# Headset-free Immersive Flight Simulators for Improved Training Throughput

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## ABSTRACT

The U.S. Air Force (USAF) faces a persistent pilot shortage. AF-AETC Deputy Commander Maj. Gen. Clark Quinn noted a 2,000-pilot shortage in 2023, with about 30-40% open civilian training positions. Various programs, including Pilot Training Next (PTN), Initial Pilot Training (IPT), and Undergraduate Pilot Training (UPT), seek to increase pilot training throughput through low-cost immersive training with virtual reality (VR) headsets. However, they are limited by the vergence-accommodation conflict (VAC), latency, and lag, which induce cybersickness in trainees during prolonged use. At least three DAF MAJCOMs–AMC, ACC, and AFSOC–require alternative solutions to support training sessions longer than one hour.

To overcome these limitations, Brelyon has developed Ultra Reality (UR) display technology, a headset-free virtual training flight simulator. Its human-vision-centric-design–enabled by the concept of "horopter" to optimally fuse binocular and monocular depth perception–generates an immersive visual experience with the required specifications for desktop training: a 122" true-depth, curved focal plane spanning 1.5 m to 2.5 m, 110° field of view, and 4K resolution, all through a 30" aperture. This architecture causes trainees' eyes to physically focus to the correct depth, avoiding eye strain, enabling efficient interaction time, and ultimately increasing training throughput.

Fundamental research through commercial and USAF studies suggest that UR effectively addresses the capability concerns associated with traditional VR headsets, providing visually ergonomic immersion for extended training sessions while maintaining cost-effectiveness. Here, we describe UR's fundamental optical principles and specifications as a path toward universally scalable, headset-free immersion for the USAF and other military branches.

## ABOUT THE AUTHORS

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## INTRODUCTION

### Pilot Training Need and Importance

The U.S. Air Force (USAF) has been continually wrestling with a severe and persistent pilot shortage that threatens its operational readiness (Beebe, 2024; Cohen, 2023; Mitchell, 2023). In 2024 alone, the shortage was estimated at around 2000 pilots (Larson, 2025), with roughly half of those being fighter pilots. This shortfall not only impacts the Air Force's ability to fulfill its missions but also increases the operational burden on existing pilots, risking burnout and reduced effectiveness across the force. This shortfall is driven by several factors, including high retirement rates, trainer shortages, shrinking/aging fleet, and more lucrative opportunities in the civilian sector (Ceder, 2025). Addressing this shortage is a top priority for Air Education and Training Command (AETC) and other major commands.

To help alleviate the pilot shortage, the USAF has increasingly turned to simulation-based training as a scalable and efficient solution. Advanced flight simulators allow for more pilots to be trained simultaneously and reduce the need for costly in-aircraft training hours. By expanding the use of immersive simulators, the Air Force aims to accelerate the production of qualified pilots and ensure that trainees are better prepared.

### Alternative Solutions

For example, VR headsets have been a technology assessed for simulation training within pilot programs. The modernized Undergraduate Pilot Training (UPT) and Pilot Training Next (PTN) programs enable trainees to log simulator hours alongside actual flight time for improved progression (Tadjdeh, 2020; Pawlyk, 2024). Simulation training has multiple benefits, including safe rehearsing of complex or dangerous scenarios, reduced wear and tear on aircraft, and (ideally) higher throughput through more frequent, accessible curricula.

However, despite the promise of VR headsets as a solution, their widespread use is hampered by cybersickness, which manifests with, e.g., nausea, dizziness, eye strain or fatigue, and disorientation, ultimately reducing the effectiveness of training sessions. This affects up to about 80% of headset users generally, and it precludes the necessary long interaction time (greater than one hour) for efficacious training. Moreover, traditional VR headsets struggle to provide the depth perception and visual accuracy required for advanced flight training. The narrow field of view, limited resolution, and lack of true-to-life focal cues can hinder a trainee's ability to accurately judge distances and spatial relationships—critical skills for safe and effective piloting. As a result, VR headsets have not yet delivered the expected improvements in training throughput or trainee performance. These ergonomic and perceptual shortcomings have prompted the USAF and other military branches to seek alternative solutions that deliver both immersive realism and long-term comfort.

