There are six main disadvantages/ challenges to extensive simulation training.

They are 1. simulation sickness, 2. poor motion cueing, 3. lack of user motivation

4. complex system architecture applications, 5. over regulation and 6. costs can be prohibitive purchase and maintain the simulators (Myer and Mullins, 2018). However, there are additional challenges with simulators.

Simulation sickness in humans falls under the umbrella of motion sickness. The term simulation sickness refers to not the usual sickness caused by turbulence on a plane, but also the miscalculation of computer cueing by the brain and other general aspects of the simulation (Pausch, et al, 2017).

Symptoms of simulation sickness include cold sweating, dizziness, headaches, fatigue, nausea, and vomiting, as well as increased saliva production (Geyer, D. J., et al, 2018). Simulator sessions can have lasting effects on the user that extend beyond the immediate experience. An individual can exhibit symptoms like pallor, sweating, and nausea during a simulator session. If these side effects persist, they could be hazardous when operating a car or aircraft. Thus, it is crucial to recognize the consequences of simulator exposure and the need for caution and safety measures to combat this exposure. Trying to incorporate the polysymptomatic nature of the simulator sickness, as well as it being polygenic makes trying design around it difficult (Pausch, et al, 2017).

Motion cueing

There are many functions of aviation simulators, including research and education. The peak certifications in the training vehicle industry get their certification by having motion cuing platforms. Unfortunately, unlike this generation's audiovisual technology, self-motion cuing presents significant economic and technological limitations. Because of this, the motion cuing produced by current technology generally does not match what is anticipated by the user/trainee. Motion cueing is important, as it enhances the level of realism, and can help with the forming of helpful reactions and habits. There is not one widely accepted solution for the technological limitations of simulators, even after over fifty years of motion-based flight simulators being used. One of the main challenges faced by engineers when building or trying to create the motion cueing platforms, is delivering a convincing sense of motion in the simulations. The human body requires physical movement to trigger the symptoms caused by motion and often flight simulators have limited space (Casas-Yrurzum, et al, 2021). Due to these limitations, there are considerate differences between each different flight simulator, which also calls into question the value of motion cuing when training pilots at least until more technological advances are made (Hosman and Advani, 2016)

User motivation

In simulated environments, participants are aware that they are not actually inside an aircraft, which can potentially influence the motivation of the pilots which may make them not take their training seriously. The awareness of being in a simulated setting could also lead to a diminished perception of danger and lower levels of stress than would happen in a real-world situation. Consequently, this altered perception can impact their motivation, decision-making, and overall performance when faced with real-life challenges in an actual aircraft (Myer and Mullins, 2018).

Complex architecture and system integration

The flight simulator architecture is a highly complex system that involves various technical requirements for seamless integration. Any modifications or alterations to the architecture can become a tedious process due to the stringent government regulations. This regulatory framework necessitates extensive paperwork and adherence to specific guidelines, making it crucial to follow proper procedures when making any changes to the simulator's architecture (Myer and Mullins, 2018). Additionally, the integration of a flight simulator system requires specialized knowledge beyond that of mechanical engineers who primarily work on real aircraft. It also requires the expertise of professionals in avionics, computer systems, software programming, and human factors engineering. These specialists collaborate to seamlessly integrate components such as flight controls, visual systems, and motion platforms, creating a realistic training environment. This expertise is essential due to the unique complexities of flight simulation technology (Aslandere, et al, 2014).

Software Faults and Stability

The aviation industry now faces more cyber security challenges than ever before. In aviation this new threat level is compounded with an increase in hardware and software requirements to increase efficiency. This increase and the weaknesses of it, has not gone unnoticed by threat actors/ hackers who could cause serious damage to aircraft systems and simulators should they successfully hack into or hold a system to ransom (Ukwandu, et al, 2022).

Regulatory Compliance

In New Zealand, our flight simulators use the same regulations for flight simulators as the United States (D. Franklin, June 08, 2023). With the advancements in technology, there has been a large uptake in the use and production of flight simulators. With such large numbers of different flight simulators, regulations and rules need be kept up to date to make sure pilots are training on adequate devices so that there are not significant discrepancies between different pilots' skills (Federal Aviation Administration, 2014). Even small changes to the architecture of flight simulators can be hindered because of the strict regulations in place (Myer and Mullins, 2018).

Cost

Additionally, the average cost of a flight simulator for an Airbus A320 and Boeing 737 aircraft ranges from $10-12 million US dollars (approximately $16-20million NZD). In comparison, the average price for an Airbus A320 or Boeing 737 aircraft alone is approximately $100-125 million US dollars (approximately $164-$205 million NZD.) The prices of wide-body passenger planes like the Airbus A350 and Boeing B787 average around $300 to 350 million USD ($500-577 million NZD), while their corresponding flight simulators cost between $15-17 million USD (approximately $25-28 million NZD).

Then there are maintenance expenses. Flight simulator maintenance typically costs around $1,000 dollars per month (roughly $12,000 USD annually). In contrast, the monthly maintenance cost for a Boeing B737-700 aircraft is around $270,000 USD ($3,000,000 million USD annually)., Nevertheless, these are still costs that must be paid for by the business in order to start flight training (Grujić and Tanasković, 2020).

Reference List

Aslandere, T., Dreyer, D., Pankratz, F., & Schubotz, R. (2014, September). *A generic virtual reality flight simulator*. [Paper presentation]. In Virtuelle und Erweiterte Realität, 11. Workshop der GI-Fachgruppe Tagung Band (pp. 1-13). Shaker Verlag. https://www.researchgate.net/publication/312170014_A_Generic_Virtual_Reality_Flight_Simulator

Casas-Yrurzum, S., Portales-Ricart, C., Morillo-Tena, P., & Cruz-Neira, C... (2021). On the Objective Evaluation of Motion Cueing in Vehicle Simulations. *IEEE Transactions on Intelligent Transportation Systems, 22*(5), 3001–3013. https://doi.org/10.1109/tits.2020.2978498

Federal Aviation Administration. (2014). *FAA Approval of Aviation Training Devices and Their Use for Training and Experience*. https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/1034348

Geyer, D. J., & Biggs, A. T. (2018). The Persistent Issue of Simulator Sickness in Naval Aviation Training. *Aerospace Medicine and Human Performance, 89*(4), 396–405. https://doi.org/10.3357/amhp.4906.2018

Grujić, V., Tanasković, M. (2020). *The Role of Flight Simulation in Flight Training of Pilots for Crisis Management.* [Paper presentation]. International Scientific Conference on Information Technology and Data Related Research. doi:10.15308/Sinteza-2020-214-221

Hosman, R. J. A. W., & Advani, S. (2016). Design and evaluation of the objective motion cueing test and criterion. *The Aeronautical Journal, 120*(1227), 873-891.

Myers, P. L., Starr, A. W., & Mullins, K. (2018). Flight Simulator Fidelity, Training Transfer, and the Role of Instructors in Optimizing Learning. *International Journal of Aviation, Aeronautics, and Aerospace, 5*(1). DOI: https://doi.org/10.15394/ijaaa.2018.1203

Pausch, R., Crea, T., & Conway, M. (2017). A Literature Survey for Virtual Environments: Military Flight Simulator Visual Systems and Simulator Sickness. Simulation in Aviation Training, 147-166.

Ukwandu, E., Ben-Farah, M. A., Hindy, H., Bures, M., Atkinson, R., Tachtatzis, C., ... & Bellekens, X. (2022). Cyber-security challenges in aviation industry: A review of current and future trends. *Information, 13*(3), 146.