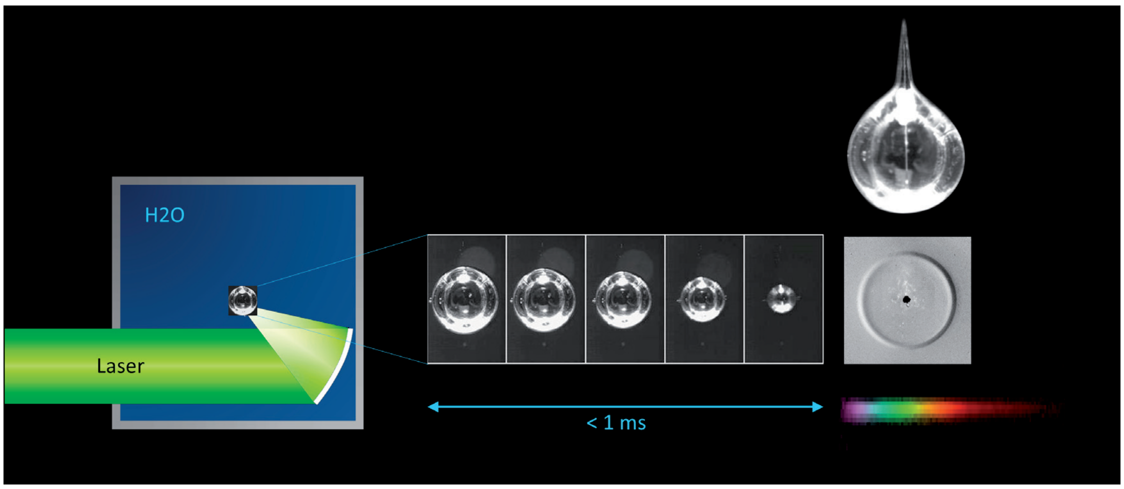
Since gravity acts on the bubble through buoyancy, Archimede's principle tells us that its effects will be proportional to the displaced volume of water, i.e. to the size of the bubble. To observe the effects of gravity (and compare with the case of absence of gravity), one should thus create large bubbles. Therefore we chose a laser with high energy (its power is just 100 times inferior to a lightning!). In addition, we will partially reduce the pressure of the water to a fifth part of the ambient atmospheric pressure.

