Collegiate Aviation Review International

Volume 42 | Issue 2 Proceedings of the 2024 UAA Annual Conference, Article #10

12-30-2024

Integrating Enhanced Flat Panel Trainer (EFPT) and Virtual Reality (VR) Technologies into an Aircraft Systems Course

Derren Duburguet
Metropolitan State University of Denver

Michael Botyarov
Metropolitan State University of Denver

The Advanced Commercial Aircraft Systems course at Metropolitan State University of Denver delves into the design and operation of regional jet aircraft systems, specifically focusing on the Bombardier CRJ 700. The virtual training environment developed early on to simulate pilot-system interactions or procedural flows originally incorporated two separate elements: 1) a desktop workstation flight deck simulation software and 2) a separate static layout of the flight deck. Technological advancements have since enabled the integration of these components into a single interactive touch-screen procedural trainer platform, which provides systems simulation within the spatial context of the flight deck layout. This enhanced flat panel trainer (EFPT) technology has been successfully employed in the Aeronautics and Aerospace Systems Jet Laboratory at Metropolitan State University of Denver and has been utilized for this class since 2015. As of fall 2024, the facility has expanded to include a 3D computer-generated Virtual Reality (VR) representation of the flight deck for procedural flow training, providing a more immersive experience for the learner. This presentation will review the implementation of VR technology, including preliminary student feedback received thus far.

Recommended Citation:
Duburguet, D. & Botyarov, M. (2024). Integrating enhanced flat panel trainer (EFPT) and virtual reality (VR) technologies into an aircraft systems course. *Collegiate Aviation Review International, 42*(2), 259-266. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/10009/8910

Introduction

The senior-level course “Advanced Commercial Aircraft Systems” in the professional pilot degree curriculum at Metropolitan State University of Denver’s Aviation and Aerospace Science Department focuses on the study of Transport Category aircraft systems. Using the Bombardier CRJ 700, a 70-seat regional jet aircraft, as the case study, students explore the various aircraft systems and examine standard operational procedures, as well as abnormal and emergency protocols in the event of system failures. Therefore, a key component of the course is the study of pilot-system interactions within the flight deck environment, also known as procedural flows. These procedural flows are memory-based task patterns that crew members can perform independently to optimize workload balance on the flight deck (Federal Aviation Administration, 1995). A procedural flow completes a series of actions that configure the aircraft while operating on the ground or during different phases of flight. Once a procedural flow is completed, the crew verifies the configuration by reviewing a corresponding checklist, ensuring no critical items essential for the safe operation of the aircraft are omitted (Federal Aviation Administration, 1995). When utilized in response to critical system failures, flows are referred to as immediate action memory items. These emergency procedural interactions are generally much shorter in sequence than flows conducted during normal operations, explicitly addressing items that must be performed in immediate response to an emergency event. Studying these procedural interactions reinforces the student’s understanding of aircraft systems in the context of standard operating methods utilized in Transport Category aircraft.

This presentation outlines the evolution of the training environment employed in this course to simulate the aircraft systems and flight deck layout of the CRJ 700 regional jet aircraft. Challenges encountered by some students in learning the procedural flow interactions are discussed including an overview of the implementation of Virtual Reality (VR) technology as a potential solution to these challenges, including preliminary student feedback and the observed effectiveness.

Training Environment

The training environment for the Advanced Commercial Aircraft Systems course has evolved over the past 12 years, driven primarily by both technology and increased budget allocations. In the earlier course design, desktop workstation software from Aerosim (now L3Harris) was utilized to simulate aircraft systems during the in-class lecture. A separate photo-realistic scale model of the flight deck layout was then employed to practice procedural flows. The computerized aircraft systems simulation, combined with the separate static depiction of the cockpit, formed a non-immersive virtual training environment (Duburguet & King, 2015). Using this approach, students were restricted to exploring system responses and procedural interactions using two separate mediums asynchronously.

The acquisition of an Enhanced Flat Panel Trainer (EFPT), designed by L3Harris, improved the training environment for this course by providing an accurate aircraft system simulation with touchscreen interfaces aligned in the correct spatial layout of the CRJ 700 cockpit. This higher fidelity design provided a more immersive experience for students, allowing them to interact with the aircraft systems while utilizing procedural flows simultaneously.

Training sessions in the EFPT now permitted a realistic application of systems knowledge while employing meaningful crew interactions.

