

Marques, Andre; Zorro, Sara; Patrão, Luís; Silva, Jorge; Castelo-Branco, Miguel

Conference Paper

Light Aviation And Flight Safety: Monitoring System For Unpressurised Cabins. Flight And Physiological Data Acquisition

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Marques, Andre; Zorro, Sara; Patrão, Luís; Silva, Jorge; Castelo-Branco, Miguel (2012) : Light Aviation And Flight Safety: Monitoring System For Unpressurised Cabins. Flight And Physiological Data Acquisition, 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/120697>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Light Aviation and Flight Safety: Monitoring System for Unpressurized Cabins Flight and Physiological Data Acquisition

Authors:

André Marques (corresponding author), Sara Zorro, Jorge Silva

LAETA-UBI/AeroG, Faculty of Engineering University of Beira Interior, Covilhã, Portugal
andremarques02@gmail.com

Luís Patrão, Miguel Castelo-Branco

LaC - Clinical Skills Lab, Faculty of Health Sciences, University of Beira Interior, Covilhã,
Portugal

Keywords

Light Aviation, Flight Safety, Unpressurized Cabins, In-flight Data Acquisition, Monitoring System

JEL Codes: L93, R11, R41

Abstract

The majority of light aviation aircrafts cabins are unpressurized and this may pose risks for the safety of both pilots and passengers. As altitude increases partial oxygen pressure decreases and this situation may lead to early stages of hypoxia affecting pilot's capabilities to perform simple tasks. These factors combined in several ways may affect significantly the capability of a pilot to conduct a safe flight.

Some work has been developed in this area and results show that even small changes in altitude can decrease pilot's oxygen level significantly. Thus, as pilot's behavior and flying capabilities are affected, flight safety is compromise too.

This work is generally focused on the acquisition and study of flight operational and physiological data that may affect pilot's capabilities and thus flight safety. To perform such objectives data acquired from the aircraft contains several items such as geographic coordinates, attitude, altitude, speed, g-load, heading, absolute pressure and temperature inside the cabin; also data acquired from the pilot contains several parameters such as cerebral oximetry, electroencephalography (EEG) and electrocardiography (ECG). As pilot's own

safety and comfort are important issues we developed a portable system that may be installed and operated in a safe and ergonomic way inside any light (small) aircraft cabin. Also this equipment is flexible enough so that it may be used inside a hypobaric chamber or in a flight simulator to test, prior a real flight, some specific pilot's reactions to different flight scenarios. The specific objective of this paper is to report the acquisition, processing and monitoring of flight data collected directly and in real time from both the aircraft and the pilot, so it may be analyzed to determine pilot's major physiological changes facing different flight scenarios and the consequents alterations of his flying capabilities.

Legislation for pilot licensing is quite similar all over Europe, and in practice it is not capable to prevent such in-flight individual performance problems. Taking in account the results of this work we also sustain the basis for a revision of the actual European legislation for pilot licensing, thus improving flight safety.

1. Introduction

The majority of light aviation pilots fly their aircrafts with unpressurized cabins and this factor can become a severe risk for their safety. Due to the altitude increase and consequent decrease in the partial pressure of oxygen hypoxia becomes a serious danger for the pilot and several accidents have occurred with fatalities involved. During a flight temperature and humidity inside the cabin also change and can also affect pilot performance.

Recent work (Rocha, 2011) have been developed at the University of Beira Interior regarding Flight Safety and the next step in this study passes through an extended acquisition of flight and physiological data from the aircraft and pilot. After a review of several studies our motivation passes through the elaboration of an investigation that could help improve the overall flight safety.

The main objective of this work is the development of an in-flight system that can be used in the cabin of an unpressurized light aircraft to record data from pilot physiology and the aircraft flight. This system records information about the flight of the aircraft by acquiring several data like geographic coordinates, ground speed, attitude, altitude, g load, pressure and temperature inside the cabin. This system also acquires information from the pilot physiology that contains data from electroencephalography (EEG), electrocardiography (ECG) and brain oximetry.

All this information is recorded and provides the flight path, principal characteristics of the aircraft flight dynamics and the physiological response of the pilot to different flight

scenarios. A second main objective from this work is the capability for this system to be used in a hypobaric chamber to test the physiological response of a pilot prior a real flight scenario.

