Future of Aircraft Accident Investigation (AAI) Training: "Digital Crash Lab" through the Applications of Augmented Reality (AR) and Virtual Reality (VR) Technology

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Introduction

Aircraft Accident Investigation (AAI) has long been a challenging and demanding task due to the complexity of accidents and the involvement of various institutional levels, sectors, and other stakeholders. Many articles and literatures have placed a strong emphasis on the conduct of investigation (e.g., techniques, framework, evidence gathering, application of technology, etc) but the idea of leveraging the advantages of modern technology in training investigator is still underdeveloped. (Roed-Larsen & Stoop, 2012) identified training and competence of personnel as one of the four major challenges for any investigating bodies. To remain competitive, national investigating bodies must invest in an effective and cost-efficient training for their workforce. In this highly-specialised field, training program must be constantly revised to adapt with the rapidly-evolving aviation environment in order to produce a versatile and competent investigator. This paper is primarily focused on the future potential of Augmented Reality (AR) and Virtual Reality (VR) as well as the advantages they could bring into a classroom environment.

Challenges of AAI Training Today

The challenges to train accident investigators come in several ways. Oftentimes, budgetary allocation remains the cornerstone that limits other critical factors such as training aids, facilities, and logistics support. As a result, this will ultimately influence an investigator's learning experience, hands-on exposure, and the overall competency of workforce within an organisation. AAI learning can come from several entities such as tertiary education, professional organisation offering certified training courses, or national body such as National Transportation Safety Board (NTSB). In order for trainees to put their theoretical and methodological knowledge into practice, training program frequently involves practical session at a crash lab that is usually equipped with accident reconstruction site. However, these facilities are often very limited, or not available, in certain part of the world. Thus, trainees are often sent to a specified location for days or weeks to attend a training course.

Considering the tuition and logistic cost (e.g., accommodation, travel, meal, etc), the opportunity for a small company to invest in their employee's upskill training may be very limited. With the volatile economic climate, it is not surprising that continuing professional training and education (CPE) is often the first item to be rejected in a budget planning (Fabian, 2010). Putting the above into perspective, a roughly estimated total cost to attend an AAI course ranges between 2,175 USD to 6,335 USD taking into account tuition, lodging, international flight, and general expenses. These values were estimated from the AS101 AAI and AS301 AAI for Professionals course offered by NTSB (NTSB, 2022).

Furthermore, with the infinitesimally small number of accidents per million departures (refer **Figure 1**) as aircrafts have become more reliable, the chances for investigators to get access to real crash sites are even smaller. Therefore, a value-based training is essential in ensuring return on investment (ROI) (Kearns, 2005) and a chain of impact for an organisation (Phillips, 2003).

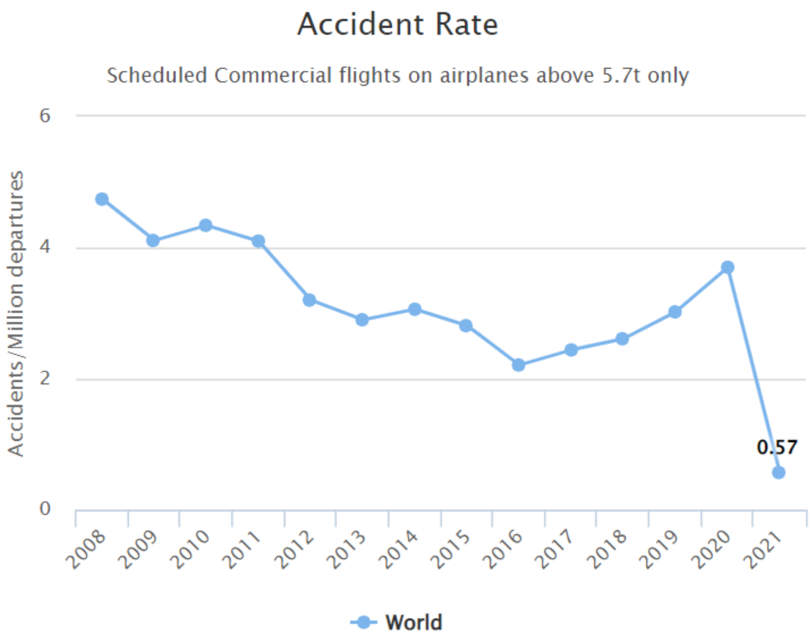

Figure 1 Accident rate from year 2008 to 2021 (ICAO, 2022)

The unforeseen Covid-19 had changed the world the usual ways of conducting daily business. People are forced to be conversant in handling technology such that virtual meetings are now more frequent than physical meetings. In today's increasingly interconnected world, we must adapt and re-innovate to maximise the usage of technology. Hence, this paper is recommending the use of AR and VR to digitalised crash lab and use it as a supplementary tool to train future investigator.