To optimize the new EFPT training environment, the course was redesigned to incorporate a blended learning modality. Aircraft system lectures were moved to an asynchronous online format, while students scheduled weekly EFPT sessions in the Aeronautics and Aerospace Systems Jet Laboratory with the instructor. During each session, two students worked under the instructor's supervision, one in the role of Captain and the other as First Officer. The students progressed through the simulated scenario, applying the proper procedural flows and checklists to modify aircraft configuration. Abnormal or emergency conditions were also properly addressed when encountered in the lesson. After completing all tasks in the session and reviewing the corresponding checklists, the two students swapped roles and repeated the scenario.

Procedural Training Limitations

In addition to studying the aircraft systems online, students prepared for the EFPT sessions by reviewing written descriptions, graphical representations, and demonstration videos detailing the pertinent procedural flows. Students also practiced these flows on a photorealistic static scale model of the cockpit environment. Physically practicing flows establishes a procedural memory of the pilot-system interactions, often referred to as a "muscle memory" because it appears the muscles have recalled the procedure (Budson & Kensinger, 2023).

Despite these resources, some students still struggled to accurately apply the procedural flows from memory during a session in the EFPT's interactive cockpit environment. This may indicate that students are not effectively engaging in non-immersive practice to establish a useful retention of the flow procedures. When a student is not adequately prepared for an EFPT session, the efficiency and effectiveness of the lesson are compromised due to the lag time of recalling the procedure from either a written description or diagram. These situations have arisen often enough to underscore the need for a more engaging approach for students to practice procedural interactions in preparation for scenarios in the EFPT.

Virtual Reality (VR) and Procedural Training

Modern virtual reality (VR) systems consist of both the software to render a simulated three-dimensional (3D) space and the hardware to immerse users in that environment (Steffen et al., 2019). Terminology associated with VR includes augmented reality (AR), mixed reality (MR), and extended reality (XR). As the name suggests, AR augments the physical environment and is not a full replacement for it since AR superimposes virtual objects within the context of the user's real-world surroundings (Steffen et al., 2019). In contrast, mixed reality (MR) is a hybrid of VR and AR by allowing a user to interact with both digital and real-world objects in real time, optimizing benefits of each technology to enhance the user experience (Milgram, 1994). Extended reality (XR) has become the comprehensive umbrella term that encompasses VR, AR, and MR, along with any other technology that blends physical and virtual realities.

VR technology enables users to interact within the 3D artificial setting in a cost-effective and controlled manner without requiring direct interaction with the real-world scenario. Numerous case studies have demonstrated VR's applicability as an effective procedural training tool across a wide variety of industry domains (Renganayagalu et al., 2021). Adoption of VR training is driven, in part, by how effective VR can be in fostering the retention of procedural tasks that require spatial and visual information (De Lorenzis et al., 2023; Jensen & Konradsen, 2018; Majchrzak et al., 2022). In addition, when used for immersive learning in education, the novelty of VR's realistic simulations and interactive scenarios spark student motivation and engagement (Allcoat & von Mühlenen, 2018; Sanfilippo et al., 2022). By allowing students to directly interact with a simulated cockpit during procedural flow practice, VR provides a unique active learning experience compared with passive methods of learning through written descriptions and video demonstrations (Allcoat & von Mühlenen, 2018). This more immersive approach can better engage students and make their preparation time for the EFPT session more effective.

Although at the time of this writing, no specific VR training devices have been approved by the Federal Aviation Administration (FAA), in 2021, the European Union Aviation Safety Agency (EASA) granted the first regulatory approval for a VR-based flight training device (Auer et al., 2023; Shevchenko, 2021). This milestone suggests a clear potential for integrating VR training into traditional flight training curricula. VR software that facilitates procedural flow practice on Transport Category aircraft are becoming more available in the market. For example, VRPilot (https://vrpilot.aero/) offers VR training solutions for aircraft such as the Airbus 320 and Boeing 737. In collaboration with the Metropolitan State University of Denver's Aviation and Aerospace Science Department and funded by an aviation educational grant from the Colorado Department of Transportation (CDOT), VRPilot customized a VR procedural flow trainer for the Bombardier CRJ 700 tailored to the procedural flows developed for the Advance Commercial Aircraft Systems course.