2. State of the Art

2.1 Earth's Atmosphere

The atmosphere provides to the human being a protective shield against radiation from space, oxygen and a moderated temperature for the survival of species. The atmosphere composition is composed by a constant mixture of nitrogen and oxygen with traces of other gases and as altitude increases barometric pressure decreases exponentially, producing a proportional decrease in the partial pressure of oxygen and other constituent gases (Harding, 1988; 2002), as shown in Figure 1.

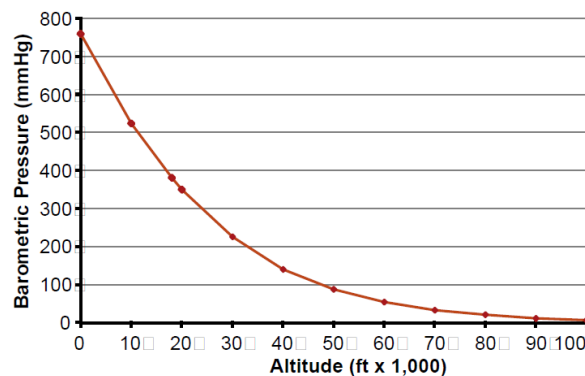


Figure 1: Atmospheric Properties (Harding, 2002)

Along with the decrease in the partial oxygen pressure as altitude increase temperature also decreases and this condition represents a disadaptation of human being to high altitude conditions.

2.2 Hypoxia

Hypoxia stand for “reduced oxygen” or “not enough oxygen” and although any tissue will die if deprived of oxygen for a long time the main concern is with getting oxygen to the brain, since any reduction in mental functions while flying can result in life-threatening errors (Harding, 2002; FAA, 2008). There are four types of hypoxia (Harding, 2002):

- Hypoxic hypoxia that results from reduction of oxygen in arterial blood or hypoxemia (i.e.: altitude flying due to low atmospheric pressure, heavily smoking);

- Anemic hypoxia that occurs when blood cannot carry enough oxygen (i.e.: anemia, carbon monoxide poisoning and hemorrhage);
- Ischemic hypoxia when oxygen cannot leave blood carriers into tissues (i.e.: low cardiac output, high G forces);
- Histotoxic hypoxia that takes place when tissue is not able to use oxygen taken from blood (i.e.: alcohol ingestion).

Hypoxia symptoms vary depending the individual but common symptoms include cyanosis (blue fingernails and lips), headache, decrease reaction time, impaired judgment, euphoria, visual impairment, drowsiness, lightheaded or dizzy sensation, tingling in fingers and toes and numbness. Hyperventilation can be caused by hypoxia (Harding, 2002) and consists in the excessive rate and depth of respiration leading to abnormal loss of carbon dioxide from the blood. This condition occurs more often among pilots than its recognized and it can causes disturbing symptoms that can alarm the uninformed pilot (FAA, 1997, 2008).

2.3 Impact of Hypoxia on General Aviation Pilots

A study perform by the FAA (1997) was carried out where ten subjects were randomly assigned to an hypoxia group that breathed altitude equivalent oxygen mixtures, and other ten subjects were assigned to the control group that breathed compressed air throughout the experiment. Results from this study show that significantly more procedural errors were committed by the hypoxia group during cruises flights at 10,000 feet and during the descent and approach phases of the flight from 10,000 feet (FAA, 1997).

(Rocha, 2011) performed a study about the impact of hypoxia in sport aviation by measuring the cerebral oximetry of different pilots when flying in unpressurized gliders. Different pilots were equipped with a cerebral oximetry monitor system during all the duration of the flights; all data were collected and analyzed and although the maximum altitude were just 3,600 feet results show a significantly change in cerebral oximetry saturation levels.

2.4 Human Physiological Data and Flight Parameters

The human body is submitted to different conditions when flying in an unpressurized aircraft and therefore it makes the acquisition of physiological parameters very important.

Information regarding the flight of the aircraft is important to understand the impact of possible physiological changes in the behavior and flights capabilities of the pilot.

EEG stands for electroencephalogram and consists in the recording of electrical activity of the brain over a certain time. This electrical activity is very sensitive to its oxygen supply and is regarded as a useful method of evaluating the functional state of the brain under hypoxic conditions (Meyer and Gastaut, 1961).