The cause is due to technical limitations of headsets, such as the vergence-accommodation conflict (VAC), latency, and visual lag. Of note, VAC is a significant challenge in VR headset design and arises when the brain receives mismatched visual cues for vergence (the inward or outward rotation of the eyes to fixate on an object) and accommodation (the eye's focusing mechanism to produce a sharp image). In most current VR systems, stereoscopic displays create a sense of depth by presenting slightly different images to each eye, which prompts the eyes to converge as they would in the real world. However, the lenses in VR headsets typically focus the eyes at a fixed distance, usually between one and two meters, regardless of where virtual objects appear to be located. This means that while the eyes' vergence adjusts to perceived depth, the accommodation system remains fixed, leading to a conflict between these two natural visual processes. Therefore, an entirely different optical architecture is worthwhile to explore.

**Brelyon Ultra Reality (UR)**

Brelyon's Ultra Reality (UR) display technology provides an alternative paradigm in flight simulation training (Figure 1). Unlike conventional VR headsets, UR uses a headset-free, ultra-wide display that mimics human vision and optimally supports both binocular and monocular depth perception. It generates an immersive visual field (122″ virtual image size, 110° field of view (FoV), 4K resolution) and avoids the discomfort and eye strain typical of VR headsets. The technological approach enables trainees to physically focus to the correct depth (2.5 m), reducing fatigue and enhancing interaction time, which ultimately increase training throughput. UR overcomes the limitations of traditional VR and offers a universally scalable, ergonomic solution. Here, we describe the design principles of UR technology as they pertain specifically to comfortable immersion for flight simulation training platforms, and we provide initial user evaluations comparing UR to other solutions.

**Figure 1. Brelyon Ultra Reality (UR) flight simulation platform. Note that the on-screen content is in focus, whereas the hardware itself (the surrounding housing, for example) is slightly blurred. This demonstrates that the image is optically deeper than the aperture, as the camera focused farther to capture it clearly.**

## PRIOR WORK

**Psychological and Physical Fidelity**

In flight simulation training, fidelity refers to how closely a simulator mimics the real-world flight environment and is traditionally divided into psychological and physical axes. Physical fidelity describes the extent to which the simulator replicates the actual cockpit controls, instrumentation, motion cues, and external visual scenes, while psychological fidelity relates to how accurately the simulator elicits the cognitive and emotional responses a pilot would experience in real flight scenarios. Although high physical fidelity is often assumed necessary for effective pilot training and assessment—especially for expert pilots who must interpret large swaths of real-world cues—psychological fidelity can be equally or even more critical for learning, particularly for novice pilots who may become overwhelmed by highly realistic but complex environments. For novices, simulators with lower physical fidelity but higher psychological fidelity (such as those focusing on procedural training and emergency response in a controlled, less complex setting) can actually maximize initial learning rates by reducing cognitive overload and allowing trainees to focus on mastering fundamental skills before advancing to more realistic, high-fidelity systems (Noble, 2002; Pollit, 2024). Thus, the optimal balance between psychological and physical fidelity in flight simulation training depends on the pilot's skill level and the specific learning or assessment objectives, with both types of fidelity playing distinct but interrelated roles in effective pilot development.

### Negative Training

Negative training occurs when pilots develop incorrect behaviors or responses due to discrepancies between the simulated environment and real-world aircraft operation. Now, although trainees using VR performed better in post-training flight maneuvers on a flight training device than those using desktop simulators (Zhang, 2022), cybersickness and other VR-related effects may hinder those gains (Aaltonen, 2022). This can happen if the VR system fails to accurately replicate the flight dynamics, cockpit layout, or procedural fidelity of the actual aircraft, causing trainees to learn habits or reactions that are ineffective or even dangerous in live flight. To mitigate negative training, it is essential that VR flight simulation systems maintain high fidelity in both physical and procedural aspects. To avoid negative training, it is important to use high-resolution, low-latency VR systems as proper ergonomic adjustments, so trainees develop the right muscle memory and procedures for safe and effective real-world performance.

