The Third ESA Student Parabolic-Flight Campaign

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Introduction
After the successful Student Parabolic-Flight Campaigns conducted in 1994 and 1995, ESA has now resumed their organisation on an annual basis. The Third Campaign was held in Bordeaux, France from 16 to 27 October 2000. The flights were conducted at Novespace's facilities at Bordeaux-Merignac airport, which is home to the Airbus A300 Zero-g aircraft. Novespace operates and manages the A300, which is specially adapted for microgravity experimentation. The aircraft is maintained by Sogerma and operated in flight by the Centre d'Essais en Vol (Flight Test Centre).

Today's students will become tomorrow's workforce and hence they should be involved in the global space programme as early as possible so that they will be motivated to follow space careers and create a space-educated next generation for working within the space domain. Getting students involved in today's space programmes is important not only for the space industry in terms of providing a talented workforce for the future, but also for the general public who will be the future voters and potential political supporters of future European space activities. With this in mind, ESA's Office for Education and Outreach organises and runs many space-related activities for young people in order to stimulate their interest in space in particular and in science in general. One of these activities is the 'Student Parabolic-Flight Campaign'.

Figure 1. The Airbus A300 Zero-g aircraft (courtesy A. v.d. Geest)

From the 150 applications received for this Third Campaign, a total of 31 experiments were selected using the criteria of originality, demonstration of 0g, technical complexity and outreach performed by the team. Each experiment team consisted of four students, whereby each experiment was flown twice accompanied by two students each time. (The list of experiments, along with short descriptions and preliminary results, can be found in Table 2).

The flights took place over four days, and a total of 122 students from 11 countries (Table 1) were able to experience weightlessness first hand.

Table 1. Numbers of student teams participating in the Third Campaign

Belgium	5
Finland	3
France	6
Germany	2
Italy	6
Netherlands	1
Portugal	1
Spain	1
Sweden	1
Switzerland	1
United Kingdom	3
International Teams	1
Total	31

Students were asked to address outreach as part of the selection process and several student groups brought along their own journalists, who followed their progress throughout the application and selection processes, and eventually got to fly with their chosen group. Other outreach activities conducted by the students included creating their own web pages, giving talks to local schools, and publishing newspaper reports and articles in scientific magazines.

Figure 2. A free-floating journalist

Approximately 30 European journalists covered the campaign, with 18 of them actually participating in the flights.

The following TV broadcasters participated in the campaign:

– DRTV, Denmark
– MTV 3, Finland
– France 3, France
– TF1, France
– Spiegel Magazine/ TV, Germany
– Deutsche Welle, global
– Canal 24 Horas, global (in absentia)
– RAI Leonardo, Italy
– RAI SAT, Italy (on the ground)
– RTP, Portugal (on the ground)
– Antena 3, Spain
– SVT Nova, Sweden
– TROS, The Netherlands
– BBC 1, United Kingdom
– BBC 2, United Kingdom (in absentia).

The following press/radio reporters participated in the campaign:

– Le Soir, Belgium
– Tahdet ja avaruus Journal, Finland
– EADS Magazine, France
– Newton Magazine, Italy
– Volare, Italy
– RDS, Italy
– Kijk Magazine, The Netherlands.

Figure 3. The A300 Zero-g during the injection phase before a parabola (courtesy of Novespace)

A representative of the Italian Space Agency (ASI) was also included on one flight in recognition of the funding and support that ASI gave to three of the Italian experiments.

Flight-week activities

During the first week of the campaign, the students arrived in Bordeaux with their experiments and took up residence in the specially constructed marquee in Novespace's grounds to prepare their experiments. Last-minute modifications were carried out in order to pass the security tests performed by the Centre d'Essais de Vol (CEV). Once they were cleared, the experiments were loaded into the Zero-g aircraft, ready for the flight.

The four flights were performed as planned during the second week of the campaign, with each flight accommodating approximately 50 passengers: 30 students, an average of 5 journalists, the ESA photographer, Novespace and ESA representatives and a cabin crew of 5 CEV safety personnel.