Multichannel human EEG signals were studied topographically simultaneous with electrocardiography and vertical eye movement in fifteen students ranging in age from 19 to 25 years old (Ozaki *et al.*, 1994). These students were exposed to an atmosphere of reduced air pressure in an experimental high altitude chamber and results from this work show that even under the condition of 3.000 meters the subject's brain activity may start to become affected and suggest that the first stage of hypobaric hypoxia is characterized by selective suppression of alpha EEG activity (Ozaki *et al.*, 1994).

ECG stands for electrocardiogram and consists in the recording of electrical activity of the heart during a certain period of time. This electrical activity is used to measure the rate and regularity of heartbeat as well as the presence of any damage to the heart.

A study performed with in a group of 10 subjects performing a fast cable car ascent from 990 meters to 2.700 meters, revealed that the hearth rate (HR) increased and that cardiovascular and central nervous systems are already affected by the reduced amount of oxygen at an altitude of 2700 meters (Guger *et al.*, 2005).

The monitoring of cerebral oximetry by sensors that are placed in the forehead provides a more central measure of blood hemoglobin oxygen. A study perform in 2010 shows that a forehead sensor is more sensitive to altitude induced changes in cerebral oximetry (SpO₂) (Simmons *et al.*, 2010).

A Flight Data Recorder (FDR) is a device that records several flight parameters of an aircraft. With the evolution of air transport and flight recording technology today's FDR are capable of digital recording several data from multiple equipment in an aircraft (Grossi, 2003).

2.5 Physiological Monitoring of Pilot Performance

Despite human physiological monitoring is a well studied area with several studies developed the physiological monitoring of pilot performance in unpressurized aircrafts is a study area with few specific studies.

In August of 1967 a study was performed by the FAA where student pilots were equipped with different sensors to acquire different physiological data (FAA, 1967). This study main objective was to analyze the performance of a student pilot by performing tests before, during and after the flight. Preflight questionnaire consisted in a brief story of the past 24 hours of each individual regarding sleep, enthusiasm, medication, alcohol ingestion. During the flight each student pilot were fitted with different sensors for detection of different data. The post-flight questionnaire asked each individual to describe their opinions about procedures, maneuvers and overall feelings about the flight.

A Pilot Physiologic Assessment System (PPAS) is being developed to collect physiological measurements in an aircraft and predict, detect and alert the user of hypoxic state in real time (Rood *et al.*, 2011). This system is capable of measuring exhaled oxygen (O₂) and carbon dioxide (CO₂), ventilation, oxygen saturation (SPO₂), cardiovascular data and environmental temperature and pressure by the use of several sensors in an MBU 23 oronasal oxygen mask (Figure 2).



Figure 2: MBU 23Oronasal Oxygen Mask (Rood *et al.*, 2011)

2.6 Legislation

A review of the legislation that affects unpressurized aircrafts was performed with the objective to understand the requirements regarding supplementary oxygen systems. International (ICAO, July 2001), United States of America (FAR, April 2012), European (JAR-OPS, May 2007) and Portuguese (DR, Decreto-lei 289/2003, 2003) legislations were

analyzed and all determined that until 10,000 feet isn't necessary the use of any supplemental oxygen although there are several study that states that hypoxia can begin at altitudes bellow 10,000 feet.

3. Case Study

After an extensive analysis of all the work developed regarding this study area a preliminary search for equipment was performed taking in account all the different specifications.

In order to acquire data regarding cerebral oximetry Nonin Model 7600 system (Figure 3) was selected due to its technical specifications, light weight, compact size, battery life and internal memory for data storage. This equipment offers one of the most advanced technologies in Near-Infrared Spectroscopy (NIRS) that eliminates surface effects, isolating measurements of the cerebral cortex oximetry, and provides trend and numerical rSO_2 values. This equipment has a battery life of approximately 3 hours, it can be storage in temperatures from -40° to 70° C (-40° to $+158^{\circ}$ F), operated in temperatures between 0° to 40° C ($+32^{\circ}$ to $+104^{\circ}$ F) with humidity varying from 10% to 90% non condensing and up to 3.700 meters (12,000 feet), (Nonin Medical Inc., 2012).



Figure 3: Nonin Model 7600 (Nonin Medical Inc., 2012)

The Olimex EEG-SMT (Figure 4 and 5) was the device selected because it contains a module unit that performs the recording of electrical activity along the scalp providing an electroencephalography (EEG). This device also has the technical capabilities to perform an electrocardiogram (ECG) (Olimex, 2012).