### Situational Awareness and Cognitive Load with VR

Situational awareness (SA) during flight simulation training is assessed using a variety of objective and validated techniques designed to capture a pilot's grasp of the current environment and their ability to anticipate future events. It is generally understood as comprising three levels: perception, comprehension, and projection of future states (Endsley, 1995). A widely adopted method to measure SA is the Situation Awareness Global Assessment Technique (SAGAT), which pauses the simulation at random intervals and queries the pilot on key elements of the scenario—such as aircraft position, system status, or environmental factors—to objectively measure SA. Another approach, the Situation Present Assessment Method (SPAM), allows pilots to respond to queries without pausing the simulation, measuring both accuracy and response speed to gauge SA during ongoing tasks. Cognitive load (CL) may be measured along with SA using, e.g., physiological measurements like eye tracking technology and biometric sensors. Because SA, CL, and fatigue are all coupled in a highly nonlinear mechanism, immersive systems like VR or UR must be designed to optimize that constraint. Whereas VR headsets impose a tradeoff between immersion-based SA and CL (enhancing SA increases CL, being exacerbated by cybersickness), UR is designed specifically to provide immersion while maintaining visual ergonomics, reversing this constraint.

## THEORY/DESIGN

### Binocular and Monocular Depth Cues

Based on the prior work above, flight simulation training (a) is necessary for alleviating training shortages, (b) has strong pedagogical merits for successful training and skills transfer, and (c) requires an optimized immersive experience to promote comfort and avoid potential negative training effects and CL, with which headsets struggle. To support all three factors, UR's optical architecture relies on monocular depth cues—each eye correctly focuses to the generated depth, and together they verge to that same depth, eliminating the VAC. A schematic of the optical architecture is shown in Figure 2. The light starts from a point source (i.e., a pixel from a flat panel seed display D), which emits a spherical-like wavefront. This light then travels through a set of optical films and elements to be prepared to enter a "field-evolving cavity" (FEC), which uses a sparse-depth wavefront-shaping architecture (Heshmat, 2020) to flatten that wavefront and effectively move that pixel farther away from the viewer. The angular profile is shaped into a cohesive focal plane (in contrast to stereoscopic pairs) across the viewing field to provide a curved ~4X lateral expansion of the virtual image compared to the aperture. The result is that the viewer's eyes accommodate a farther depth while simultaneously seeing a large field of view.

FECs are non-resonant optical cavities that sample the light in large space intervals and provide depth corresponding to a wavefront that is about 100X more precise than existing stereoscopic displays. Unlike spatial light modulators

(SLMs) or (auto)stereoscopic systems, FECs do not rely on projection techniques, avoid diffractive artifacts, and experience no cross-talk or aberration effects. Avoiding refracting optical elements (e.g., lenses), the FEC mitigates optical aberrations—coma, astigmatism, and chromatic aberration—and can surpass limitations of wearable devices (Heshmat, 2019).

