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PARABOLIC FLIGHT MICROGRAVITY EDUCATIONAL ACTIVITIES IN BARCELONA:  
THE "BARCELONA ZERO-G CHALLENGE"

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**Abstract**

This paper reports on different innovative research and educational activities related to parabolic flights conducted in Barcelona, based at Sabadell Airport and operated by Aeroclub Barcelona-Sabadell, since 2006. A CAP10B single-engine aerobatic aircraft is used, operating in Visual Flight conditions (VFR). Results from test flights have shown that these aircraft provide an environment of hypogravity for small experiments with a gravity quality of at least 0.01 g<sub>0</sub> for as long as 8.5 seconds. An experimenter may operate her or his own experiment in parabolic flight from within the aircraft cockpit.

A specific flight simulator based on SolidWorks was developed to optimize the manoeuvres. This software was used to later train the pilots and get less residual accelerations during the hypogravity period. Results from recent test flights show that these advancements have significantly improved the gravity quality of the platform. Sensitivity to wind gusts have been analyzed. According to our analysis, acceptable wind conditions are a maximum of 15 knots of horizontal gusts, whereas thermal and vertical gusts should be avoided.

Research campaigns and student campaigns have since 2008 been conducted. A student campaign consists of between 2 and 6 local flights, where the student conducts her or his experiment on board during every flight. A local flight provides up to 12 parabolas for each subject. These educational campaigns are known as the "Barcelona Zero-G Challenge", an international contest aimed at motivating students to conduct research in this field. A total of 12 students have flown their experiments on board the aircraft in 3 different educational campaigns (2010, 2011 and 2014), having published their results in relevant symposiums and scientific journals. These campaigns have attracted media attention and have promoted public awareness on aeronautical and space studies. The projects have been carefully peer-reviewed and selected by members of ELGRA (European Low Gravity Research Association) and ESA Education. A new edition of this contest is underway, with the winners expected to fly their experiment in 2017. Furthermore, students from our own University, UPC, have the opportunity of designing and testing their experiments within the framework of this parabolic flights platform. Further information on the contest "Barcelona Zero-G Challenge" can be found at: [window2theuniverse.org](http://window2theuniverse.org). In conclusion, this platform has shown to be excellent for educational and outreach campaigns, and also as a testbed for a proof-of-concept, before accessing other microgravity platforms.

**Keywords:** parabolic flights, outreach, space education, microgravity, hypergravity.

**Acronyms/Abbreviations**

European Space Agency (ESA)  
Centre National d'Études Spatiales (CNES)  
Universitat Politècnica de Catalunya (UPC)  
International Space University (ISU)  
ISU Summer Space Program (ISU – SSP)  
Space Generation Advisory Council (SGAC)  
European Low-Gravity Research Association  
(ELGRA)  
European Aviation Safety Agency (EASA)

**1. Introduction**

Parabolic flights have been conducted for a long time as a way of performing short-time duration experiments and technical demonstrations [1, 2]. Aircraft parabolic flights provide up to 23 seconds of reduced gravity and are used for conducting short investigations in Physical and Life Sciences, both for senior researchers and for international student experimentation and motivation, and public outreach.

We report on educational experiments conducted in the Barcelona parabolic flight platform (Sabadell Airport, Barcelona, Spain) with single-engine aerobatic aircraft such as the

CAP10B, achieving up to 8.5 seconds of reduced gravity.

The flight profile results coming from a steady flight profile an introductory pull-up maneuver is performed at increased acceleration (roughly 3-3.5g for these aircraft), pilot reduces thrust and, with throttle or idle engines the airplane follows the parabolic trajectory of a free-flying body. As a consequence, after a short phase of transition, microgravity is obtained for 5-8 seconds.

After the recovery maneuver at increased acceleration (2.5-3g), the airplane flies again horizontally to the ground level for some minutes before introducing the next parabola. During one flight mission typically 10-15 parabolas are performed. Larger aircraft provide between 20-25 seconds of microgravity thanks to a more powerful engine.

ESA has used since 1984 six types of aircraft to conduct its parabolic flight campaigns [3]: the KC-135, the Caravelle from CNES, the Russian Ilyushin Il-76 MDK, the Cessna Citation II, the Airbus A-300/A-310 'zero-g' from Novespace, all of them with 2 or 4 engines. An important number of physical and life sciences experiments have been conducted showing the success of this kind of access to microgravity.

Our approach is different from the successfully previously reported parabolic flights as we propose the use of a small single-engine aerobatic plane. This kind of aircraft (Fig. 1) is certified to conduct this manoeuvre and could also be used for professional experiments, testing technology and educational and outreach campaigns as well. Hypogravity is experienced within the cockpit for about 8 seconds with a flight profile significantly different from that of larger aircraft. [4].