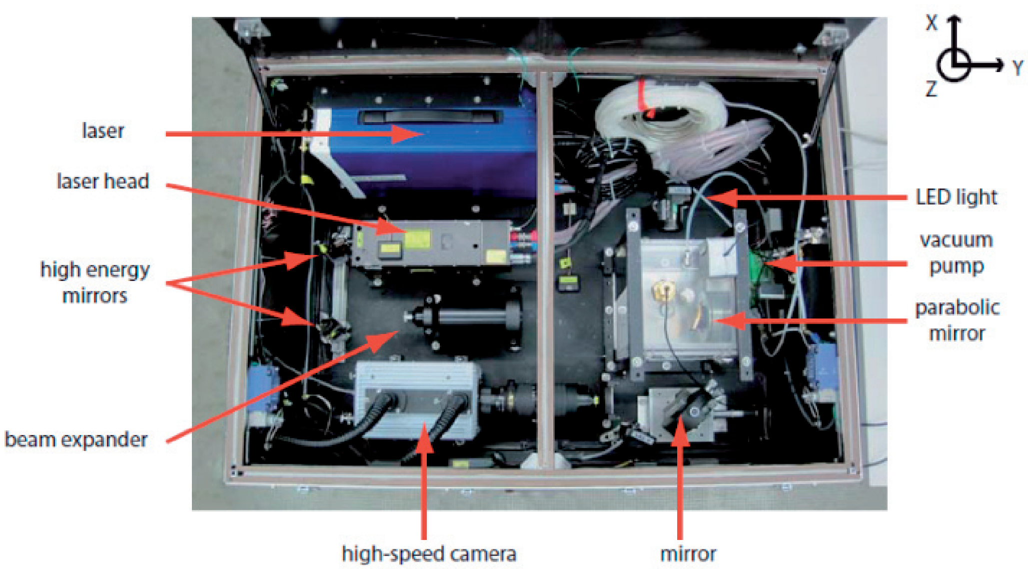
APPLICATIONS OF THE RESEARCH

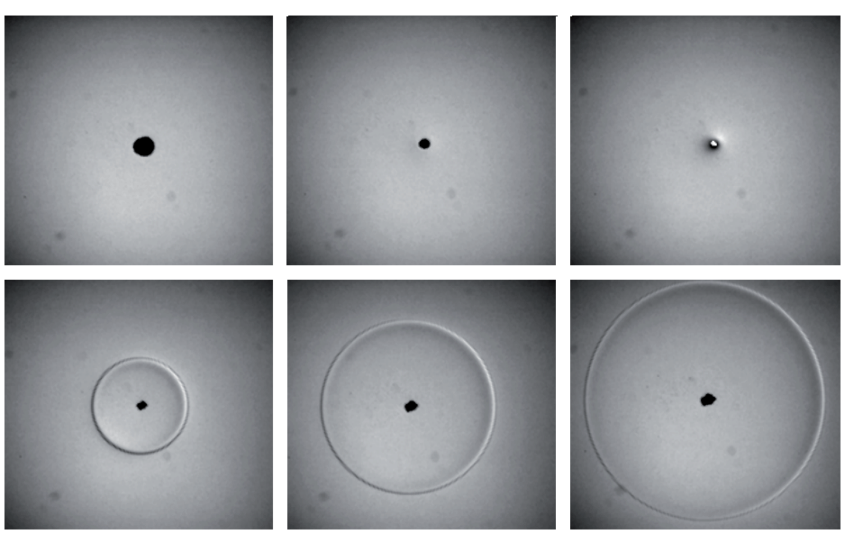
Cavitation is a serious problem for all hydraulic machinery, causing losses of efficiency and erosion damage. Even if the phenomena associated with the erosion are rather well identified (jets, shock waves), the magnitude of these energetic events depend on several factors in a way that is currently poorly understood. Besides the harmful effects of cavitation erosion, cavitation has found a recent breadth of applications in food industry, medicine (fat treatment, cancer therapy) and microfluidics.

The ultimate goal of our research is to find a unified theory to predict the energy released in the energetic events occurring at the cavitation bubble collapse. Such a theory would provide a unique tool to optimize virtually any cavitation-based application.

As end note, we mention that the pressure stratification that gravity induces in the fluid can be considered a first-order approximation of more complex pressure fields such as appearing in hydraulic machines. Varying the gravity level onboard parabolic flights thus offers a controlled way to study the effects of any complex pressure field on the bubble dynamics.







VIBRATIONAL PHENOMENA IN LIQUIDS (VIPIL)

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SCIENTIFIC OBJECTIVE

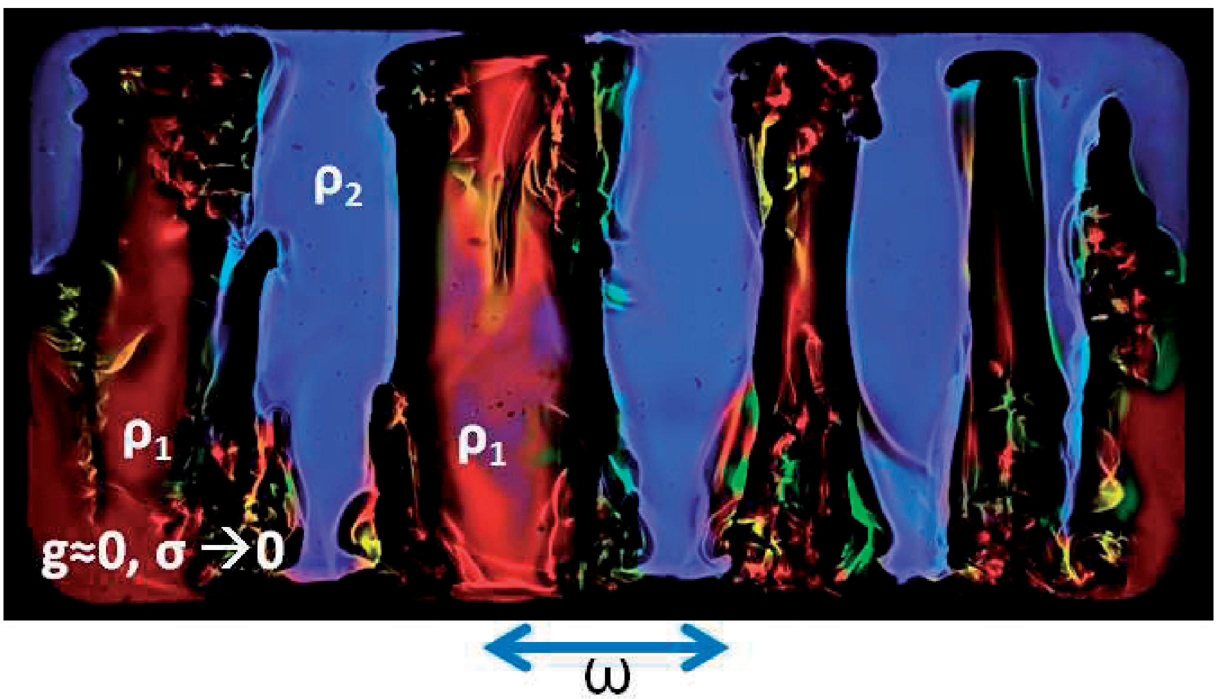
During the 59th ESA PF campaign we successfully studied the dynamical phenomena on miscible liquid-liquid interface in a single pair of liquids (water-isopropanol) whose viscosities differ by two times and density only by 0.92 times. We experimentally demonstrated that a new type of interfacial instability may occur between two miscible liquids of similar viscosities under horizontal vibration. Under the low gravity conditions of a parabolic flight, the amplitude of the interfacial waves grows continuously until it nearly reaches the limiting walls. The final and long lived pattern consists of a series of vertical columns of alternating liquids, as shown in the figure. To understand the role of various parameters, usage of different liquid combinations would be required. Thus, two other pairs of liquids, one with similar viscosities and the other one with a larger density difference, will be examined. Exact repeatability imposes difficulties because the gradient of concentration between liquids depends on the filling process and interface dynamics is affected by the quality of gravity. Thus, each experiment has to be repeated at least twice. Furthermore, on one of the flight days we are planning to analyze the impact of vibrations on the interface between immiscible fluids. Although immiscible interfaces have received much attention in ground studies, it will be the first experiment under reduced gravity conditions.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

