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European parabolic flight campaigns with Airbus ZERO-G: Looking back at the A300 and looking forward to the A310

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Abstract

Aircraft parabolic flights repetitively provide up to 23 s of reduced gravity during ballistic flight manoeuvres. Parabolic flights are used to conduct short microgravity investigations in Physical and Life Sciences and in Technology, to test instrumentation prior to space flights and to train astronauts before a space mission. The use of parabolic flights is complementary to other microgravity carriers (drop towers, sounding rockets), and preparatory to manned space missions on board the International Space Station and other manned spacecraft, such as Shenzhou and the Chinese Space Station CSS.

The European Space Agency (ESA), the '*Centre National d'Etudes Spatiales*' (CNES, French Space Agency) and the '*Deutsches Zentrum für Luft- und Raumfahrt e.V.*' (DLR, the German Aerospace Centre) have used the Airbus A300 ZERO-G for research experiments in microgravity, and at Moon and Mars gravity levels, from 1997 until October 2014. The French company Novespace, a subsidiary of CNES, based in Bordeaux, France, is in charge of the organisation of Airbus A300 ZERO-G flights. A total of 104 parabolic flight campaigns have been organised by ESA, CNES and DLR since 1997, including 38 ESA, 34 CNES and 23 DLR microgravity campaigns, two Joint European ESA-CNES-DLR Partial-g Parabolic Flight Campaigns, and seven ESA Student campaigns.

After 17 years of good and loyal services, this European workhorse for microgravity research in parabolic flights has been retired. The successor aircraft, the Airbus A310 ZERO-G, is being prepared for a first ESA-CNES-DLR cooperative campaign in Spring 2015.

This paper looks back over 17 years of microgravity research in parabolic flights with the A300 ZERO-G, and introduces the new A310 ZERO-G that will be used from 2015 onwards.

Keywords: Weightlessness; Microgravity research; Parabolic flights; Reduced gravity; International collaboration; Airbus A300 and A310

1. Introduction

Aircraft parabolic flights are a useful tool for performing short duration scientific and technological experiments in reduced gravity. Together with drop towers, sounding rockets, the International Space Station (ISS) and other manned and unmanned spacecraft, aircraft parabolic flights with the Airbus A310 ZERO-G completes the set of flight research opportunities for European scientists.

The principal value of parabolic flights is twofold: firstly, in conducting verification tests prior to space

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Fig. 1. The Airbus A300 in pull-up (Photo: Novespace – Eric Magnan/Airborne Films).

experiments in order to improve their quality and success rate, and after a space mission to confirm or invalidate (sometimes conflicting) results obtained from space experiments; and secondly, in providing a flying laboratory in which the gravity level can be modified, producing, at a relatively low cost, scientific results for experiments operated by the scientists themselves and for which the microgravity duration and levels are adequate. Aircraft parabolic flights are the only flight opportunity beside ISS and Chinese spacecraft where medical research on human test subjects can be performed in weightlessness.

For these purposes, ESA[1] has organised 61 parabolic flight campaigns (Pletser, 2004) since 1984 in the frame of its Microgravity Programme, CNES[2] has organised 47 campaigns since 1989, and DLR[3] has organised 35 campaigns since 1987, with several airplanes: NASA's KC-135, CNES' Caravelle, the Russian CTC Ilyushin IL-76-MDK, and the Airbus A300 ZERO-G. In addition, two Joint European Partial-g Parabolic Flight Campaigns were jointly organised by ESA, CNES and DLR using the Airbus A300 ZERO-G for experiments at reduced gravity levels, typically at Moon and Mars g levels (Pletser et al., 2012). In parallel, nine ESA Student campaigns were organised by ESA's Education Office for experiments proposed by European university students with NASA's KC-135, CNES' Caravelle and the Airbus A300 ZERO-G (Callens et al., 2011; Pletser et al., 2005).

From 1997 until October 2014, the Airbus A300 ZERO-G was used in Europe for short microgravity investigations by ESA, the French space agency CNES, the German Space Agency DLR, the Japanese Space Agency JAXA and by industrial customers. The Airbus A300 was the largest airplane in the world used for this type of experimental research flight. The French company Novespace[4], a subsidiary of CNES, was in charge of the organisation of Airbus A300 flights.

After 17 years of services, and although still in excellent condition, the Airbus A300 ZERO-G (see Fig. 1) has been retired, after offering 275 teams of European, Canadian, American, Russian, Chinese and Japanese researchers access to weightlessness and other reduced gravity levels for microgravity experiments and investigations at Moon and Mars g-levels.

The new Airbus A310 ZERO-G aircraft is being readied for future parabolic flights starting in Spring 2015 with a cooperative campaign shared by ESA, CNES and DLR.

2. Objectives of parabolic flights

An aircraft in parabolic flight provides investigators with a laboratory for scientific experimentation where the gravity levels are changed repetitively, giving successive periods of approximately 20 s of microgravity in between periods of about 20 s of 1.8 g's. Details of parabolic flight profiles and levels can be found in Pletser (2004) and Pletser et al. (2012).

Parabolic flight objectives pursued by the European space agencies and by the invited scientists are multifold. From a scientific point of view, the following objectives can be attained:

- to perform short duration experiments, for which the reduced gravity is low enough, for:
  - qualitative experiments of the "look and see" type, using laboratory type equipment to observe and record phenomena in microgravity; and

[1] http://www.esa.int, http://www.esa.int/Our_Activities/Human_Spaceflight/Research/Parabolic_flights.
[2] www.cnes.fr.
[3] www.dlr.de, http://www.dlr.de/rd/desktopdefault.aspx/tabid-2282/3421_read-5230/).
[4] http://www.novespace.fr/en,home.html, http://www.novespace.fr/en,vol.html.