Figure 4: Olimex EEG-SMT (Olimex, 2012)



Figure 5: EEG-SMT Sensor (Olimex, 2012)

With two channels, each one with two sensors, the MOD-EEG-SMT has a very low price when compared to professional EEG devices and is based in the OpenEEG project (OpenEEG, 2012). This equipment requires the connection to a computer for power supply and data transfer.

Information regarding the aircraft flight dynamics is acquired by the APM 2.0 Purple (Figure 6) that is an autopilot used in UAV aircrafts with compact size and different integrated sensors that can record several flight data. This board has 3 axis gyroscopes and accelerometer, 10 Hz GPS, Magnetometer, micro SD card, pressure and temperature sensors that allow the acquisition of several aircraft flight data (DIY DRONES, 2012). This equipment has a current consumption of approximately 200 milliamps with an input voltage between 5 and 6 VDC and in this study is powered by a Zippy 1,000 milliamps battery and a Turnigy BEC voltage regulator providing an input voltage around 5.24 VDC (Figure 7).

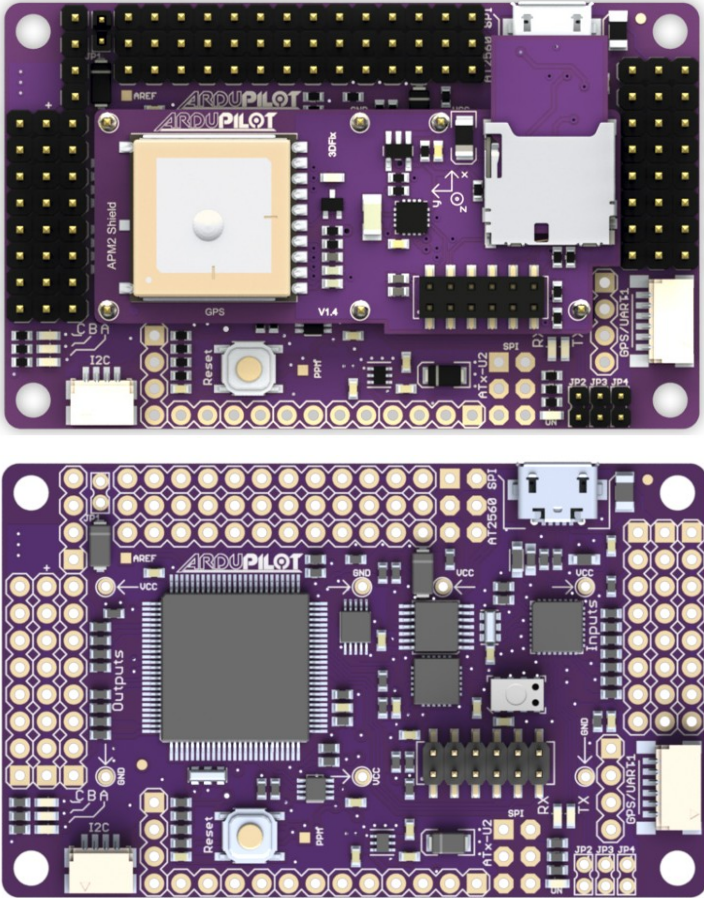


Figure 6: APM 2.0 Purple

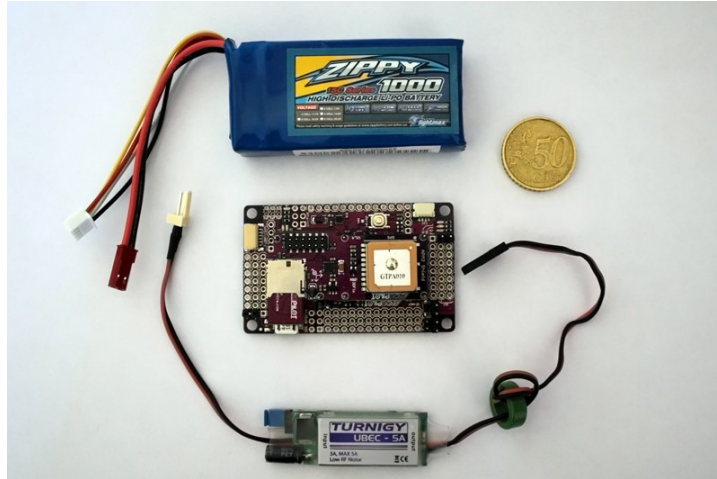


Figure 7: APM 2.0 Power Supply

The combination of all this equipment was projected taking in account many different aspects of the operation of an aircraft and all the equipment were submitted to several tests before the first flight. All test flights were performed using an ultra light aircraft CZAW Sport Cruiser, ICAO code CRUZ, (Figure 8).