We consider two layers of binary mixtures of the same constituents (water–alcohol mixtures of different percentage). The both liquids are injected into the transparent cell (L×H×W=15.0mm ×7.5mm×5.0mm) simultaneously by two identical syringe pumps through the orifice at the bottom (the denser liquid) and top (the lighter liquid) walls. The excess of liquid leaves the cell through the orifices located in the side walls. Because of irreversibility of mixing process, each experiment with miscible liquids requires a fresh refill of the cell. In the case of immiscible liquids, the cell is filled in advance on the ground. The cell is fixed to a linear motor, which performs translational oscillations in the horizontal direction: $X = A \cos(\omega t)$, here $\omega = 2\pi f$, A is the amplitude of vibrations. The direction of vibrations is perpendicular to the concentration gradient and coincides with the initial interface. The used linear motor is capable of independent adjustment of frequency and amplitude within the ranges 2–24Hz and 1.5–16mm, respectively. The flow dynamics was monitored from the side by direct shadowgraphy of the interface. An optical system is adjusted to provide the gradient of refractive index which corresponds to the concentration gradient. The deviation of the light path due to the high density gradient results in images with dark regions corresponding to the interface.

APPLICATIONS OF THE RESEARCH

The challenge is to find an optimal process to manipulate small liquid quantities, down to the nanoliter scale where convection is negligible. The mixing processes that may be generated by the oscillations are of primary importance to the chemical, biological and process industries



MUSCULAR FORCE GENERATION IN MICROGRAVITY

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SCIENTIFIC OBJECTIVE

Available data suggest that high-load, muscle-specific exercise is necessary to maintain muscle mass and function during prolonged spaceflight. However, based upon existing literature, we can postulate that individuals may not be able to reach as high muscle forces at all lower-limb joints during voluntary contraction in microgravity (μG). This hypothesis has, however, not been tested and parabolic flight offers an ideal environment to test it. If the hypotheses was true, this would limit our ability to perform exercise to maintain the musculature in microgravity. One possible mechanism is that, based upon neurophysiological studies, reduced muscle spindle afference in microgravity reduces the peak drive voluntarily attainable for muscle activation. We aim as a first step to examine whether there are indeed alterations of peak force generation characteristics in microgravity in the lower-limb. Specifically, we will examine whether maximum voluntary capacity and rate of force development of plantarflexion and leg-press are impeded in the microgravity phases of parabolic flight. Maximal hand-grip force is to be measured as a control condition. As secondary outcome measures, we will assess muscle electromyographic activity, superimposed twitches and ultrasound parameters of musculotendinious loading.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

In order to investigate muscle force and function, muscle strength is tested during three different tasks: (1) grip strength, (2) leg press and (3) plantarflexion. The grip strength will be tested with a hand-dynamometer. The maximum voluntary contraction (MVC) of knee extensors and plantar flexors will be carried out on a self-made dynamometer (picture1), which enables both isometric plantarflexion and isometric leg extension. To measure the force exerted during the MVCs, two force plates are implemented. For the plantarflexion the subject's leg is extended and the foot will be attached to the small force plate on the bottom. For the knee extension the subject's foot is attached to the big force plate on top. The dynamometer is specifically designed to be used in the parabolic flight. Muscle activity is measured using electromyography, position of the ankle and knee joints are measured using a camera and muscle behaviour is visualized using an ultrasound probe (picture2). Tests will be performed in microgravity and normal gravity.

