Paper ID: 3358

IAC-09-A2.I.2

60th International Astronautical Congress 2009

MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2.)
Interactive Session on Microgravity Sciences and Processes (I.)

PROJECT DAEDALUS: THE FIRST LATIN-AMERICAN MICROGRAVITY RESEARCH PLANE

Author: Ronnie Nader, EXA ASA/T Astronaut, CMAE – Eng.
Ecuadorian Civilian Space Agency - EXA, Guayaquil, Ecuador, rnader@exa.ec

Gonzalo Naranjo, Electr. Eng.
Ecuadorian Civilian Space Agency - EXA, Guayaquil, Ecuador, rd@exa.ec

Abstract

Up until May 2008 there was no way to access a microgravity research facility in the Latin-American region that can offer more than 4 or at most 5 seconds of high quality microgravity conditions, Project DAEDALUS was a joint project of the Ecuadorian Civilian Space Agency (EXA) and the Ecuadorian Air Force (FAE) to develop the 1st Latin-American microgravity plane. So far 7 missions have been flown achieving a maximum of 18 seconds per parabola in microgravity conditions with averages of 0.006G. The plane uses a cybernetic approach to achieve high quality micro-G conditions, with the design and implementation of the Multi Vector Gravimetric Computing Platform (MGCP-MK4) by the EXA, a tool that allows pilots with almost no experience in parabolic flight to perform near perfect parabolas for creating high quality, research grade micro-G conditions.

Introduction: EXA is the Ecuadorian Civilian Space Agency, a civilian NGO created in 2007, in charge of the administration and execution of the Ecuadorian Civilian Space Program - ECSP. (5)

The ECSP has a key educational and academic component where the objective is to provide low cost access to space research facilities and tools to bolster the scientific production and inspire new generations of engineers and scientists in the country. The first task in order to accomplish this objective was to have access to a microgravity research plane and the original plan called for renting seats on an existing µG plane: American, Russian or Japanese, however, costs were very high for this option and funding was very limited and we also could not know if the selected researchers were to be granted with visas to visit any of these countries.

In November 2007, EXA Astronaut Ronnie Nader, currently Aerospace Operations Director at EXA, was a freshman from the Advanced Suborbital Astronaut - ASA/T training program, developed for the EXA at the Gagarin Cosmonaut Training Center – GCTC, in the Russian Federation, being a Systems Engineer and having extensive training experience on µG parabolic flights, he proposed the idea of a national µG plane.(1)

The plan was to modify an existing plane with a device capable of sensing in real time the variations of the Z acceleration vector and inform the pilot a prediction of the next most probable value of the computed vector, so the pilot could take immediate action. Such device would have to be tailor-tuned for the possible response time of the human pilot hand-eye coordination response in order to be accurate enough to produce µG variations of hundredths of G. Such device was called Multi-Vector Gravimetric Computing Platform or MGCP

The project was proposed to the Ecuadorian Air Force – FAE (for its spanish acronym), and it was accepted. The responsibilities of the project were shared: EXA would have to build and test the MGCP, provide mission planning and mission command services, FAE would provide logistics, fuel, planes and pilots.

On February 2008 the MGCP was ready and tested and the mission planning phase began; 2 missions were designed by the EXA's Aerospace Operations division, the EXA/FAE-01with the objective of field testing the MGCP and gather real data on the plane capabilities, and the EXA/FAE-02 mission with the objective of producing the µG target conditions in a plane capable of transporting passengers.

The first mission was flown successfully on April 10 2008 on a Mirage F1JE by Major Xavier Coral and Astronaut Ronnie Nader as the mission commander in charge of operating the MGCP and thus directing the parabolic flight operations: 301 seconds of µG were obtained in 21 parabolas.