Solution: "Digital Crash Lab" using AR or VR Technology

AR is defined as a real-time direct or indirect view of a physical real-world environment that has been enhanced or augmented by adding virtual computer-generated information to it (Carmigniani & Furht, 2011). An ultimate example would be the popular mobile game "Pokémon Go!" where virtual 3D "Pokémon" creatures appear in a real-world environment. The overlaying computer generated information runs interactively in real time and aligns real and virtual object together (Azuma et al., 2001). It is observed that there is currently no implementation of AR in AAI training and a very limited literature exploring the capability that it offers to the aviation industry. (D'Anniballe et al., 2020) explored the application of AR to re-create real aircraft crash scene in a full-scale 3D presentation without compromising the accuracy of data acquired. In the study, the digitisation of a crash site used both aerial photogrammetry and laser scanning techniques to re-create crash scene before it is being transferred into an AR device for analysis. However, this example only explores the usage of AR in actual investigation setting but not in a training environment. In short, a similar application in the training domain can also be optimised with the introduction of AR.

Meanwhile, VR is an environment whereby one is totally immersed in, and able to interact with, a completely synthetic world (Milgram & Kishino, 1994). VR applications in aviation are currently used predominantly in engineering, maintenance, and the recently approved first VR Flight Simulation Training Device for rotorcraft pilots (EASA, 2021). The increasing trend of using VR as a training tool can be seen in other sectors such as the reconstruction of mining operation incident (Schafrik et al., 2003, Kizil, 2003) and digital forensic investigators (Karabiyik et al., 2019). In the field of AAI, a Virtual Lab Environment (VLE) had already been materialised at the Embry-Riddle Aeronautical University (ERAU) (Burgess & Moran, n.d.). Hiverlab had also collaborated with Singapore Aviation Academy under the recognition of Civil Aviation Authority of Singapore to pioneer and develop AAI course with VR simulations experience for aircraft crash site investigation training (CAAS, n.d.; Hiverlab, n.d.).

Multiple crash scenarios such as SQ006, ET302, and MH17 can be converted into 3D model immediately after the crash, making overall learning experience more engaging and interactive through a VLE. These aforementioned examples proved that there are potential for the future generation AAI training developments in the realm of AR and VR.

The Advantages of AR or VR Leading-edge Technology

The introduction of this modern technology into AAI training possesses tremendous potential. The following are some of the advantages of training in a "Digital Crash Lab" using AR and VR compared to the conventional training method.

1. **Cost-Effective** – While initial cost may be a setback, investing in AR or VR technology is more cost-efficient in the long run than maintaining a physical lab. Virtual training course can be flexibly conducted anywhere around the world at the preference of the customer, reducing travel time and overall cost. It even allows organiser to bring the "Digital Crash Lab" (VR devices) as a "traveling classroom" to a specific location for this purpose. The latest VR Headset Oculus Quest 2 costs 397-497 USD per unit which is a huge cost difference compared to a physical course. To put numbers into perspective, investing in one trainer for a basic course is equivalent to the price of purchasing 15 to 17 units of Oculus Quest 2.
2. **Train Higher Number of Trainees** – More trainees can be trained at a particular time for different level of courses such as basic, recurring, or advanced.
3. **Modularisation of High-Fidelity Models** – Trainees are able to access to different 3D models modularised to specific airframe and widen their exposure to a variety of crash site scenarios. Wreckage components from a real crash site can easily be reproduced for classroom learning.

4. **Database for Team Learning** – Encourages cooperation and collaboration among the AAI community. Knowledge sharing and idea exchange can take place with other experts from different organisation. A collection of crash scenes forming a big database can be stored and access for future reference regardless of the user's physical location.
5. **Connectivity and Networking** – Worldwide trainees are able to connect through any online platform in a virtual lab environment that still allows for in-group learning or team projects.
6. **Health and Safety** – Without compromising learning experience, digitalised crash lab mitigates the exposure of trainees and instructors to hazards that may present in a physical crash site.
7. **Versatility** - The usage is not limited to only AAI training but also in conducting actual investigation. It can preserve important perishable evidence for future learning, providing a real-world experience for large number of students. In addition, AR and VR devices can also be tailored to different non-AAI related learning topics within an organisation.
8. **Machine Learning (ML) and Artificial Intelligence (AI)** – In the long term, ML and AI should be incorporated within the AR and VR environment in facilitating investigators in the future. These ground-breaking innovations are emerging as technology slowly takes over human routine work with more accuracy.

Conclusion and Future Consideration

AAI is a technically demanding role which should only be undertaken by well-trained personnel with exceptional qualities. In order to train an investigator with sound knowledge of investigation skills, organisation should trace back to the training that prepares them for the job. It is not sufficient to nominate someone with aviation experience and knowledge when occasion arises because AAI itself is considered a 'specialist task' that requires specific training (Smart, 2004). This paper stresses the importance of focusing on AAI training and addresses some challenges to train a well-qualified AAI.

With budget being the overarching concern, the objective to be cost-efficient has led to the recommendation of using AR or VR technology as an alternative. Since training is a systematic process (Salas et al., 2012) and organisation resources are limited, wise decisions must be made on allocation of funds without neglecting training requirement. Virtual lab experience is an effective tool to supplement the existing training method as it provides a good perspective of a real-world accident. This state-of-the-art technology is still in the maturity stage that presents some setbacks and limitations (Carmigniani et al., n.d.). With increasing research and rapidly improving technology (Buttussi & Chittaro, 2021), "Digital Crash Lab" should be well-matured and more cost-efficient in the years to come.

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