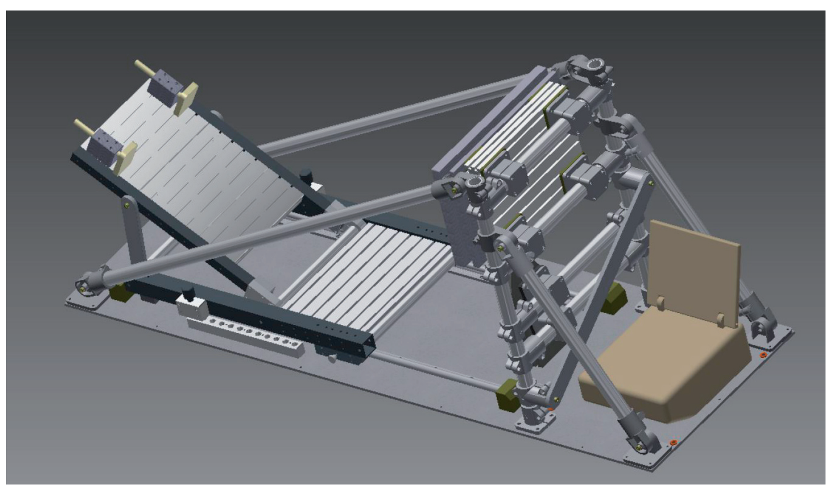
Lastly, the ability to fully activate the calf muscles during a volitional effort and some of your neuromuscular properties will be studied by applying a brief electrical stimulation to the nerve commanding the calf muscle both during a maximum voluntary contraction and during rest.

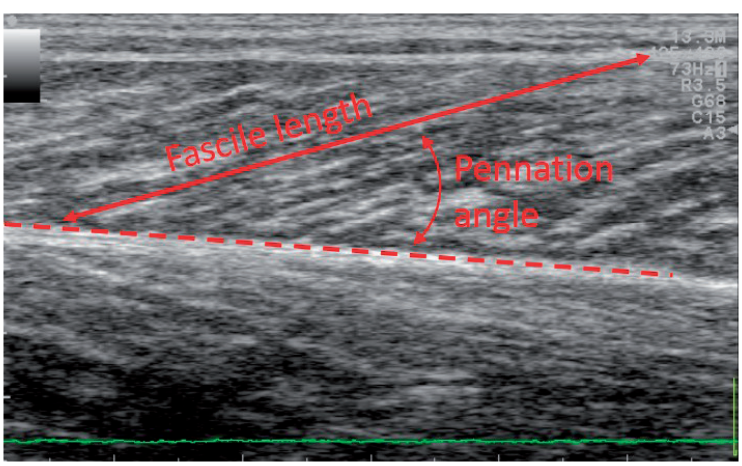
APPLICATIONS OF THE RESEARCH

The goal of the project is to perform a deeper examination of muscle force and function during high-load resistive exercise in microgravity. Therefore, the benefits of this examination are clearly based on the applicability of countermeasure against muscle atrophy in manned spaceflight.

The importance of this issue for spaceflight is that if it is not possible to attain high load levels during µG, or if the force generation profile is impeded, then it might not be possible to exercise the musculature at the load levels that are better suited for maintaining muscle mass. This may be one explanation for the only moderate effect of exercise countermeasures in prolonged spaceflight against (calf) muscle atrophy.

The findings of this project will contribute to our basic understanding of human neurophysiology and biomechanics, in particular the influence of gravity on voluntary and involuntary force-generating capabilities.





TECHNICAL VALIDATION OF A NEUROCOGNITIVE TEST BATTERY FOR IMPLEMENTATION ON THE RUSSIAN SEGMENT OF THE ISS

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Living in extreme environments is accompanied by a number of stressors, which can be classified either as physiological (e.g. microgravity, missing sunlight) or psychological stressors (e.g. confinement). From a multitude of studies a negative impact of stress on mental health and cognitive performance is well known and both factors might impair mission success and mission safety during longer inhabitation of space.

Based on this consideration, a first set of experiments is proposed for embedded neuro-cognitive testing within the restrictions on board of the International Space Station (ISS). By using the existing Soyuz docking manoeuvre training, which is currently performed on board of the ISS, and integrating an active EEG system to allow for localisation of brain cortical activity using source localisation algorithms, it is aimed to (1) assess mental load and cognitive performance by using neurocognitive markers (P300) and to correlate these with docking performance, (2) to explore how these markers are influenced by stress and (3) to check whether exercise could act as a "neuro-enhancer" and an adequate countermeasure to stress as currently discussed in the literature.

CYTOSKELETON INVESTIGATION (CSI HOHENHEIM) – GENE AND PROTEIN ANALYSIS

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SCIENTIFIC OBJECTIVE

Gravity sensing is well examined in living organisms. Along with the different organisms, the mechanics of the gravity perceiving systems vary (e.g. the vestibular organ of vertebrates, statocytes in plants). Single cells also react to changes in gravity, but there are many open questions about the molecular mechanisms.