VRPilot Implementation

The VRPilot software immerses the student in a three-dimensional simulation of the CRJ 700 regional jet cockpit for the purposes of flow training. Utilizing a PICO 4 head-mounted display (HMD) and two handheld controllers, students can interact with the artificial cockpit environment from either the captain seat or the first officer seat position. Students train with either a virtual automated crew member or with another student in a shared VR session. Shared VR sessions require only an internet connection, which permits students to interact within the same virtual cockpit without having to be physically in the same location. Furthermore, a shared VR session can also be hosted from such devices as an iPad or computer where the instructor can observe the students procedural flow training.

The VRPilot software supports self-guided procedural flow training, allowing students to select and practice various flows and immediate action memory items. In training mode, the VRPilot software guides students through a selected procedural flow by providing visual cues to interact with the applicable control interface in the correct sequence. Interaction with the specified control is achieved when the student physically reaches out and touches the control location in the virtual cockpit using the handheld controller's index finger trigger. When applicable, the software also directs where students must look to acknowledge any system feedback and ensures compliance through gaze-based eye tracking. The VRPilot software also offers a testing mode where students do not receive any guidance from the system. Employing this feature allows students to work through the selected procedural flow from memory while the software assesses their accuracy.

When providing a VR experience for students, it is crucial that the facility can support a dedicated space, or VR arena, that facilitates unobstructed use of the VR hardware (Majchrzak et al., 2022). An open room with seats spaced widely around the perimeter is more suitable than a traditional classroom with rows of chairs and desks. The open room allows students to sit along the outer perimeter and face inward toward the center of the room. During the VR simulation, students remain seated and can freely reach outward, upward, and side-to-side without colliding with desks, chairs, or other students. In addition to establishing a VR arena, it is also helpful to locate the VR hardware in an easily accessible location. To this end, the Looking Glass XR PowerCart is an ideal storage solution. The PowerCart is a wheel-mounted storage unit that can charge up to 24 VR HMDs simultaneously and can easily be repositioned as needed.

Informal Student Feedback and Observations

After purchasing the VR hardware, establishing the software licenses, and identifying the VR arena, implementing the VR technology for this course proved surprisingly straightforward. Students, already familiar with other flight simulation technologies, required minimal guidance on setup and immediately recognized the value of this immersive resource. Students also intuitively understood how the use the VR handheld controllers to interact with the simulated flight deck environment. After a brief demonstration on how to configure the VR hardware and interact with the VRPilot software, students were quickly able to engage in the self-paced training activities. An initial demonstration at the beginning of the course ensures students will not waste time struggling with the administrative aspects of establishing a VR environment (Majchrzak et al., 2022).

Student responses to working with the VR technology for procedural flow practice were resoundingly positive. They reported a high level of satisfaction with being immersed in the three-dimensional rendering of the CRJ 700 flight deck and enjoyed the self-paced guided training. Several students reported that during their non-immersive flow practice, they would only look at the controls and not reach out to touch them. These students appreciated that the software required them to physically reach out to the controls during the flow, thereby reinforcing “muscle memory.” Furthermore, many students felt strongly that flow documentation should be reviewed prior to training in the VR system. These students observed that their training time improved when they could anticipate the next item in sequence rather than rely solely on the VRPilot software to guide them.

One of the benefits of VR technology is that it can provide a multi-sensory learning approach involving visual, auditory, and tactile feedback (Sanfilippo et al., 2022). Students liked the visual interaction and audio responses of the VRPilot system. Some students felt that the normal view mode in the VR environment was visually “blurry”, but this issue could be quickly mitigated with the magnification function in the VR handheld controllers. Students did not comment on the lack of tactile response with this simulation. Although haptic stimulation makes the experience more realistic, it is less important than visual and auditory feedback (Auer et al., 2023). Since students apply the procedural flows in the EFPT, a device that uses touch-screen technology to simulate most of the aircraft system interface, tactile response in the VR environment was not a necessary feature.

Swivel chairs and chairs on wheels are not ideal for this application. During the VR sessions, students in these types of seats slowly crept forward toward the center of the VR arena. In addition, students practicing flows from the captain position tended to slowly pivot to the right, given that most actions in the flow involve reaching in that direction. The use of stationary chairs, however, completely mitigated this issue.

Previous studies have noted the use of the HMD when interacting in a fully immersive environment can induce motion sickness, referred to as cybersickness (Auer et al., 2023; Majchzak, et al., 2022; Oberhauser et al., 2018; Sanfilippo et al., 2022; Thomas et al., 2021; Weech et al., 2019). While students did not report any nausea in this application, a few did comment on experiencing oculomotor eye strain. To address this concern, time-limited exposure to the VR environment was recommended. In addition, the non-immersive photorealistic scale cockpit model remains available to students who find discomfort in using VR technology to practice procedural flows.

