Project title: Modelling respiratory physiology during acute exposures to altitude to enable digital test and evaluation of future fast-jet environmental control and life support systems

Project reference: DT4H_21_2024

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Aim of the Project

The aim is to develop a respiratory model that works during simulated acute exposures to altitude, which can then be paired with a Digital Twin of the environmental control and life support system. This will allow simulated testing of prototype systems and an exploration of their effect on the users' physiology both in terms of efficacy of protection and exploration of potential detrimental side effects. The model will include routine flight exposures with changing barometric pressure, supplemental oxygen use, speech and moderate exercise. It will be developed to include hypoxia during oxygen delivery system failure modes, rapid decompression at high altitude, and high-G flight scenarios including use of positive pressure breathing for G protection. This Digital Twin will enable rapid iteration of concept designs, enhancing the efficiency of the design process and helping better focus manufacture of prototypes for physical system testing.

Project Description

The last 20 years has seen a rise in so-called unexplained physiological events, which were a diverse collection of symptoms experienced by pilots in flight that had potential to interfere with their safe operation of the aircraft and with (potentially) uncertain aetiology. The likely cause of these physiological episodes are now understood to vary between aircraft platforms, and often can be explained with appropriate investigation of the aircraft, environmental control and life support system, and pilot experience. They are a diverse mix of historically recognised and understood conditions that can occur in flight such as hypoxia, hyperventilation, and acceleration atelectasis. Some of the contributing factors, however, were also a failure to appreciate the importance of some of the standards documents around ECLSS component and sub-system performance criteria that led to potentially compounding or synergistic effects to alter the expected breathing resistance or performance of the oxygen delivery system, which could impact the users physiology.

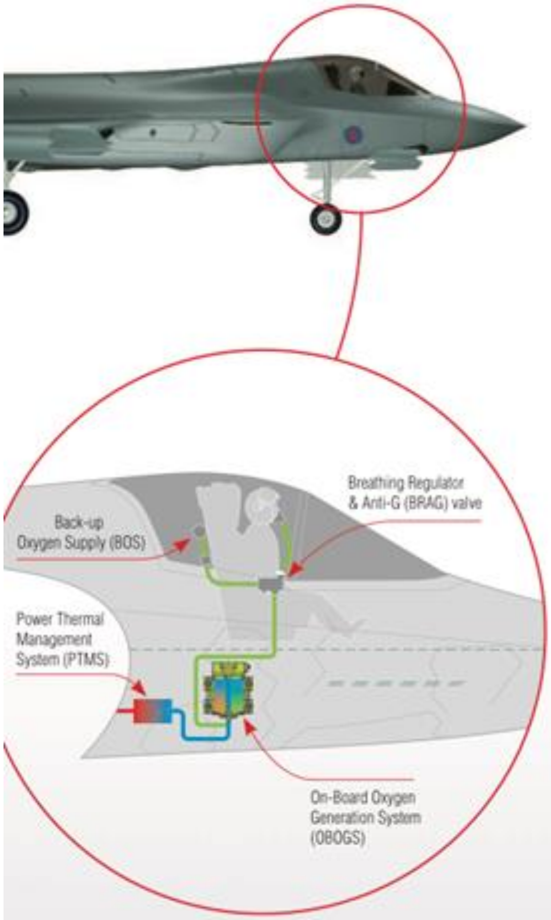
There had also been a collective international loss in aerospace medicine knowledge over the preceding decades that had contributed to uncertainty around their causation when they started to occur. This was compounded by a loss of connection between the aerospace medicine and engineering communities, which historically would have enabled a more informed response to this. As a result these events led to grounding of multiple billion-dollar fleets of military aircraft, especially in the US but also some other countries for prolonged periods of times at significant cost and loss of operational capability.

This has driven an interest in physiological monitoring but also a reinvigoration of aerospace medicine and physiology training internationally, and the need for closer interaction of this community with aerospace engineering. This collaborative approach across disciplines is now presenting opportunity for novel and innovative approaches, including the potential of Digital Twins to aid in the test and development of new ECLSS.

One area that is lacking in these efforts though is a respiratory model that adequately describes physiological responses to acute exposure to altitude and how these responses would be modified by ECLSS. Therefore, a core component of the work is to develop a next generation mathematical model of human respiratory physiology using up to date modelling techniques. Another key component is to use the model to assess the impact on physiology of different Digital Twin prototypes of the ECLSS to help test and refine system design and performance criteria prior to manufacture and testing of physical prototypes. It also presents opportunity for post event simulation to recreate the conditions around in-flight physiological episodes.

Requirements

The successful candidate will work with world-leading experts in data science and physiological modelling, as well as exerts in human physiological responses to extreme environments and aerospace ECLSS engineers. The candidate will also test the efficacy of the model against data obtained from real lab experiments with human participants exposed to a variety of simulated altitude conditions.



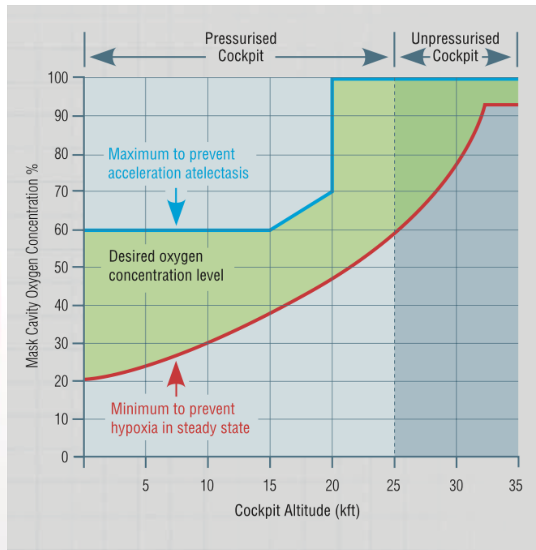


Figure 2: Typical oxygen requirements against altitude

Fig 1a. Typical On Board Oxygen Generation (OBOG) system architecture

Fig 1b. Typical oxygen requirements against altitude

Images show components of the life support system within the aircraft that can affect the users physiology and a graph of the concentration of oxygen required at different exposure altitudes. Figures taken from open-source Honeywell Life Support Systems PDF.