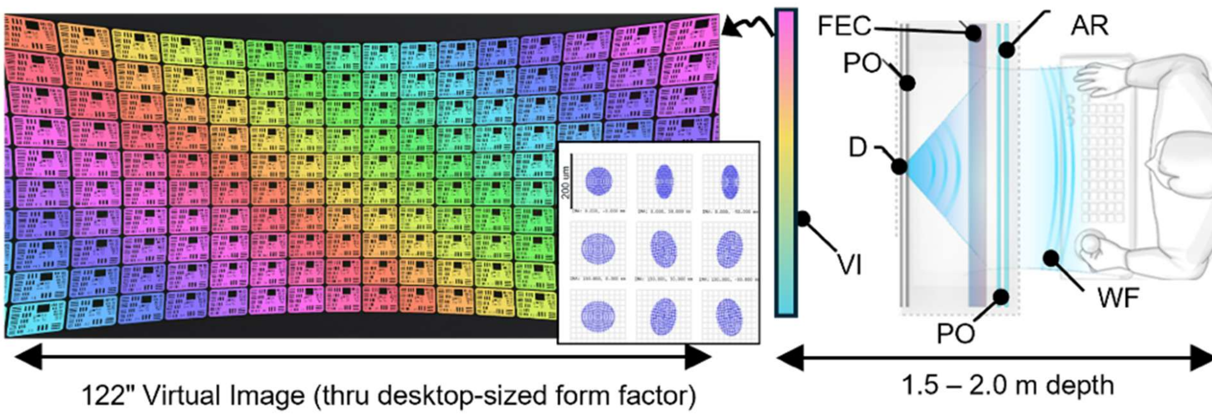


**Figure 2. Schematic diagram of Ultra Reality (UR) technology. A seed display (D) emits light through a field-evolving cavity (FEC), which evolves the wavefront (WF) and optically pushes the light farther from the trainee. Profiling optics (PO), including ambient reflectivity (AR) reduction layers, optimize brightness and visibility. The virtual image (VI), here, a colored 1951 Air Force Resolution chart, spans 122″ with minimal aberrations (inset).**

UR's optical architecture begins with the constraint that the monocular and binocular depth cues must agree with each other for a comfortable viewing experience and a sensation of immersion (Heshmat, 2020). This varying optical depth brings more natural realism and a sensation of 3D from the 2D content, especially for simulation training content, which benefits from depth and panorama. UR jointly optimizes depth cues based on the human vision system (HVS), and the angular and depth profiles are identified (Figure 3a) and curved in such a way to follow the human "horopter" (Figure 3b,c). A horopter is a locus or surface whose points form an image on corresponding parts of the retinas. Intuitively, both eyes perceive a given point on the horopter as being at the same location in space, so it is required to create a single, fused image for binocular depth perception. More generally, there is a volume, Panum's fusional area, that contains the horopter. The HVS will fuse the retinal images of points within this volume to perceive binocular depth. Panum's fusional area depends on several factors, including the depth from the viewer, the viewer's visual acuity, and even on the content itself. Thus, the visual field of UR-based content closely aligns with natural and comfortable human perception.

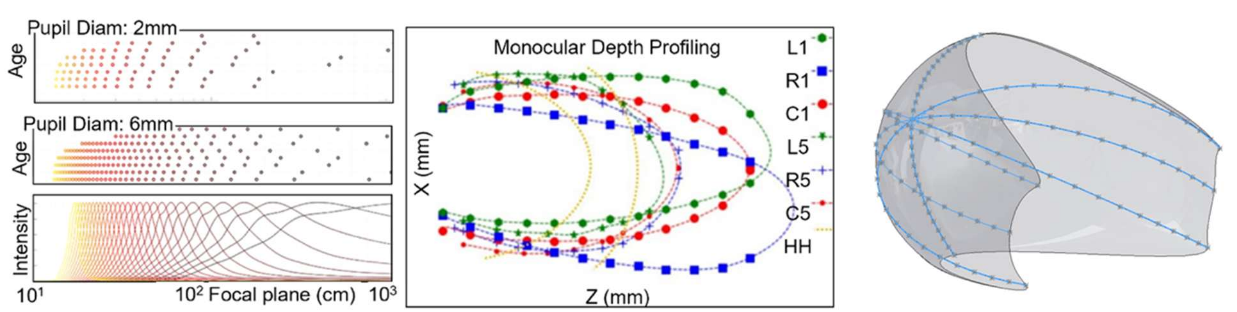


**Figure 3. Depth and horopter profiling for optimal immersion. Left: Quantized monocular distinguishable focal planes with age and pupil diameter variations for (top) 2 mm pupil size, and (middle) 6 mm pupil size. Colorbar: total eye diopter (60 D from a relaxed eye, plus accommodation power). Bottom: Depth of field profiles for a pupil diameter 6 mm and age 30. (Adapted from (Aghasi et al., 2019).) Center: Point-cloud data for optimized monocular depth (true-depth) profile of UR displays recreating the human horopter (H) for visual ergonomics. Each curve corresponds to different left/right/center iteration number. Right: Horopter generated by point-cloud data. The curved focal plane balances psychological and physical fidelity.**