On each flight, 30 parabolas were performed and the quality of the microgravity generated was found to be very good, with an average level of between 10^{-3} and 10^{-4} g being generated.

A quick turnaround between the two groups occurred on Tuesday afternoon and Wednesday, when all Group 1 experiments had to be unloaded and the new Group 2 experiments loaded into the A300.

Despite such difficulties, all of the experiments and the participating students were flown, which led to many CEV records being broken, including those of the most experiments ever flown and the most parabolas/flights performed in one week.

Table 2. The experiments in the Third ESA Student Parabolic-Flight Campaign

Material Science/Material Processing

Experiment name: **Foam** *From:* Cambridge University, UK

Description: Creating Structural Foams: an investigation into the isotropic properties of plastic foams formed in microgravity.

Results: Optical microscopy showed little geometric difference between the vertical and horizontal zero-g cores, as predicted. However, unexpectedly, the zero-g samples showed a mass distribution with a minimum in the centre of the sample. The bubble structure also caused surprises with an angular structure being preferred over the expected spherical form.

Experiment name: **Eutectic** *From:* University of Technology, Tampere, Finland

Description: Producing samples of eutectic and other alloys under microgravity conditions.

Results: Pending

Experiment name: **Welding** *From:* University of Bologna, Italy

Description: Observing how microgravity affects the phenomena related to the solidification of an aluminium alloy, which will be melted during a welding process.

Results: Weld beads were obtained in 0g, 1g and 2g environments. Polishing and chemical attack in 0g: The top of the weld bead was flat and bright whereas the bottom had a lack of metal due to cooling. Different (round) phases were observed in the bead, indicating a bad mixture and poor convection and heat diffusion. This is due to the dynamic Marangoni effect. The structure has local orientation and is globally irregular. In 2g there was good heat diffusion and the phases were more extended along the thermal flow direction. The structure was globally oriented. Stereomicroscopic imaging revealed that the flux lines in the molten material inside the welding bead radically change from 0g to 2g. Further analysis will include XRD X-ray diffraction, tensile tests and wrinkle profiling.

Experiment name: **Poly** *From:* University of Parma, Italy

Description: Production of low-density expanded polyurethane under microgravity conditions and comparison with 1g-produced polyurethane.

Results: The static mixer system was found not to be a good system for creating foam in 0g due to the fact the reaction time was not quick enough. This led to the foam being non-uniform and full of veins and streaks. In spite of this, the following tests were made on the18 polyurethane foam samples produced:

- The compression test: due to the non-uniformity of the samples the test calculated different resistance coefficients depending on the direction of compression.
- The optical test: it revealed more spherical cells in 0g than in 1g.

Fluid Physics

Experiment name: **Beer** *From:* Technological University of Delft, Netherlands

Description: Studying the behaviour of gaseous and non-gaseous fluids in microgravity, including the tapping of beer.

Results: Beer tapping: The modified beer barrel was declared perfect for use in space, enabling the beer to be tapped without spluttering. However, no foam head was created; instead the CO_2 bubbles spread out homogeneously in the liquid, resulting in a grey-brown turbulent liquid.

Amongst many other fluid-physics experiments conducted, the contact surfaces between different liquids were observed:
- water-glycerine: this created a curving surface – are non-viscous fluids therefore more sensitive to 0g than viscous fluids?
- acetone-oil: surface became very faint – good mixability of acetone in oil in zero-gravity
- water-air: most unexpected result – surface was undisturbed! Surface tension on water surface is strong enough to keep the surface intact and avoid 'curling'.

Experiment name: **Mix** *From:* Imperial College, London, UK

Description: Studying the immiscibility of fluids (water and silicon oil) under standard and microgravity conditions.

Results: Many different behaviours were observed, some expected and others not. The latter could be due to the fact that an air bubble and impurities were present in the fluids, and also the discrete fluctuations in the g-field. Particular examples include: spherical bubble formation occurred throughout the experiment, as expected, but these were of water and not oil, due to the higher surface tension of water. These spherical bubbles were deformed by adhesive forces when they came into contact with any of the solid surfaces present. Cohesive forces were only visible through the smaller water molecules and the air bubble.