Biological cell membranes and the cytoskeleton are necessary for cell function.

Our team wants to perform two separate experiments. In the first experiment we want to collect samples of fixed cells for later gene and protein analysis.

The second experiment works focuses on membrane and cytoskeleton stress during gravity changes. Here we want to explore if the biophysical parameters of cell membranes are changed during gravitational stress with cells where we damaged the cytoskeleton.

In the last years fluorescent dyes have been developed for a variety of intra-cellular ion-concentrations and for other relevant membrane parameters as lateral pressure. Using these dyes, among others the influx in cells through the given selective ion-channels can be studied very efficiently, i.e. under conditions of changing gravity. Additionally, with instruments working with multiwell plates a high number of data points can be acquired within one parabolic flight day.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

We are using two high-throughput plate readers (PHERAstar FS from BMG Labtech) which was adapted to parabolic flight conditions.

The cells will be grown in the 96-well plates in the lab and before flight they will be incubated with the dyes.

During the parabolic flight, changes in membrane properties measured by fluorescence changes will indicate among others changes in membrane transport processes.

APPLICATIONS OF THE RESEARCH

A high-throughput fluorescence reader adapted to micro- and hypergravity, gives the opportunity for many fields of research to perform modern experiments under space conditions with a high data-yield.

PROGRA2 (PROPRIÉTÉS OPTIQUES DES GRAINS ASTRONOMIQUES ET ATMOSPHÉRIQUES)

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SCIENTIFIC OBJECTIVE

In many regions of the Solar System, clouds of solid particles are present. Most dust clouds are not characterized by a high density but they might be remotely detected by the light they scatter. In-situ observation, remote observations or direct investigation of interplanetary dust are common practice for the research on light scattered by clouds of solid particles. This light scattering can be studied using different techniques. Reduced gravity can be used to reassemble the conditions close to those existing in space. Such a set-up allows laboratory experiment measurements which can serve for relating remote or in-situ observations to physical parameters (size, porosity, nature). Parabolic flights are used for that purpose because light scattering measurements can be made within seconds for any kind of particles without discrimination by weight or composition.

The PROGRA2 project was set-up to provide key scientific results in terms of astrophysics (e.g. agglomeration processes in proto-stellar clouds, evolution of dust particles in cometary comae) and physics of the atmospheres (e.g. Titan, Earth). The PROGRA2 experiment allows measurements under microgravity conditions of polarization phase curves for clouds of dust particles. The sizes that can be used range from a few micrometers to hundreds of micrometers; regular or irregular particles can be tested.

The PROGRA2 instrument is mainly funded by the French space agency CNES

PROGRA2 is an imaging polarimeter with a rotating arm to change the phase angle (angle between direction of illumination and direction observation). It allows to retrieve the complete polarization phase function between 10° and 165°. The light sources are between 540 and 1500 nm. The detectors are cameras, with a spatial resolution of ~20 µm per pixel. The PROGRA2 project performs measurements in microgravity during parabolic flights since 1994. The microgravity conditions are suitable for levitating compact particles with diameters greater than 20 µm. For smaller and/or lighter particles, the microgravity produces agglomerates of particles.

This PROGRA2 parabolic campaign is partly the continuation of works in the frame of the ICAPS program, funded by ESA, onboard the International Space Station. The ICPAS Light Scattering Experiments require a careful selection of the dust particles samples. Their physical properties are defined as follows: composition and complex refractive indices, size and size distribution, shape and morphology. They are chosen in order of providing key scientific results in terms of astrophysics (e.g. agglomeration processes in proto-stellar clouds, evolution of dust particles in cometary comae) and physics of the atmospheres (e.g. Titan, Earth). The samples need to be appropriate for the ICAPS instrumentation (injection device, sticking on the surfaces) and to be accurately calibrated.

A second objective is the study of carbonaceous particles that can be found in the different places of the solar system. During this campaign, carbon particles produced in laboratory and that can be a simulant of material found on comets and asteroids will be studied.

APPLICATIONS OF THE RESEARCH

Our light scattering researches were used to develop a new concept of light aerosols counter (LOAC). This instrument is now produced by the Environnement-SA and MeteoModem companies and is used in routine for the monitoring of air quality and for the study of aerosols from ground up to the middle stratosphere.