Fig. 1: Mudry CAP10B aerobatic aircraft used for educational parabolic flight campaigns. (Photo: Barcelona Flight School)

## 2. Objectives of single-engine aerobatic parabolic flights

The objectives of parabolic flights with an aerobatic single-engine aircraft are:

### 1. Scientific

- To study different processes in which abrupt changes of gravity workload are applied. In particular hyper (3 – 3.5g) to hypogravity (0.05g), and hypo to hypergravity periods.
- To analyse transient phenomena that may occur after short periods of hyper and hypogravity.
- To allow experiments for testing the equipment in a real parabolic flight, with the opportunity to manually interact with the equipment and provide a proof-of-concept before accessing other microgravity research platforms.
- If the experiment can be run in less than 8 seconds of exposure to hypogravity, and the residual acceleration of 0.05 g is acceptable, then quantitative and qualitative measurements can be made, thus providing meaningful data. The parabolic flight can provide 10-15 parabolas in a single flight, and weather permitting the procedure can be repeated in a single day.
- In regard to human physiology experiments in which and the hypo and hypergravity environment plays a role, the facility enables different subjects to test the scientific hypotheses, one by one on board.

### 2. Technological

- Assessment of technological equipment behaviour in a hyper and hypogravity environment with abrupt changes in a tiny environment.
- Safety assessment of experiments and technological demonstrations within a parabolic flight aircraft cockpit.
- Training of wannabe or future astronauts for foreseen private or public space missions.

### 3. Educational and outreach

- Allowing students to conduct hands-on experiments in a real weightlessness experience.
- Increasing their interest for studying Science, Technology, Engineering and Mathematics (STEM) syllabus, in particular in the aerospace field.

- Providing students from different backgrounds and nationalities with the opportunity of working as a team with a common goal, while interacting with space professionals.
- Raising public interest in space research.
- Creating the opportunity for students to write and present their space research in relevant journals and congresses, and also to further apply to the space agencies educational programs.

### **3. Educational opportunities: Barcelona ZeroG Challenge**

#### *3.1 Educational activities and experiments*

Students from undergraduate and Masters level of our university have benefit from different educational opportunities related to these parabolic flights.

An educational tutorial has been developed, containing an introduction to space physiology, how the data was obtained and why it was useful, and a hands-on material where students can actually use a simulation software to see what changes may happen to the human body when exposed to long-term scenarios, like a long expedition to the Moon, or a trip to Mars. The material was tested by engineering students, who had nearly no previous understanding of medical concepts, but it can easily be used also for life sciences students with no knowledge of simulation techniques. A final survey, and an evaluation of the students work results was conducted, in order to assess the impact of this activity.

The students had to work out what changes were important, what implications have the data for the hypothesis of the experiment, and propose future lines of research. Students had a one-hour tutorial workshop introduction, two hours of class work, and 4 days to submit their work. All student teams presented their work on time, and the evaluation was fairly good to excellent for all teams. Students have qualified along courses 2010-14 with a 4.2 +/- 0.3 the activity (1 being boring, 5 exciting) and provided some quotes as 'the activity was the most original of my studies' or 'I wish to also take part in the experiments'.

A limited number of UPC graduate research collaborators, and UPC undergraduate students have also been invited to actually take part in these in-flight tests and the calibration processes; in motivational flights funded and directed by UPC and operated by the Aeroclub Barcelona-Sabadell (Barcelona Flight School). Some Master Thesis have been conducted on this topic up to now, with interesting experiments proposed by our students [5].

#### *3.2 Barcelona ZeroG Challenge*

The International Space University is the leading University in the space sector providing top education under its three lines of inspiration: International, Interdisciplinary and Intercultural. As part of its educational curricula it organizes every year an intensive 9-week Summer Space Program (SSP). This program is attended every year by more than 100 graduate and undergraduate students from all over the world. During the program, they are exposed to a number of fundamental core lectures, workshops, and departmental activities. The last three weeks are dedicated entirely to the development of a Team Project in a topic related to space activities. During the SSP10 one of the proposed activities was to design and actually build an experiment to be flown with our platform. A 1-hour workshop was conducted, in which the students were introduced with the basics of parabolic flight, the special features of our platform, and then they were challenged with the possibility to actually fly their designs with us. The students were given the detailed requirements that had to be taken into account, as well as safety mandatory requirements.

A 1-hour guided work time was granted, during which the students formed their teams and began making their experiment designs, with the mentoring of experienced professors of this particular field.

Finally, the students, had to develop and submit a detailed form, in a professional way, detailing all aspects concerning their experiment, with the endorsement of an expert professor in the space field.

A selection process was conducted based on this form, with the best experiment selected for flying in this platform. Suitability, scientific merit, team diversity, outreach plan and safety issues were taking into account in the evaluation. Students during all the process of design, build and fly the experiment, clearly benefit from the interaction of a leading university in the space sector, and an innovative challenge to actually experiment in zero-g their ideas.