Experiment name: **Phase** *From:* Imperial College, London, UK

Description: Investigating the effects of microgravity on two-phase flow.

Results: After an initial leak in one of the connections was repaired, many interesting observations were noted, including the fact that colliding air-bubbles underwent elastic collisions and different flow patterns were observed in 0g than in 1g, which depended on the amount of air present.

Experiment name: **Marangoni** *From:* **Catholic University of Louvain, Belgium**

Description: Investigating the induction-driven Marangoni effect

Results: Pending

Experiment name: **Fluid Disc** *From:* University Frederico II, Naples, Italy

Description: Creating a fluid disc and studying fluid jets

Results: Due to technical problems, the disc formed only for a few seconds during each parabola. After that the water floated into the cell, which led the pump to drain air and hence broke the disc into droplets. Horizontal ejection did not seem to be optimal.

Experiment name: **Bubbling** *From:* ETSI, Madrid, Spain

Description: Studying bubble behaviour and effervescence in microgravity

Results: Pending

Experiment name: **BlobTrap** *From:* University of Oulu, Finland

Description: Studying how liquids of different viscosities can be handled in the microgravity environment without physical contact

Results: Successful liquid injection was achieved and liquid blobs were seen moving slowly through the experiment tube. However, no difference was observed between the oil and water blobs, perhaps because of the air stream being too powerful.

Experiment name: **SOAP** *From:* University of Liege, Belgium

Description: Studying the creation and evolution of bubbles in a liquid and investigating the drainage and wetting of foams.

Results: 2D Foams: In the Hele-Shaw cells, the zero-gravity stage induced a fast wetting of the foam and the creation of spherical bubbles - microbubbles being transported upward and large bubbles moving downwards.
3D foams: In zero gravity, the wetting of the foam in the HS cells was first of all observed and then when sufficiently wet, the foam started to flow along the walls of the cylinder, finally surrendering the large air bubble located at the centre of the cylinder.

Biology

Experiment name: **Fruit Fly** *From:* University of Trieste, Italy

Description: Studying the behaviour of Drosophila flight in different gravity and lighting conditions

Results: Pending

Experiment name: **Plant** *From:* ENSIA, Nancy, France

Description: Studying the influence of microgravity stress on maize exudation and on the colonisation of the rhizosphere by the bacteria communities.

Results: At the time of writing, analysis of the 750 bacteria and root samples obtained was just getting underway, with results expected in a couple of months.

Experiment name: **Catch** *From:* Santa Anna's School, Pisa, Italy

Description: Evaluating the behaviour of the upper limb during grasp in zero-g and hypergravity conditions.

Results: Preliminary results focus on the two degrees of freedom of the index finger only. By plotting time versus channel value, the graphs clearly show the difference between the behaviour of the middle finger in 0g and 1g. The constant repetition of the same phalanx movement during the parabolas can be seen, as can the large gap between the 0g data compared with the data obtained in 1g.

Experiment name: **Fish** *From:* University of Oulu, Finland

Description: Monitoring the changes in behaviour and orientation of a shoal of fish in different environments

Results: The fish reacted to the different gravity conditions individually rather than as a shoal. Each fish started behaving nervously and looping during different parabolas. Group formation was only intact during the 1g and 2g environments. The different lighting conditions had no effect on their behaviour or orientation.

Experiment name: **Orientation** *From:* University Joseph Fourier, Grenoble, France

Description: Studying the kinematics and accuracy of pointing movements without visual feedback towards the subjective horizon, when applying pressure and contact cues on different parts of the subject's body.

Results: Subjects 1, 2 and 3: During the parabolas the pointing movements towards the horizontal were considerably lower than the absolute horizontal reference. The subjects also showed an 'order effect', whereby there was an increasing gap between the motor response and the reference during the parabola. Only subject 2 showed any signs of adaptation between parabolas. Subject 4 had a lot of experience in 0g and his pointing measurements were no different in 0g than 1g and remained the same throughout the flight. However, he was the only subject to show an effect due to pressure simulation; foot pressure made him point too high and head pressure made him point too low.