Figure A: The EXA team that designed and developed the MCGP-MK1, which can be seen in the hands of Eng. Hector Carrion, second from the left, moments before mission EXA/FAE-01

The second mission was flown on a Sabreliner T-39 on May 6 2008 by Lt Col Tirso Guerra and Lt.Col Marcos Chiluiza as pilots, Sgt. Jorge Nolivos as flight engineer, Major Xavier Coral as observer and Astronaut Ronnie Nader as mission commander in charge of parabolic flight and MCGP operations: 165 seconds of µG were obtained in 18 parabolas. The plane was nicknamed FuerzaG-1 CONDOR and at the date of this paper publishing it remains as the first and only microgravity plane in Latin America.

System Design: The practical approach for the MCGP was to use COTS components, military grade when available, to implement the following system approach:

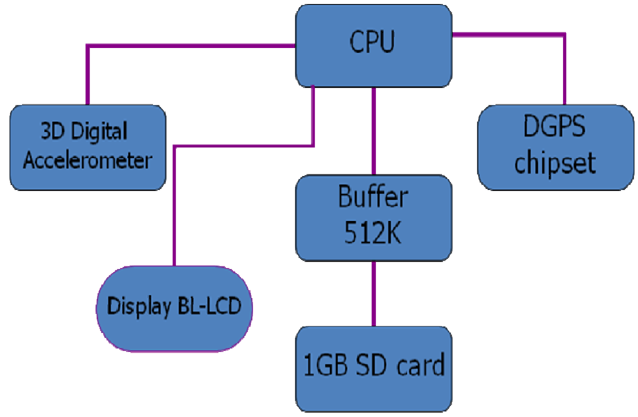

Figure B: The system block design for the EXA MCGP-MK1

To compute the following spatial vector set:

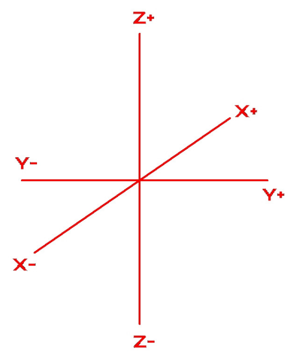

Figure C: The 6 axis spatial vector set to be computed by the MCGP-MK1 platform

In sum, 8 variables were to be computed:

-6 vectorial spatial variable axis:

(1) $<\Delta X, \Delta Y, \Delta Z>$ (+ , -)

-1 temporal variable:

(2) $\Delta V = \partial d/\partial t$

-1 escalar variable, H

The software was written in-house by R. Nader and G. Naranjo using CUblock software development kits, The design was implemented at first in a protoboard, using CUblock components.

The first MCGP-MK1 had one display only, for the second version, the MCGP-MK2 a second display was added to the mission command area of the plane, a data only display that allows the mission commander and the researchers to check the values of X, Y, Z, H, ΔV and also the command functions as number of parabolas, time in µG for each parabola and the total sum of time in µG.

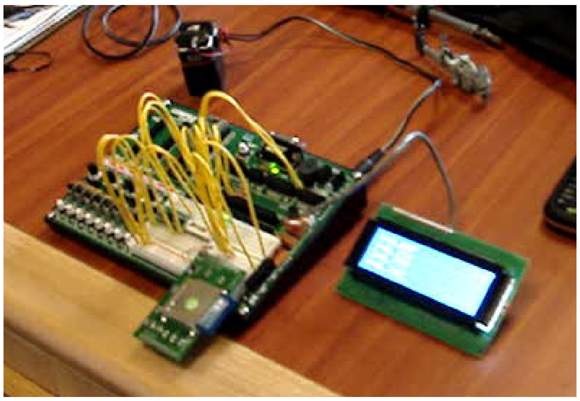

Figure D: the first prototype of the MGCP, 2 were built, the depicted MK0A and the MK0B

The main MCGP central processing unit housing has 3 terminal devices that link to the main unit via cable: 1 for the GPS antenna and accelerometer pod, this one goes as near as possible of plane's center of mass; 1 for the Pilot's Display Unit – PDU and 1 for the Mission Command Display Unit - MCDU

The data logging capabilities of the MCGP are limited to 2GB of data due the 32 bit bus architecture of the CUblock processor; however the unit has a second RS232 port available to the flight participant researchers for connecting any logging or control signaling device that the experiments on board may need.