BLOCKAGE TRANSITIONS IN CONCENTRATED SUSPENSIONS OF NON COLLOIDAL PARTICLES IN THE PRESENCE OF FLUIDIZES

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SCIENTIFIC OBJECTIVE

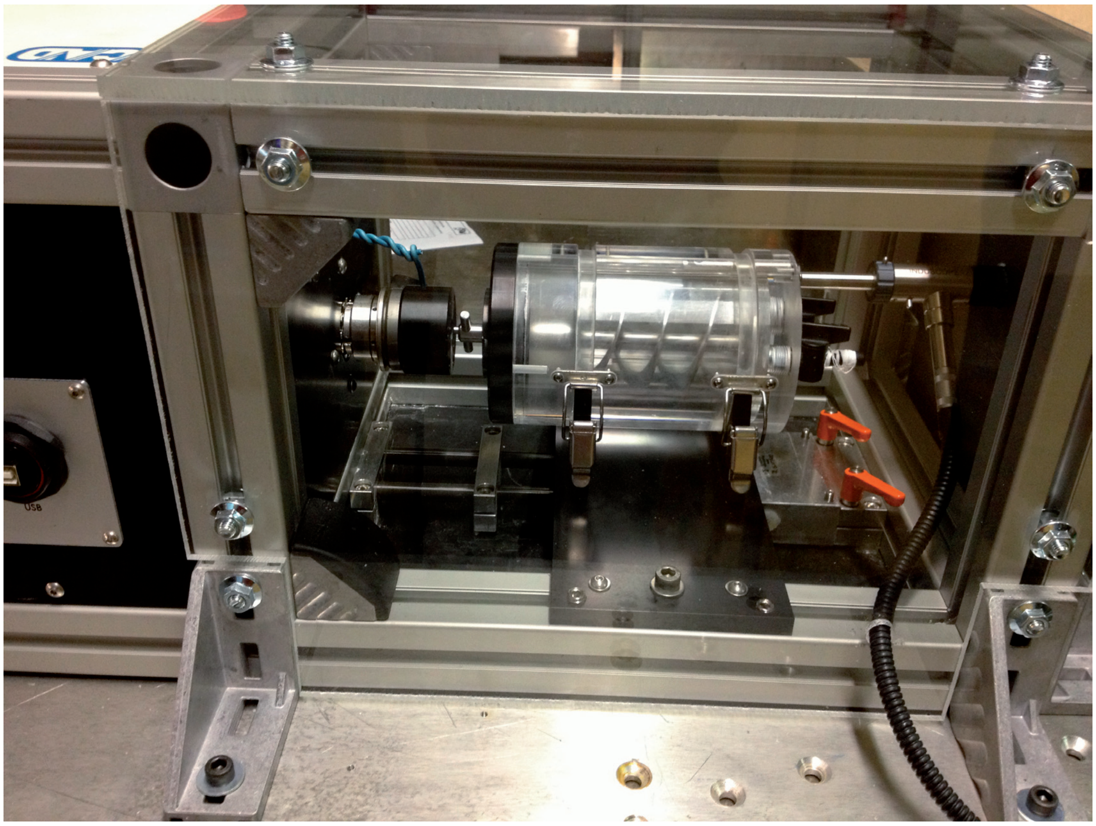
The plasticizers are polymers which can significantly reduce the viscosity of dispersions of inorganic particles in water. They are polymers widely used in the cement or plaster industry where it is desired to have the highest possible fraction of solid particles while maintaining a good «flowability». On the other hand concentrated suspensions or dense granular media are known to have blocking transitions above a certain shear rate. We want to push this critical shear rate as high as possible and for that we need to understand the factors determining the onset of this blockage: the length of the polymer chains, their adsorption energy, their surface density ,the polymer-solvent and polymer-polymer interactions etc ... .. One of the problems is the sedimentation:: the system becomes inhomogeneous and, as blocking phenomena are very sensitive to the contacts between particles, it becomes very difficult to interpret the results By studying these phenomena in microgravity we can achieve fundamental results that will allow us to develop models able to predict these blocking transistions whatever the experimental conditions.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

We use, as an experimental system , a suspension of calcium carbonate particles which is sheared by a propeller rotating in a cylindrical vessel (see figure). The recorded data are the torque and the speed versus the time .These are the data which are compared to those recorded in normal gravity and which will allow us to feed the parameters of numerical models under development

APPLICATIONS OF THE RESEARCH

The applications are directly related to the design and synthesis of new plasticizer molecules used in order to increase the performance of concrete. More generally are concerned all the applications where flowing pastes or granular materials are used.