Figure 8: CZAW Sport Cruiser

4. Results

On the 13th June 2012 the aircraft departed from LPVZ airfield, and reached a maximum altitude of 1.520 meters (4986 feet). In this flight data from APM 2.0 Purple (Figures 9, 10, 11 and 12) and Nonin Model 7600 (Figure 13) was collected and analyzed.

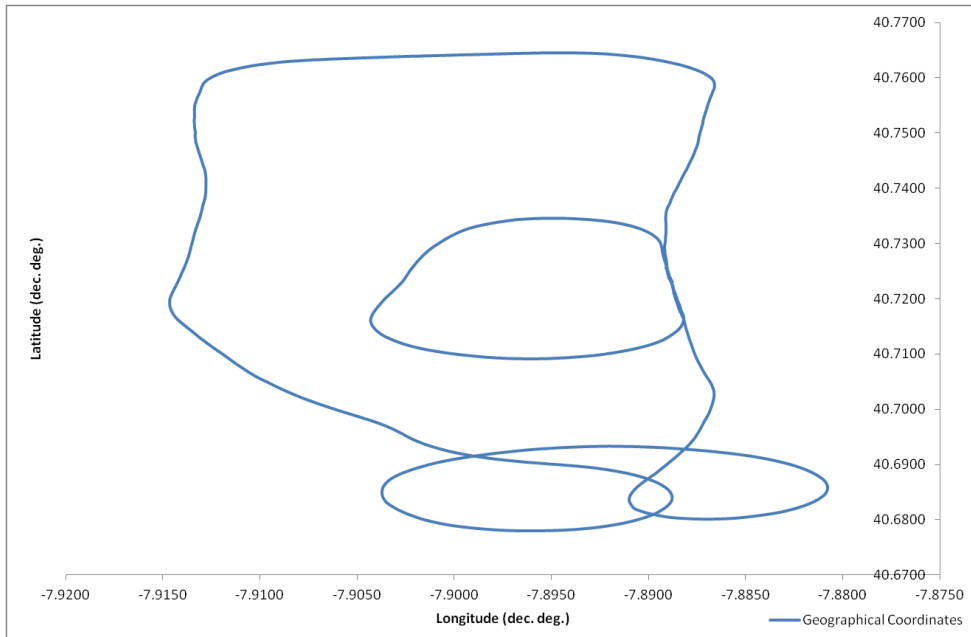


Figure 9: Flight Path Coordinates

The flight route that is illustrated in Figure 9 consists in a takeoff follow by a steady ascent to the maximum altitude performing then a descent in a circular pattern and a low approach to the airfield. After the low approach a landing procedure was initiated with a circular turn to the approach pattern. The altitude variation of the flight was updated every second and is illustrated in Figure 10.