Experiment name: **Centrifuge** *From:* University of Lausanne, Switzerland

Description: Developing an easy to use, small and light centrifuge capable of achieving 50 000g and using it to test the effects of gravity on the reorganisation of prokaryotic nucleosome and eurcaryoitc nucleus after centrifuging.

Results: Both centrifuges worked perfectly during both flights. Of the three species of cells (bacteria, cyanobacteria and yeast) fixed in microgravity, only one (bacteria Bacillus megaterrium) showed a different DNA repartition in 0g than with fixation in 1g. Big globules were observed in the cytoplasm of Bacillus megaterrium when the cells were fixed in microgravity. The size and repartition of these globules are different from the cells manipulated in normal gravity. This leads to the conclusion that there is a mechanism of internal arrangement present in the bacteria which depends on the gravity level.

General Physics

Experiment name: **Strain** *From:* ENSMA, Poitiers, France

Description: Studying the behaviour of different materials (Teflon, PVC and steel) and their state of strain in microgravity

Results: The Teflon behaved as expected, with the length variations following the acceleration without any reaction time. However, the results from the PVC and steel were very surprising; at the end of the 0-g phase, the sample first returned to its original length then continued to shrink during the hypergravity phase. This will require further study!

Experiment name: **Detector** *From:* Catholic University of Louvain, Belgium

Description: Developing a new generation of particle detector; preparing a stable mixture in which the freon is uniformly spread out as tiny droplets.

Results: In spite of technical problems during the second flight, 34 samples were prepared and the six parameters below changed to find out their influence on the polymerisation:

1. Changing the diameter of the samples: the larger diameter samples were not polymerised across the entire section, leading to the conclusion that the mixing in 0g made the gel less transparent to UV light.
2. The concentration of Solkane did not seem to influence the curing of the gel.
3. Too strong a concentration (20%) of KCL generated a rapid autopolymerisation. A reasonable concentration of KCL in order to produce a homogeneous polymerisation was 9.1%.
4. 24% of $BaCL_2$ seemed to be the appropriate value for proper polymerisation.
5. It was also found that it was imperative to polymerise the entire sample in microgravity.
6. Dishwasher soap (5%) was found to improve the mixing of the two components by decreasing the surface tension.

Experiment name: **Dustgun** *From:* Technical University of Braunschweig, Germany

Description: Conducting dust-aggregation experiments with magnetised and non-magnetised dust grains in order to study the effects of magnetisation of pre-planetary grain growth

Results: SEM imaging revealed that the purely magnetic samples favoured chain-like particle growth as expected. However, the mixture of magnetic and neutral (spherical) particles showed a much more surprising result - the spherical particles appeared to be caught in complicated web-like structures of almost linear dimensions. Dust aggregation in-situ was also observed using a CCD camera and long-range microscope. Initial analysis shows that a few, rare grain-grain collisions may have even been captured on film. Further analysis of individual aggregates using X-ray spectrometry will also be conducted to clarify the role of the individual grain types in the dust-growth process.

Experiment name: **Magnetism** *From:* University of Orleans, France

Description: Studying the effect of diamagnetism and deducing the atomic radius of different materials

Results: Pending

Experiment name: **Convection** *From:* Polytechnic of Milan, Italy

Description: Studying temperature changes due to microgravity effects in free and forced convection between two co-axial cylinders of different diameters, the inner one being heated by resistors.

Results: Major changes in temperatures were noted due to macro- and microgravity conditions when the fan was off and the lid closed, and when the lid was open. No changes in temperature were noted, however, due to macro- and microgravity conditions when the fan was on, at both voltage levels. These tests showed important phenomena that could cause problems during the thermal modelling of space instruments.

Mechanics

Experiment name: **Lubricate** *From:* INSA, Toulouse, France

Description: Studying the lubricating power and the kinematic behaviour of oil in zero gravity in transmission gears.

