UPC parabolic flight platform: providing inspiration for the explorers of tomorrow

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Abstract

Recent research undertaken by the joint venture led by the Universitat Politecnica de Catalunya, with its partners, the Aeroclub Barcelona-Sabadell and BAIE, Barcelona Aeronautics Space Association, has shown that it is possible and safe to obtain zero-gravity conditions for up to 8 seconds with single-engine aerobatic planes. The quality of the microgravity is comparable to that obtained by conventional parabolic flights. The main advantage of this technique is that a lower cost-to-time of microgravity ratio, during the parabola is obtained. Small life science experiments that require no more than this short period of time and cannot be run in drop towers, benefit from an easy access to the experimental platform. We present here how data of small medical experiments which had own with our platform are thereafter used for the first time as an educational tool. Students of our University also have the opportunity to design their own experiment, and actually build and fly it in zero gravity at Sabadell Airport (LELL, Spain), very near to our Faculty premises in Barcelona. Barcelona ZeroG Challenge is an international contest to which international student teams from any university worldwide can submit their experiments and the winner is entitled to fly with them. The contest is open to university students in its 3rd edition until January 2014.

Keywords: Parabolic flight, microgravity, life sciences, physical sciences, education.

1. Introduction

Parabolic flights are a common way nowadays to obtain microgravity. About 20-30 seconds of microgravity can be obtained during parabolic flights. Jet airplanes such as the KC135(NASA) and the Caravelle or the Airbus A300(ESA) or the Ilyushin IL-76 MDK (Gagarin Cosmonaut Training Center, Moscow) are used with their interiors completely empty and padded with foam rubber [1]. These planes are operated in professional or student experimental campaigns involving a number of different teams and experiments on-board, and typically require months of preparation.

The flight profile is the following: coming from a steady flight profile an introductory pull-up maneuver is performed at increased acceleration (roughly 2g for these planes), 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 about 20-30 seconds. After the recovery maneuver at increased acceleration (2g), the airplane flies again horizontally to the ground level for some minutes before introducing the next parabola. During one flight mission about 20 parabolas are performed.

Due to flight perturbations and the presence of many crew members, however, there is a comparatively low microgravity level of only about 0.01g. The utilization of such procedures ranges from testing of technology and procedures to qualification of experiments and subsystems to astronaut training.

ESA has used since 1984 six types of airplanes to conduct its parabolic flight campaigns [2]: the KC-135, the Caravelle from CNES, the Russian Ilyushin Il-76 MDK, the Cessna Citation II, and the Airbus A-300 'zero-g' from CNES, 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 tiny 2-passengers aerobatic plane. This kind of aircraft is already certified to sustain this maneuver and could also be used for professional experiments and testing technology. The advantage of this approach is the immediate preparation and saving cost as the budget of the flight is significantly small than those parabolic flights with bigger and more complex airplanesajor headings are capitalized, underlined and centred in the column.

2. Calibration and operations

We first reported the implementation of parabolic maneuvres for professional experimentation in microgravity with a CAP-10B aerobatic airplane, certified to make aerobatic maneuvers at IAC in Glasgow 2008, after our maiden flight in November 2007 with the first calibration data [3].

The plane is a 2-passenger light model of airplane (Figure 1) and can be flown easily from an aerodrome with little preparation apart from the usual procedures in private flying.

Figure 1: CAP-10B plane owned by ACBS. (Credit: Aeroclub Barcelona-Sabadell).

The only limitation of this approach is that no huge equipment can be loaded into the cockpit as this was designed to be smart for aerobatic sport, but it is quite adequate for rapid testing and prototyping of technology subsystems, as well as physical or life science experiments that don't need a huge space to be stowed.

We conducted in this mission six parabolic flights from the Sabadell Airport in November 2007 with an experiment on board. Every parabola was carefully planned and coordinate between the pilot (Ventura) and the mission specialist (Perez-Poch) of this mission. Timing of every part of maneuvre, g acceleration, and a number of parameters regarding the experiment on board were recorded through a laptop on board.

As this is a single-engine plane with a limited capacity of thrust, the power available from the plane engine to perform the parabola was less than those available from the other planes reported to have undergone parabolic maneuvres. As a result of this limitation, a more intense acceleration is needed in the pull-up entry reaching 3.8 g instead of the usual 1.8g found when using the Airbus 300 zero-g. With this approach we report six series of 4.5 to 6.8 seconds of microgravity during the parabola zero-g phase. Again, a nearly 4g pull-out maneuver is performed by the pilot to recover horizontal flight. We repeated the maneuver every two minutes with the experiment on board.

The quality of the gravity attained is comparable to that obtained with earlier parabolic experiments, although we didn't control the z-axis so precisely as other planes do as the control of

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this plane is totally manual. However it can be estimated that the order of magnitude is comparable to that of 0.01 g obtained in bigger airplanes with more precise and strict control of the balance.