The software adds a tolerance range between +0.03G and -0.02G for measuring it as 0G, a tolerance range between +0.18G and +0.13G for Lunar gravity and +0.35G and -0.30G for Martian gravity.

During the first 2 missions, pilot response time was calculated based on the data logging capabilities of the MCGP between 0.6 and 0.3 seconds reaction time to the signaling lights in the pilot's cockpit, and so the software was adjusted to these reaction times.

Part of the data log for mission EXA/FAE-05 follows:

Z	Lat	Long	H	V	TµG	∑
0.94843	**0159.97S**	**07923.84W**	**6336.5**	**446.7**	**0**	**46**
0.99242	0159.91S	07923.83W	6347.2	446.7	0	46
0.62584	0159.91S	07923.83W	6347.2	430.8	0	46
0.47921	0159.86S	07923.81W	6444.7	430.8	0	46
0.18595	0159.86S	07923.81W	6444.7	430.8	0	46
0.00999	0159.86S	07923.81W	6444.7	393.3	4	50
0.00046	0159.86S	07923.81W	6444.7	393.3	4	50
0.00093	0159.76S	07923.78W	6497.1	393.3	4	50
0.00486	0159.76S	07923.78W	6497.1	384.8	5	51
0.00999	0159.70S	07923.76W	6547.2	384.8	6	52
0.00932	0159.70S	07923.76W	6547.2	387.2	6	52

Table A: MCGP data records showing the values for the Z gravity vector on board the FG1-CONDOR during EXA/FAE-05 mission on June 18 2008. Where Z is the gravity vector, Lat is the latitude, Long is the Longitude, H is the height in meters, V is the plane speed in km/h and TµG is the Time in microgravity measured in seconds and ∑ is sum of the total mission time spent in microgravity.

Mission Command Structure: The term we use for every mission was Aerospace Research Mission and it followed strict guidelines for mission structure, execution and command, based mostly in what we learned in GCTC during the ASA/T program. Basically each mission is treated as an astronautics mission.

The command structure is simple yet efficient: in this particular case, the command of the mission is paramount as the principle applied here is that there is no reason for a µG flight if no research is being made, thus every flight is a research mission and at least one experiment is selected to flight.

The Mission Commander – MC has the full command over the pilots and the plane; He directs the flight operations performed by the pilots in order to achieve the conditions needed for the experiments to have the µG environment they need to accomplish their task.

A flight engineer flights onboard as per FAE regulations and he reports to the pilots which in turn report to the MC. Pilots and engineer are in charge of aeronautics operations, while MC is in charge of the whole mission and that includes the science operations which are main objective of the mission.

Such command structure is supported with Bluetooth communicators installed in the pilot helmet and in the MC helmet, so they can stay in touch all the time. We have onboard anti vertigo medicines; the most proven one is an oil that has to be rubbed behind the ears of the patient in case of dizziness or nausea, and to date has proven to be very effective.

Figure E: Cmdr. R. Nader floats in μG holding a blob of water while Capt. C. Mino assists, the MCDU can be seen in the back, near the MC helmet front.

The MC can recall a mission or order ground support in the case of a medical emergency on board, although our MC is a trained astronaut with training and experience is such duties.

Every activity in the mission is dictated by the Mission Plan –MP and the Mission Protocols – MPT, those are established prior the execution of the mission and has to pass the mission directorate approval, also many checklists implement such protocols and plan. For convenience, the flight suit of the MC has Velcro patches over the legs and arms where MP and MPT printed copies are stick during flight, the MC also has a μG grade pen/pencil to work with.