BIOROCK PARABOLIC

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SCIENTIFIC OBJECTIVE

Researchers from the University of Edinburgh plan to use a parabolic flight campaign to perform preliminary investigations in preparation for 'BioRock', an ESA experiment on board the International Space Station. BioRock seeks to understand the role of gravity and microgravity on the formation of biofilms, which are communities of bacteria found commonly in nature, and which can be utilized by humans. The parabolic experiment will replicate the first seconds of the experiment, when the astronaut will inject water into the bacteria system, reviving the bacteria dried down on basalt. Water mixes differently in microgravity, and it is expected that any bacteria washed off the rock by the injection of the water are unlikely to contribute to the final biofilm production. Quantifying the loss of bacteria in these first few seconds is an important part of interpreting the data when the experiment returns to Earth.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

Simplified versions of the BioRock bioreactors containing the bacteria will be flown – the Two Syringe System (TSS). As the plane enters microgravity the first syringe, containing water, will be depressed, pushing water into the second syringe containing the bacteria dried down on basalt. This will simulate the beginning of the ISS experiment when the astronaut injects the water into the bioreactors.

Just before the plane leaves microgravity, the water will be pulled back into the first syringe. The experiment will be repeated with a new TSS every parabola.

Back on the ground the researchers will serially dilute and plate the water onto agar plates, in order to count the bacteria. The bacteria on the basalt will be thoroughly washed off, plated, and counted; the bacteria numbers from the two syringes will then be compared. With enough replicates, it will be possible to work out a range and an average ratio of bacteria on and off the rock, and will allow the researchers to predict with more accuracy the bacteria numbers contributing to biofilm formation on the ISS flight, and even to make recommendations to the astronauts about the best strategy for injecting the water.

APPLICATIONS OF THE RESEARCH

This experiment is specific to the ESA BioRock experiment. However, bacteria have many uses in space, such as for life support systems, air purification, water purification, food production, waste disposal, biofuel, biomining etc. Bacteria taken into space for these purposes are almost always dried down, and while the surfaces they are dried onto might differ, this research may inform other geomicrobiology experiments in the space environment.

PARABOLIC FLIGHT INDUCED NEUROPLASTICITY STUDIED WITH ADVANCED MAGNETIC RESONANCE IMAGING METHODS

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SCIENTIFIC OBJECTIVE

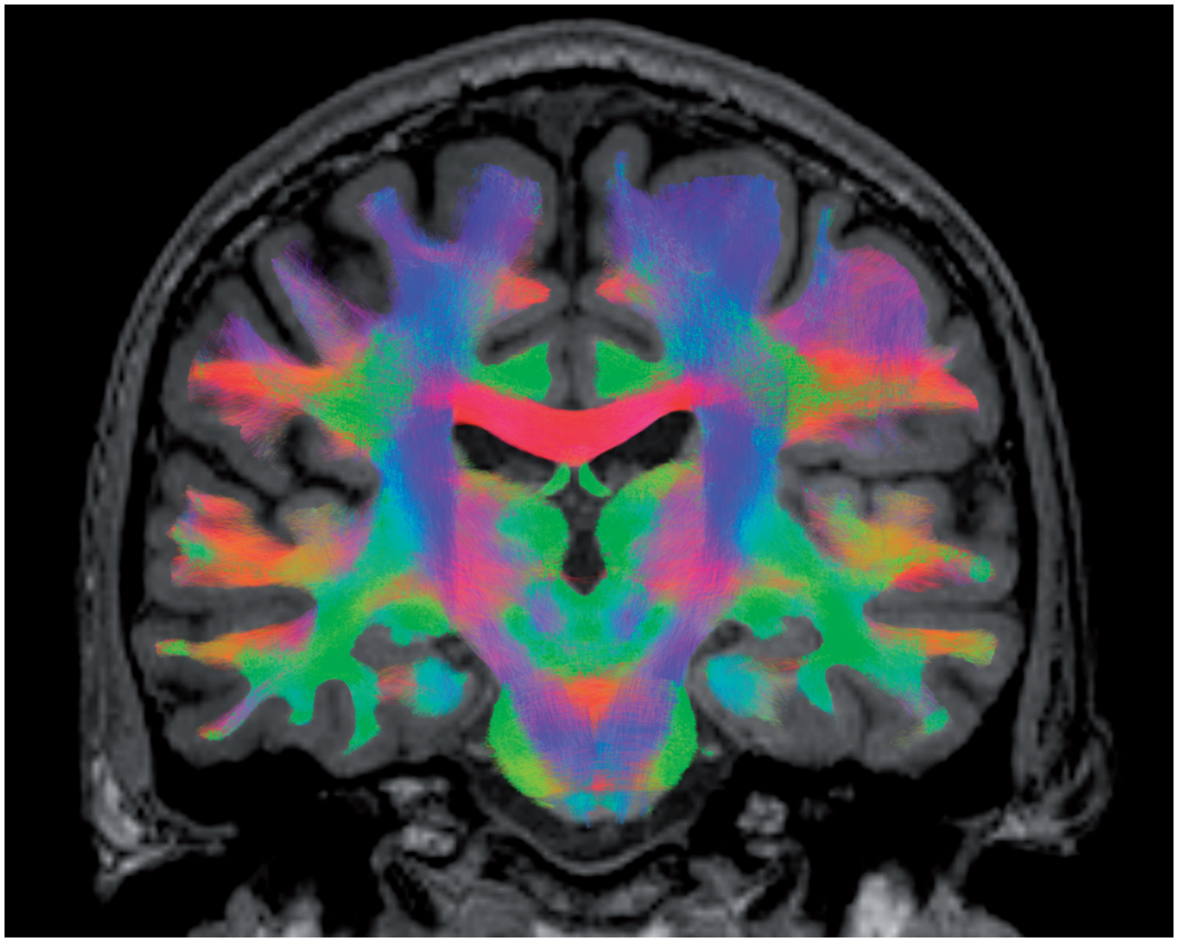
The hypothesis of this study is that short duration microgravity and gravity transitions, experienced during parabolic flight, induce neuroplasticity in different regions of interest (ROI) in the brain that are involved in the integration of neuro-sensory information, provided by the vestibular organs, vision and proprioception. Additionally, we want to compare these results with data we will collect in 12 cosmonauts flying to the ISS. Comparison between PF microgravity and spaceflight long duration microgravity could elucidate group differences at certain regions and tracts. Finally, the identification of sites of neuroplasticity related to adaptation to microgravity, g-level transitions, and 'coping with motion sickness' could be used to verify these ROI in patients that suffer from continuous vertigo or instability, due to inappropriate adaptation after lesions, or patients with 'mal de debarquement' syndrome.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