The pilot of these maneuvers is an experienced aerobatic pilot (Ventura), who trains regularly as a sport aerobatic aviator. The mission specialist is a private pilot (Perez-Poch) with no previous experience in aerobatic flight, but did not require any medical treatment previous, during nor after the parabolas. No motion sickness symptoms were reported by any of us in this mission, although it is advisable to be fit enough to sustain the nearly 4g pull-up and pull-out experience. After the maneuvers the plane was conducted from the surrounding area to Sabadell Airport, 20km from Barcelona, and safely landed with no incidences to report.

During the manual performance of the maneuver by the pilot (Ventura) the mission specialist (Perez-Poch) was carrying on himself the payload intended to in-flight validate the NELME model proposed and developed by the same author [4]. The equipment consisted of a laptop with an RF receiver, a blood pressure monitor with RF emitter, and a state-of-the-art pulsometer able to register heart rate.. Analysis of these results were found to be reliable as their variations were minimal for every one of the six parabolas performed. The numerical model predicted the variations in blood pressure and heart rate when applying 3.8g , then zero g, and back to 3.8g of the subject. The experimental findings were fully compatible with the model in spite of the few seconds available in microgravity. More detailed results can be found in [4] as well as the whole description of the model.

The total cost of this mission was estimated in less than 300 euros including the cost of hiring a professional aerobatic pilot, the same plane, essence and airport taxes. This is less than a thousand than what can be estimated for a usual parabolic campaign, thus resulting in a very advantageous time of microgravity/cost ratio.

The preparation of the mission was reduced to a series of breafing and debreafing sessions as no special requirements were needed for this life sciences experiment. Therefore, the access time to microgravity was also significantly reduced from that need in a usual parabolic campaign which may last for months.

Since then, an extensive number of flight tests have been carried out in order to improve the proficiency of the manual manuevre. Thanks to this optimization the quality of g attained has been significantly improved, and the likelihood of g jitter lessened. Thanks to these efforts, the technique was optimized in order to be able to provide a reliable source of microgravity to the European space research community, and also to provide with flight opportunities to the students. A joint venture between the Aeroclub Barcelona-Sabadell, UPC Barcelona Tech and BAIE Barcelona Aeronautics & Space Association has started early this year. This joint venture is able to provide flight opportunities and a legal framework for the researchers and students who wish to take advantage of this platform. An Announcement of Opportunity was released [5,6] by the institutions funding and leading this endeavour.

3. Educational opportunities. Barcelona ZeroG Challenge.

An educational tutorial was developed, based on the experiments, 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 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 qualified with a 3.8 +/- 0.4 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 by us to actually take part in these in-flight tests during the calibration processes. In these selected motivational flights, which were also funded and directed by UPC, and operated by the Aeroclub Barcelona-Sabadell with Mr D.V. Gonzalez as pilot-in-command performing the maneuvres, these students could, as a result of these operations, make some proposals of in-flight experiments [7].

An International Students' Contest has been established where international university students teams can apply. The winner team is entitled to actually fly in zero gravity their research experiment. Two sucessful editions of the Barcelona ZeroG Challenge have already taken place with eight students having flown in the platform. The 2014 3rd Edition of this contest is underway open to proposals with deadline January 2014 [8]. The European Low-Gravity Research Association [9] is currently supporting the activity and is in charge of the selection of the experiments based, which is based only on research and teamwork merits.

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5. References

1. Messerschmid E, Bertrand R, Space Stations. Systems and Utilization. pp 300-310. Springer Verlag. ISBN 3-540-65464-X Berlin 1999.
2. Pletser V, Short duration microgravity experiments in physical and life sciences during parabolic flights: the first 30 ESA campaigns. Acta Astronautica, 55(10) 829-854. 2004.
3. Pérez-Poch A., González, D.V. "Aerobatic flight: an innovative access to microgravity from a centennial sport". 58th International Astronautical Conference, Glasgow, 2008. Conference Paper # IAC-08-A2.3-12
4. Pérez-Poch A. "On the role of numerical simulations in studies of reduced gravity-induced physiological effects in humans. Results from NELME.". Proceedings of the 38th COSPAR General Assembly,Bremen, July 2010.
5. BAIE Announcement of Opportunity for European researchers/students: http://www.bcnaerospace.org/public/new.php?id=51 (retr.10th Oct. 2013)
6. CRAE-UPC Announcement of Opportunity for European researchers/students: http://recerca.upc.edu/crae/news/acrobatic-flight-an-innovative-access-to-microgravity-from-a-centennial-sport-announcement-of-opportunity-for-upc-students-researchers (retr. 10th Oct 2013)
7. Jordà, C. , Pérez-Poch A. "Barcelona ZeroG Challenge". Projecte Fi de Carrera en Enginyeria Mecànica. EUETIB, UPC. Juliol 2013. http://hdl.handle.net/2099.1/18741 (retr. 10th Oct 2013)
8. Barcelona ZeroG Challenge 2014. Announcement of Opportunity http://window2theuniverse.org , retrieved on 10th October 2013
9. European Low-Gravity Research Association, http://www.elgra.org (retr.10th Oct2013)