**Analysis as Compared to Flat-Panel Screens**

In comparison with flat-panel screens, effectively, UR redistributes pixels over a large area of a virtual image while keeping the viewing distance fixed. This enables high-resolution image quality (optimal pixel efficiency) without the viewing distance limitations of flat displays. This optical architecture gives rise to a pixel efficiency metric, which is a function of display resolution and size. Figure 4 compares the pixel efficiency of UR versus standard flat panel screens at three different resolutions (1080p, 4K, 8K) and three different sizes (24″, 32″, 64″). The optimal (maximum distinguishable density) pixel efficiency assuming perfect 20/20 vision corresponds to ~60 pixels/degree, which sets the upper bound as the optimal threshold. Note that for each of the different sizes and resolutions of traditional screens, there is only a single optimized viewing distance/resolution, whereas UR lies on the optical threshold line itself. This is because, in contrast to standard monitor technologies, the trainee does not need to change the physical distance between himself and the display as a function of the resolution being used. Similarly, unlike autostereoscopic displays, whose fixed resolution is always a trade-off between angular and spatial resolution, UR displays provide full resolution of the seed display panel at all viewing angles.

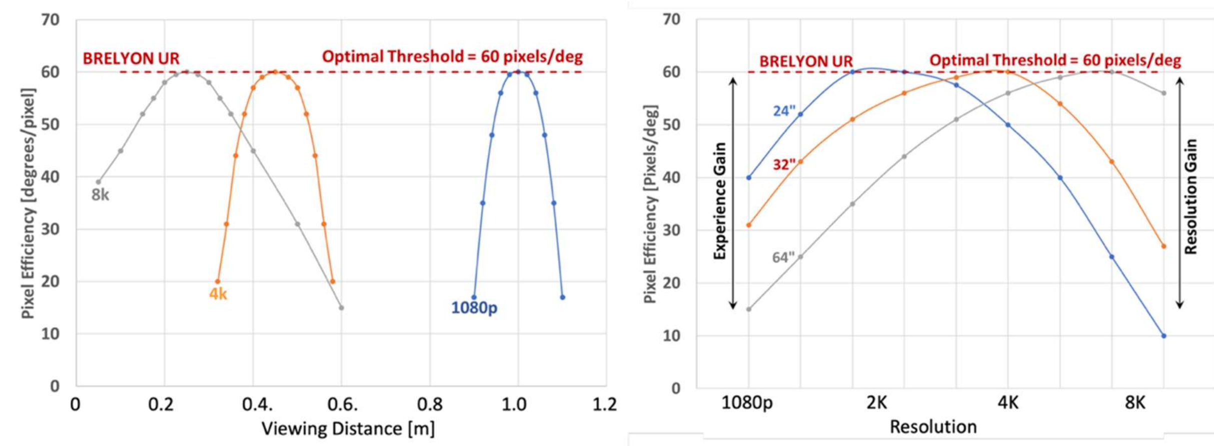


**Figure 4. Pixel efficiency as a function of (left) viewing distance and (b) display resolution. Brelyon UR does not require the viewer to physically change viewing distance to the monitor for different resolutions. UR always lies on optimal threshold line, agnostic of design resolution, as contrasted with flat screens.**