By means of advanced MRI methods (DTI, DKI, HARDI, VBM and rs-fMRI), we hypothesize that biomarkers for neuroplasticity can be identified when MRI images of the same subject, acquired before (L-10, L-2) and after parabolic flight (R+0, R+3, R+7, R+45, R+90), are compared with each other. Consequently this will allow for the identification of specific regions of interest (ROI) and fiber tracts that are involved in neuro-vestibular processes. The L-2 and R+0 scans are conducted in Bordeaux, close to the PF site, to minimize the interval between the landing of the parabolic flight and the actual scan. The other scans are conducted in Antwerp.

APPLICATIONS OF THE RESEARCH

Information obtained from this study could help for a better understanding on how neuroplasticity takes places and therefore explain what happens in microgravity at the central level. Therefore, it has a direct application for space research in that is serves as a ground-based alternative to the parallel study we are conducting in cosmonauts. Indirectly, it could also pinpoint towards the development of adequate countermeasures for space motion sickness as well as vestibular symptoms.



this experiment is not an ESA experiment, it was selected by Novespace

NET PARAMETRIC CHARACTERIZATION AND PARABOLIC FLIGHT (PATENDER)

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SCIENTIFIC OBJECTIVE

As space debris is recognized as a major risk for space missions the European Space Agency (ESA) through the Clean Space Initiative is funding several activities to mitigate this risk. The ESA-funded PATENDER activity (Net parametric characterization and parabolic flight) has a clear objective of developing a confident mean to further investigate, develop and validate the concept of using nets for actively removing space debris of different characteristics.

A net simulator will be validated in a parabolic flight experiment where microgravity conditions can be reached during some few tens of seconds. A set of nets with masses attached at the corners will be launched using a pneumatic-based dedicated mechanism in order to simulate the capture of large space debris. High-speed motion cameras will record the experiment to perform afterwards the reconstruction of the net trajectory including the wrapping around a satellite mock-up target.

TECHNICAL DESCRIPTION OF THE EXPERIMENT

The parabolic flight experiment has been designed to maximize the probability of wrapping success, by tuning net shooting velocity/angle and target position.

The launching mechanism is composed by a motherboard supporting these elements: a net container and four adjustable bullets liners and a pneumatic system managing an air tank and several latching valves. The operator places the net within the container and the corner masses over the bullets liners and fills the air tank with pressurized air. At this stage the net is ready to be launched at the desired initial velocity.

High-speed motion cameras will record the experiment in order to allow the 3D reconstruction of the deployment and wrapping around the target phases and the validation of the software simulator. Net knots have been colour-coded and their 3D trajectory reconstruction procedure is based on the image processing for colour segmentation, stereo matching of the segmented knot and iterative closest point (ICP) for time tracking of knots. Vision algorithms from Politecnico di Milano have been adapted for the specific features of this experiment and successfully tested on real acquisitions on ground. The acquisition set-up has been designed in order to reduce the occlusions due to the target mock-up and to maximize the stereo field-of-view to increase the visibility window.

APPLICATIONS OF THE RESEARCH

The output of this activity will be the implementation of a high-fidelity throw-net simulator validated through a parabolic flight campaign. It would allow to investigate the area of Space debris remediation having as envisaged mission the recovery of the Envisat satellite.