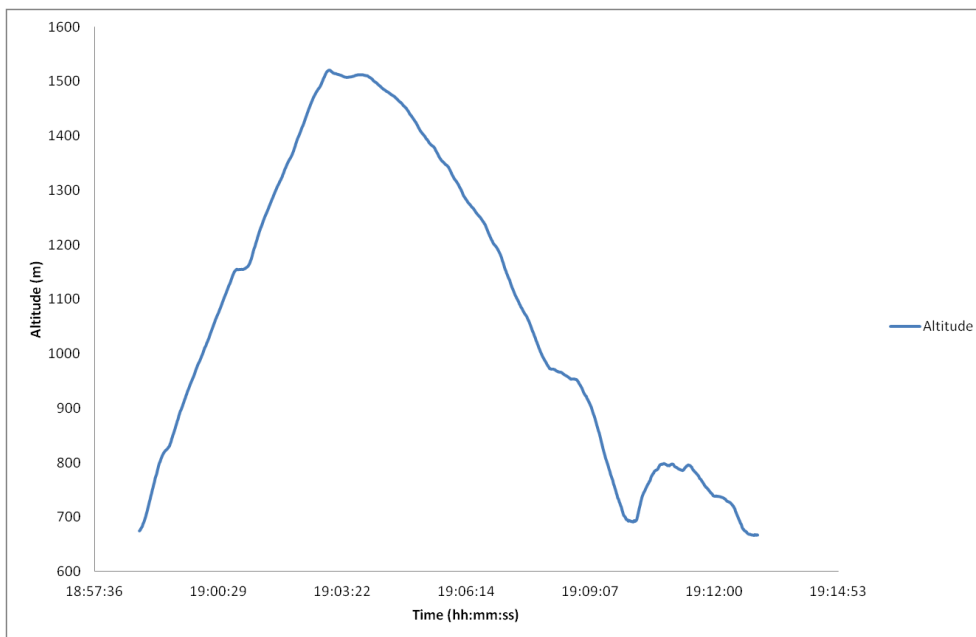


Figure 10: Flight Altitude

Information regarding the attitude of the aircraft while flying is illustrated in Figure 11, showing data from gyroscope, and Figure 12 showing data from the accelerometer. This information represents the stability of the flight by measuring the speed and acceleration from all the different maneuvers.