Results: The amount of oil was changed between the two flights (first flight – normal amount, second flight – excess oil) and the rotation speed of the gears was changed between parabolas. Using a normal amount of oil, it lost contact with the gears during zero-gravity and was ejected onto the container walls, at all rotation speeds, although the effect was more dramatic at high speeds. Only when excess oil was added did it pass through the gears, but at high speeds it still did not lubricate them correctly, due to the amount of air bubbles produced and cavitation phenomena.

Combustion

Experiment name: **COSMIC** *From:* Ecole Centrale de Paris, France

Description: Studying the combustion around a porous sphere

Results: The experiment worked perfectly during 51 parabolas and 42 successful ignitions were completed. In 0g the flame took on a spherical shape as predicted. However, the diameter of the flame was three times as big as in 1g. Fluctuations in the shape of the flame occurred and were probably due to the small fluctuations in the g-level from perfect zero-gravity. In hypergravity, the flame was much brighter and formed an even more cylindrical shape than in 1g. More soot was also produced. The relationship between fuel flow and flame diameter was also studied and it was found that as the flow rate increased, the flame diameter decreased. Many more post-analysis tasks are now scheduled, including a study of the soot formation and flame extinction.

Experiment name: **Burning Particles** *From:* Free University of Brussels, Belgium

Description: Estimation of the influence of particle burning on their motion

Results: Pending

Robotics and Technology Demonstration

Experiment name: **CRV** *From:* University of Lund, Sweden

Description: Investigating the ergonomics of the Crew Return Vehicle (CRV)

Results: All predefined procedures were executed by the end of the second flight, leading to many recommendations being put forward regarding all aspects of the ergonomics of the CRV, specific examples being seat design and ingress manoeuvres. A new design proposal will now be made for the interior of the CRV, taking into account the experiences of the team.

Experiment name: **Robot** *From:* University Nova de Lisbon, Portugal

Description: Testing the navigation and dynamics of the robot and its ability to use different radiation and magnetic sensors in microgravity.

Results: Although the robot experienced some problems due to the extra tension generated by the imposed safety straps/wires, the robot was successfully controlled using four motors in composed movements only, such as 'X and Y' and 'X and Z'.

Experiment name: **LEGO** *From:* University of Glasgow, UK

Description: Testing the GUST (Glasgow University attitude Stabilisation Tool) in microgravity conditions

Results: After some initial problems, the robot was able to track a moving source whilst maintaining continual line-of-sight with the source, hence proving the viability of using small reaction wheels for attitude stabilisation on an autonomous micro-robot.

Conclusions

The Third ESA Student Parabolic-Flight Campaign was a very successful one in terms of the numbers of students and microgravity experiments flown, the performance and quality of the experiments, and the media interest that was generated in the campaign and ESA as a result.

Once again, the students proved to be hard-working and adaptable, having invented and produced a series of very good microgravity experiments. Two of the very best experiments will now be chosen to participate in ESA's professional parabolic campaign in May 2001, in keeping with a new agreement that provides the possibility for exceptional student parabolic experiments to be up-graded for flight on a professional parabolic-flight campaign.

Next year's Student Parabolic-Flight Campaign will take place from 16 to 27 July 2001. It will have a slightly different flavour from usual due to the availability of a new Foton flight opportunity. For the first time, ESA has offered 7 kg of payload on the Russian retrievable satellite Foton to students. A parallel Announcement of Opportunity has been launched with the 4th PFC, enabling students to either propose a traditional parabolic experiment or a suitable Foton experiment. Students will need to chose carefully because parabolic-flight experiments are normally large and bulky, weighing up to 150 kg, whereas the Foton experiments will have to be autonomous, weigh less than 3 kg each and be made to fit within the special boxes provided.

Keeping the very best news until last, the budget has been allocated to allow the ESA Student Parabolic-Flight Campaign to be conducted once a year for the next five years.

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More information on the Foton opportunity is available on the dedicated web page: http://www.estec.esa.nl/outreach/pfc/Default.htm

More information on the 2001 Student Parabolic-Flight opportunity is available on the dedicated web page: http://www.estec.esa.nl/outreach/pfc/

Figure 9. The Participants in the Third ESA Student Parabolic-Flight Campaign