The 1<sup>st</sup> Barcelona Zero-G Challenge took place in October 2010 in Sabadell Airport (Barcelona, Spain) with a team of five students actually flying the experiment "Reversible images in microgravity" mentored by Prof. Gilles Clément (ISU). The same experiment tested by these students later flew in the ISS. Details of the results of this experiment in parabolic flight were reported in [6]. The same experiment was later tested in the International Space Station by astronauts. Some of the same students that participated in this parabolic flight test took part in the analysis and publication of the data of this real experiment in space [7].

The second edition of the contest was open to students worldwide, and also a workshop was conducted during the ISU Summer Space Program 2011 held in Graz (Austria). The information regarding the requirements of the contest was publicized via students' associations such as SGAC (Space Generation Advisory Council), Euroavia, and also the European Low-Gravity Research Association).

From this edition, a peer-reviewed selection process was conducted to select the best students' research project. Senior reviewers from ELGRA, experts both in physical and life science space research took part in the selection.

The experiment chosen for this edition was 'Mental arithmetic in parabolic flight', with an international team of three students mentored by Prof. Nandu Goswami (Austria). The parabolic flight was conducted in November 2011 and their results have been discussed and reported in *Microgravity Science and Technology* [8].

During these years, test flights were conducted so that the flight profile was optimized [9]. The students' competition was resumed in 2013 with a selection process in which reviewers from ESA Education and ELGRA conducted the peer-review process. The announcement was announced worldwide and also a workshop was conducted at the ISU SSP13 held in Strasbourg (France).

In this edition, two teams were selected, one being the winner and an accessit was awarded also for a second students' team. The winner team of the Barcelona ZeroG Challenge was a group of undergraduate students from ISU, Valentina Boccia (Italy) and Anja Schuster (Germany) who flew their experiment in Barcelona in July 2014 [10] entitled 'Measuring sizes in microgravity', and mentored by Prof. Hugh Hill (ISU). The objective of this experiment was to investigate whether human perception of different sizes and volumes is altered in hypogravity. Their results were reported at the ELGRA Symposium 2015, with Anja Schuster earning a Students Award for her Poster Presentation.

The second team selected of three students from the University of Copenhagen flew their experiment in October 2014. Their experiment 'Ultrasound physiology measurements in microgravity' was mentored by Dr. Lonnie Petersen, with the objective of testing the blood flow along the neck during the hypogravity and hypergravity periods.

The next edition of this educational contest is underway, with the winner students expected to fly their experiment in 2017. The deadline for submission of experiments is 15<sup>th</sup> December 2016. Details of the submission process and requirements for the experiment can be found in [11].

#### 4. Discussion

We first reported a successful series of parabolas performed with a light aerobatic plane with a life sciences experiment on board. Between 5 to 8.5 seconds of microgravity were attained with a limited operational cost. The optimization of the manual piloting has made possible to provide a quality of g between 0.05g and 0.005g with a g jitter reduction depending on the strength of wind gusts. Very limited time is needed to prepare and perform the experiment so this approach is specifically suited for those kind of rapid prototyping technology tests, or simple experiments that do not need huge or sophisticated equipments. These parabolic flights are not designed to compete with those from space agencies requiring larger aircraft. Among the limitations of small aerobatic aircraft are: limited cockpit size, reduced hypogravity time, no electricity plugs available, only one experimenter at a single flight, higher g jitter sensitivity and a more aggressive flight profile. However, from the point of view of providing a hands-on experience to students worldwide it has proven very successful.

Educational activities have been from the beginning an essential part of our motivation, and have provided meaningful results and a number of flight opportunities for students' experiments, as well as tutorials after data collection.

Only two mild episodes of motion sickness have been reported up to now. The visual flight configuration of this platform allows the participant any inconvenience during the flight, and following the pre-established protocol, he or she will be safely on ground in less than 15 minutes with specialized medical care available on site. All participants in parabolic flights are requested to pass an aeronautical EASA Class II medical certification (or equivalent) prior to their flight, and a licensed flight surgeon is supervising the operations on-site. Mandatory safety briefings are conducted pre and post-flight.

Students' associations such as the Space Generation Advisory Council (SGAC), ELGRA Students, and Euroavia are involved in this endeavour. Some of the prior participants have declared their excitement for having the opportunity of actually making space research in microgravity, providing outreach to the public, and later publishing the results in selected conferences and indexed journals.

#### 5. Conclusions

We have provided evidence that this innovative microgravity platform based on single-engine aerobatic planes in Barcelona (Spain) is making a significant impact, inspiring students around the world to get an interest on space medicine and research. Therefore, we

plan to continue these activities and expand them in the near future with more flight opportunities, both for educational and research purposes.

Among the lessons learned, the students involvement, and international cooperation have been the most important factors that have led this platform successful.

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