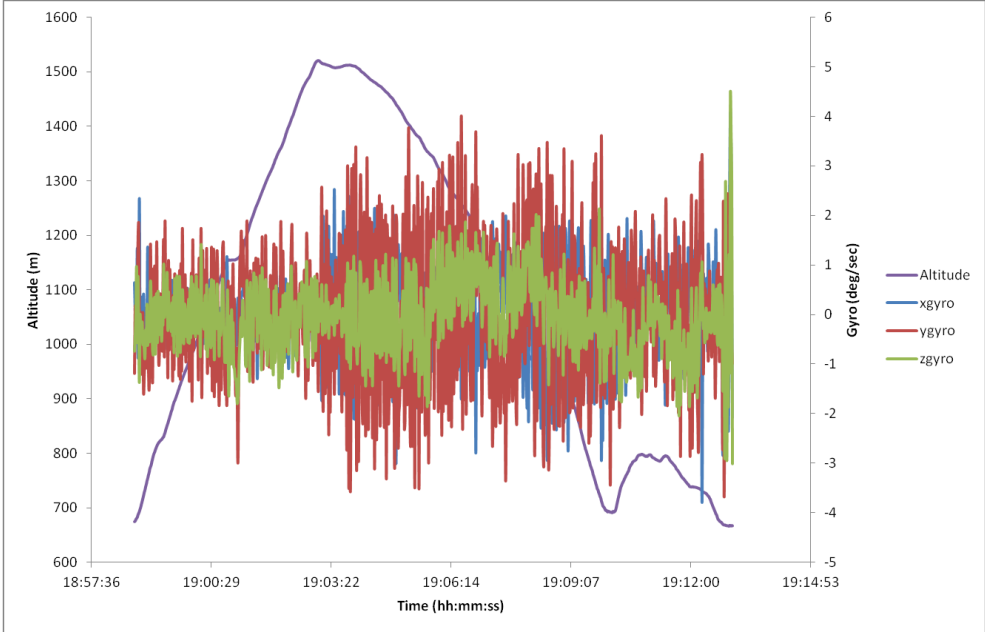


Figure 11: Gyroscope Flight Data

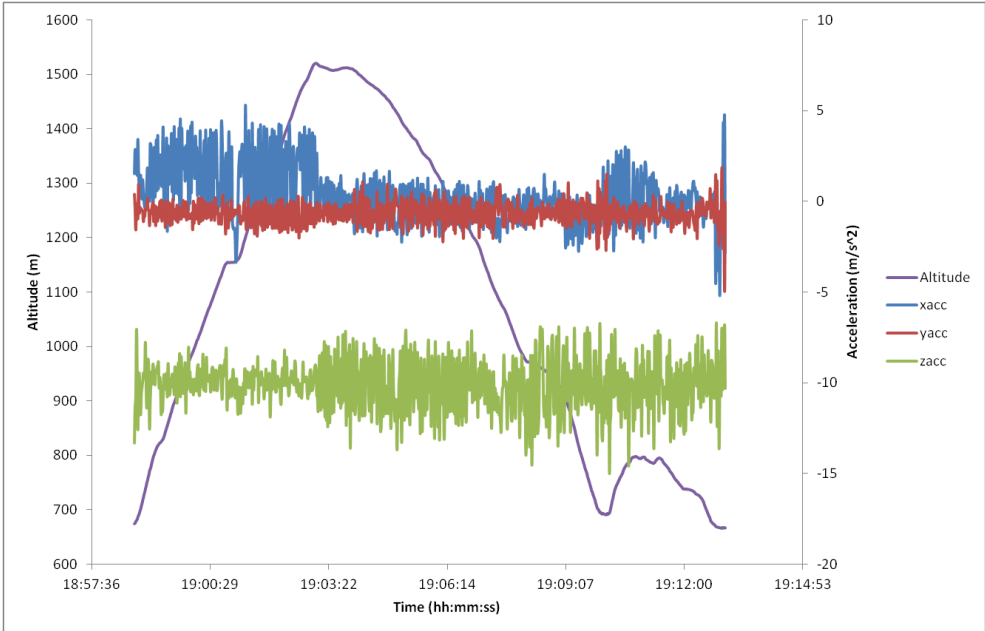


Figure 12: Accelerometer Flight Data

Figure 13 represents data from the pilot cerebral oximetry compared to the altitude path. This information is very important to determine physiological changes in the aircraft pilot.

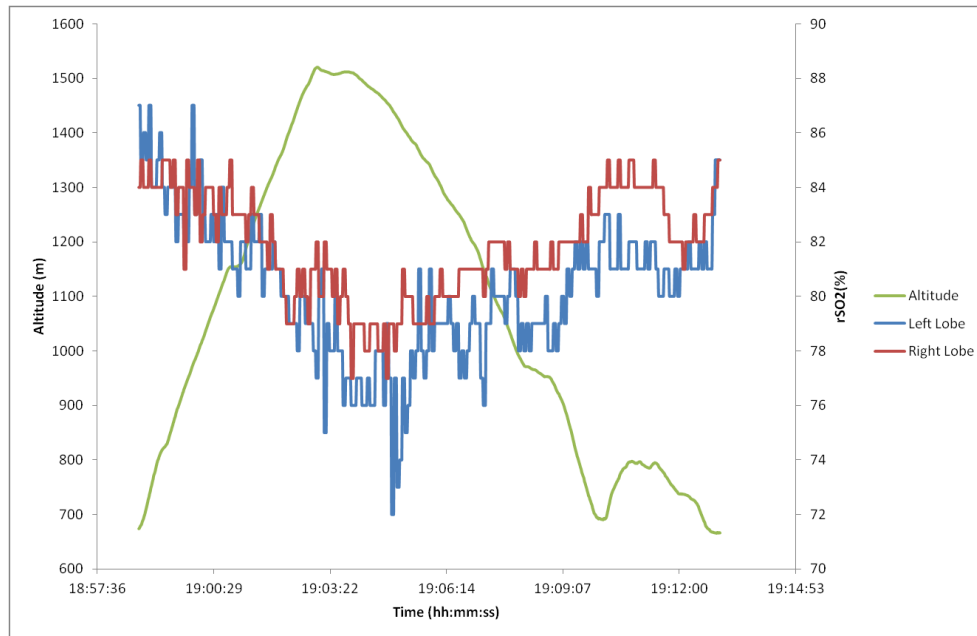


Figure 13: Cerebral Oximetry and Altitude

5. Discussion and Conclusion

After some successful tests with the EEG-SMT this device suffered a malfunction and stop working correctly being unable to conduct flight tests. The APM 2.0 Purple due to being a recent product in the market suffered from some software malfunctions which lead to errors in the memory card system and consequent error in the logging function. This problem was identified after a test flight and as consequence it didn't provide any data from the aircraft flight dynamics. After some investigation and consequent test the problem was solved and the device reassumed normal function.

During the first flight a problem related to the GPS signal lock was also identified due to interference coming from the aircraft engine and radio radiation. This problem was corrected by moving the board further away from the aircraft engine and radio and performing more tests in each position.

Despite ground tests to the various equipment and the correct function of them all, the different problems encounter could only be found after the realization of flight, which lead to several flights without complete data obtained until all problems were fixed. Despite the problems and the delay all the data acquired from the Nonin Medical 7600 is complete and

provides important information for physiological analysis of the pilot performance. After some initial errors and consequent fixes data from the APM 2.0 gives a good detail from several flight parameters such as accelerometers, gyroscopes and geographical coordinates that are important to reproduce some variables of the aircraft flight dynamics.

The combination of this data provides an important step forward in the development of an in flight monitoring system for pilot performance and provides information for the analysis of human physiological changes when flying in unpressurized aircrafts.