A high resolution point-of-view - POV, solid state digital video camera is attached to the MC helmet, another POV video camera is installed at the back of the operations area and a digital SLR still camera is installed besides this last one. This camera has a its remote control shutter connected to the MCGP dry contact relay and the software allows to send a close-contact order to this relay and start taking a rapid series of pictures when the Z vector is less than 0.4G

Research made: As our experience grew with each mission, we are able to hone our skills at producing research grade μG. We practiced with μG hydrodynamics as the fluids are the most difficult to master in μG, also other researchers made experiments involving gyroscopes and ultrasound driven "sand" oscilloscopes. The parameters of the software in the MCGP were tuned constantly until we were able to sustain an almost perfect μG condition with an average of 0.006G

But maybe the vast majority of the research was made in biometrics; In every mission flown, the crew and the researchers were fit with a Suunto T6 team biomedical wireless system and the results are still matter of study: researchers have their heart rate elevated to 150 bpm in average when they enter in a parabola, in all of the cases, but heart rate of the pilots and the MC remained steady. We also noticed a phenomenon that we came to nickname as PBS – Play Back Syndrome, which is the fact that after some hours of their flight, the participants experienced the very same sensation of floating around weightless just as if they were in μG again and usually happens when they started to recall the experience.

Figure F: A rapidly spinning blob of water demonstrate the μG generation capabilities of the FG1 CONDOR during mission EXA/FAE-05

During the POSEIDON project, that led to the Guinness World Record for the youngest human being to flight in µG, this PBS phenomenon was taken into account for the Young Microgravity Training Program –YMTP, that was applied for 40 days to the children of 10 and 7 years old that made the flight. As their mission was to make an experiment in microgravity hydrodynamics, they were going to work in µG and so the conditions will be harder for them. The application of what we learned about PBS was very important in the success of mission EXA/FAE-06 that led to the World Record achievement.(4)

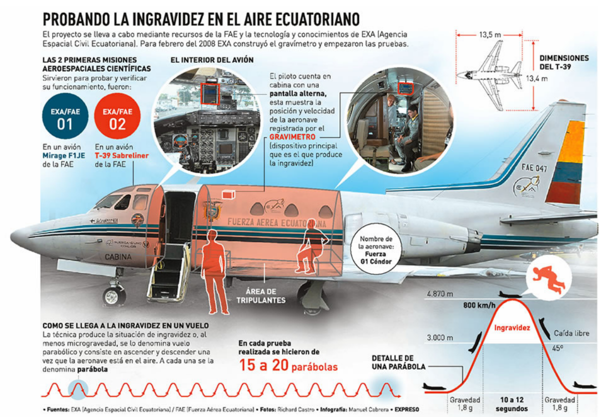

Figure G: Infography that depicts the FuerzaG-1 CONDOR interiors and its parabolic flight regime

This research was very important for our operations because as part of the YMTP, a Microgravity Induction Regime – MgIR was developed to make sure the children will not fail the record attempt and could complete the experiment as planned. This development allowed the next missions to have zero medical incidents on board and researchers were free to work in their tasks without suffering any negative µG effects(2)(3)

The hydrodynamics research also proved very important as it allowed the technical crew of the plane to adjust engine parameters so it can withstand longer µG operating periods.

Acknowledgements: The Ecuadorian Civilian Space Agency and its Aerospace Operation Division wishes to thank The Ecuadorian Air force for its support and participation, To the Gen. Jorge Gabela, former Air Force General Commander, Gen. Rodrigo Bohorquez, actual Air Force General Commander and specially to Gen. Leonardo Barreiro, Chief of Staff for their vision and support to the Ecuadorian Civilian Space Program and to our nation all.

References:

1- The Advanced Suborbital Training Program – ASA/T - Ecuadorian Civilian Space Agency – GCTC.

2- The YMTP program: Young Microgravity Training Program for young researchers – Ronnie Nader, Ecuadorian Civilian Space Agency, Aerospace Operations Division.

3- MgIR: Micro Gravity Induction Regime: A method to avoid negative side effects during parabolic flights – Ronnie Nader, Ecuadorian Civilian Space Agency, Aerospace Operations Division.

4- Project POSEIDON: The youngest human being to work in a microgravity environment – Ronnie Nader, Ecuadorian Civilian Space Agency, Aerospace Operations Division.

5- ECSP: The Ecuadorian Civilian Space Program - Ecuadorian Civilian Space Agency, Aerospace Operations Division.