Conclusions

The VRPilot software effectively enables students to independently practice procedural flow interaction within a virtual cockpit and receive real-time feedback on the accuracy of their procedural execution. This activity is self-paced and, once students are familiar with the hardware setup, requires little to no guidance from an instructor to achieve. Implementing VR involved no change to the existing course design but did require infrastructure considerations regarding classroom space and storage of the HMDs and handheld controllers.

The student feedback received so far suggests a strong preference for using VR technology instead of the non-immersive approach when practicing procedural flows. While preliminary observations are promising, a quantitative analysis of measurable student performance with procedural flows must be conducted to make any conclusive statements. A quantitative analysis could not only evaluate student performance of procedural flow execution from a timing and accuracy perspective, but also from a human cognition perspective to gain a comprehensive understanding of the workload associated with task performance. This type of analysis will yield greater insight into the implementation of VR systems in flight training.

References

Allcoat, D., & von Mühlenen, A. (2018). Learning in virtual reality: Effects on performance, emotion and engagement. *Research in Learning Technology*, 26.

Auer, S., Anthes, C., Reiterer, H., & Jetter, H. C. (2023). Aircraft Cockpit Interaction in Virtual Reality with Visual, Auditive, and Vibrotactile Feedback. *Proceedings of the ACM on Human-Computer Interaction*, *7*(ISS), 420-443. https://doi.org/10.1145/3626481

Budson, A. E., & Kensinger, E. A. (2023). Why we forget and how to remember better: the science behind memory (pp.13-25). Oxford University Press.

De Lorenzis, F., Pratticò, F. G., Repetto, M., Pons, E., & Lamberti, F. (2023). Immersive Virtual Reality for procedural training: Comparing traditional and learning by teaching approaches. *Computers in Industry*, 144, 103785. https://doi.org/10.1016/j.compind.2022.103785

Duburguet, D., & King, G. G. (2015). Leveraging virtual training environments to develop professional flight officers in a rapidly changing aviation industry. *International Journal of Aviation Research*, 7(2). https://ojs.library.okstate.edu/osu/index.php/IJAR/article/view/8115

Federal Aviation Administration. (1995*). Human Performance Considerations in the use and Design of Aircraft Checklists*. US Department of Transportation, Federal Aviation Administration.

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 23(4), 1515-1529. https://doi.org/10.1007/s10639-017-9676-0

Majchrzak, T. A., Radianti, J., Fromm, J., & Gau, M. (2022). Towards routinely using Virtual Reality in higher education. *Proceedings of the 55th Hawaii Internation Conference on System Sciences*, 94-103.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12), 1321-1329.

Oberhauser, M., Dreyer, D., Braunstingl, R., & Koglbauer, I. (2018). What's real about virtual reality flight simulation? *Aviation Psychology and Applied Human Factors*, 8(1). https://doi.org/10.1027/2192-0923/a000134

Renganayagalu, S. K., Mallam, S. C., & Nazir, S. (2021). Effectiveness of VR head mounted displays in professional training: A systematic review. *Technology, Knowledge and Learning*, 1-43. https://doi.org/10.1007/s10758-020-09489-9

Sanfilippo, F., Blazauskas, T., Salvietti, G., Ramos, I., Vert, S., Radianti, J., Majchrzak, T., & Oliveira, D. (2022). A perspective review on integrating VR/AR with haptics into stem education for multi-sensory learning. *Robotics*, 11(2), 41.

Shevchenko, N. (2021). *Design of a VR application for pilots as a complementary tool for procedure training of Abnormal Operations* (Master's thesis, University of Agder).

Steffen, J. H., Gaskin, J. E., Meservy, T. O., Jenkins, J. L., & Wolman, I. (2019). Framework of affordances for virtual reality and augmented reality. *Journal of Management Information Systems*, 36(3), 683–729. https://doi.org/10.1080/07421222.2019.1628877

Thomas, R. L., Dubena, R., Camacho, G. L. J., Nieves, N. A., Barcza, T. D., Green, S., & Perera D. (2021). Usability of the virtual reality aviation trainer for runway-width illusions. *Collegiate Aviation Review International*, 39(2), 163-179. https://doi.org/10.22488/okstate.22.100237

Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and cybersickness in virtual reality are negatively related: a review. *Frontiers in Psychology*, *10*, 158. https://doi.org/10.3389/fpsyg.2019.00158