Future work will focus first on the repair or replacement of the EEG-SMT in order to perform electroencephalogram EEG and electrocardiogram ECG. Extended analysis and processing from all the data coming from the sensors in the APM 2.0 is required to improve the precision and reliability of all the flight data and the optimization and placement of all the equipment on board the aircraft is also an important procedure that requires future work and several flight tests in aircrafts with different configurations.

Acknowledgements

To FCT (Fundação para a Ciência e Tecnologia, Portugal) for the MSc grants of André Marques and Sara Zorro, under AIRDEV (Business Models for Airport Development and Management) Project in partnership with MIT-Portugal Program (Reference: MIT-Pt-TSAAAs/0046/2008).

To Nonin Medical Inc. for supporting the empirical works with the cerebral oximetry equipment.

References

DIY DRONES, ArduPilot Mega 2.0 Purple, https://store.diydrones.com/product_p/br-ardupilotmega-04.htm, last access June 25, 2012.

DR, Decreto-lei 289/2003 de 14 Novembro 2003, Artigo 26º, Ministério das Obras Públicas, Transportes e Comunicações, Lisboa, Imprensa Nacional – Casa da Moeda, SA, 2003.

FAA, Effects of Mild Hypoxia on Pilot Performance at General Aviation Altitudes, U.S. Department of Transportation, Civil Aeromedical Institute, Oklahoma City, April 1997.

FAA, In-Flight Physiological Monitoring of Student Pilots, U.S. Department of Transportation, Office of Aviation Medicine, Oklahoma City, August 1967.

FAA, Pilot' Handbook of Aeronautical Knowledge, U.S. Department of Transportation, Flight Standards Service, Oklahoma City, 2008.

FAR - Part 91 – General Operating and Flight Rules, FAR Electronic Code of Federal Regulations, April 2012.

Grossi, D., Aviation Recorder Overview, National Transportation Safety Board, IEEE Communications Magazine, July 2003.

Guger, C., Domej, W., Lindner, G., Pfurtscheller, K., Pfurtscheller, G. and G. Edlinger, Effects of a fast cable car ascent to an altitude of 2.700 m on EEG and ECG, Neuroscience Letters 377 (1) (2005) 53-58.

Harding, R., Pressure Changes and Hypoxia in Aviation, Medical Aspect of Harsh Environments, Volume 2, 2002.

Harding, R., The Earth's Atmosphere in Ernsting, J. and P. King (Eds), Aviation Medicine, 2nd ed. London, England, Butterworths, 1988:5.

ICAO, Annex 6 – Aircraft Operation, Maintenance and General Aviation, Eight Edition, ICAO, Montreal, Quebec, Canada, July 2001.

JAR-OPS, JAR-OPS 1: Commercial Air Transportation (Aeroplanes), JAA Publications, JAR-OPS Part 1, May 2007.

Meyer, J. and H. Gastaut (Eds.), Cerebral Hypoxia and the Electroencephalogram, Thomas, Springfield, IL, pp. (1961) 599-617.

Nonin Medical Inc., Model 7600 Regional Cerebral Oximetry System, <http://www.nonin.com/ProductDetail.aspx?ProductID=61>, last access: 25 June, 2012.

Olimex, EEG-SMT, <http://www.olimex.com/gadgets/index.html>, last access: 25 June, 2012.

OpenEEG, <http://openeeg.sourceforge.net/doc/>, last access: 25 June, 2012.

Ozaki, H., Watanabe, S. and H. Suzuki, Topographic EEG changes due to hypobaric hypoxia at simulated high altitude, *Electroencephalography and clinical Neurophysiology* 94 (1995) 349-356.

Rocha, L., *Desempenho de Pilotos e Segurança de Voo. O Caso da Hipoxia em Aviação Desportiva*, Master Thesis in Aeronautical Engineering, Covilhã, University of Beira Interior, 2011.

Rood, A., Dashevsky, D., Birch, M., Glickman, E., Newman, D. and D. Dietrich, Pilot Physiological Assessment System, 82nd Annual Scientific Meeting of the Aerospace Medical Association, May 2011.

Simmons, R., Chandler, J. and D. Horning, A Forehead-Mounted Measure of O₂ Saturation: The Potential for in Cockpit Hypoxia Early Detection and Warning, Naval Aerospace Medical Research Laboratory, July 2010.