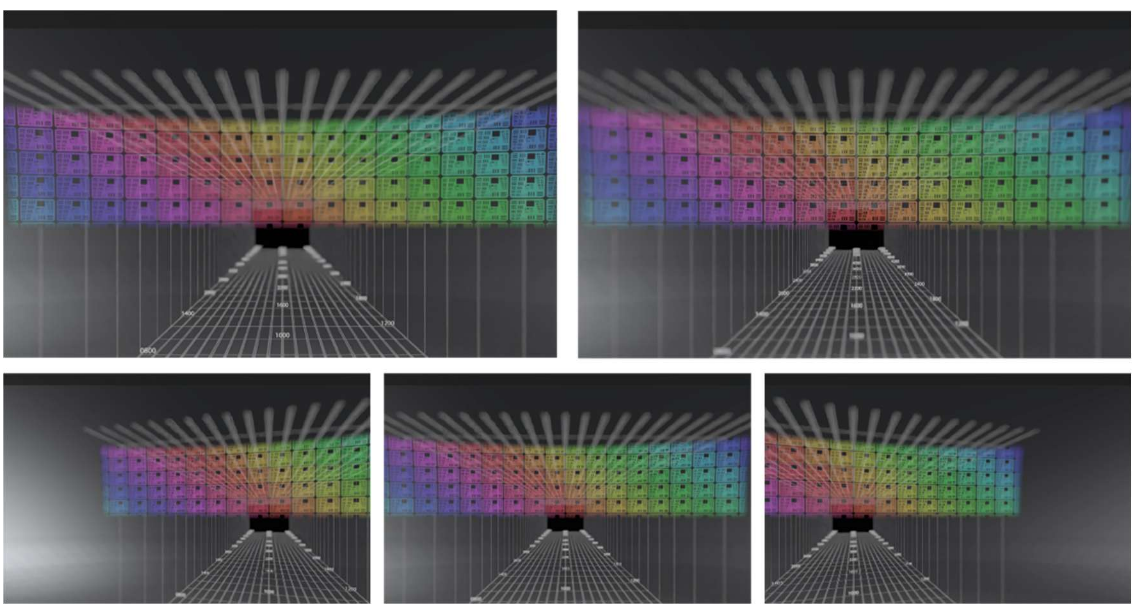

**Figure 5. VRED Renderings of virtual image as viewed through UR. Top row: image perceived as the focus is swept in depth, including closer (left) and farther (right) focusing. Bottom row: 110° field of view as the viewer's eye is rotated from left to right.**

Simulation results are shown in Figure 5. The UR optical subsystem was generated in Autodesk's VRED prototyping software, and the light rays were rendered to generate the perceived image. The top row of Figure 5 shows renderings for two different focal planes, respectively showing the periphery and the central region in focus. This demonstrates that the actual virtual image focal plane is not flat, but, rather, curved, with the central region optically deeper than the sides. The bottom row of Figure 5 shows the perceived image at three different viewing angles, demonstrating the wide field of view (FoV).

## METHODS

Two main assessments were conducted. First, Brelyon's partners at Lufthansa Aviation and Training (LAT) assessed UR for its flight simulation and training capabilities by incorporating the unit into its systems, led by pilot Felix Ehrentraut, Manager of Innovation and Flight Simulation Special Projects. The goal of the assessment was to determine which of UR's seminal design parameters would need upgrading to meet regulatory requirements (anticipating European potential regulation modulations at the time of testing). The test environment consisted of replacing the original cylindrical projection wall solution with UR in a Diamond FNPT II-MCC simulator configured for a Multi Engine Piston (DA-42 FNPT) (Figure 6, top row, second from the right). X-Plane 12 was used as a commercial off-the-shelf (COTS) image generator (IG), while the flight model remained on the original Diamond software. X-Plane's UDP interface enabled communication of situational parameters position, orientation, date and time, weather, and aircraft light's state. UR was mounted on a moveable steel frame with adjustable transverse/longitudinal positioning and tilt to test several distances and orientations. Perception-based/subjective evaluation results of FOV, image depth, and immersion were evaluated with varying distances and orientations.

Second, Cayman Airline studies were performed by three individuals, led by Kel Thompson, Commercial Airline Pilot and Instructor Pilot, and included an experienced pilot and trainer, a newly retired pilot, and a newer pilot. Each graded different simulation training platforms, and results were combined by an unweighted average (AV). Ergonomics (E) was measured by the duration when eye fatigue and strain required pausing the simulator. Image fidelity and realism (I) was measured by touchdown accuracy during landing (having a target 150 feet before touchdown). Aircraft handling (AH) was evaluated during a 60° turn bank and evaluating the time to achieve the turn. The instructional tool capacity (ITC) was a subjective measurement performed by assessing visual, equipment, cognitive, task and functional fidelity during flight. All scores were graded relative to a physical Boeing 737 aircraft.

## EMPIRICAL RESULTS

Using the above methods, UR models were introduced to end users for evaluation in various evaluation testing sites in various configurations (Figure 6), including integration into a larger simulator, bundling with COTS instrumentation and synthetic content, and standalone desktop solutions in both commercial and federal (USAF) environments.


**Figure 6. User evaluations testing of Ultra Reality flight simulator including COTS instrumentation and integration into larger flight simulator hardware. Systems integrations include COTS instrumentation (instrumentation cluster, yoke/throttle, etc.), FFSs, and pre-existing synthetic content.**

The LAT/UR-based flight simulator tested capabilities in comparison to full flight simulators (FFSs). FFS A/B configurations were deemed acceptable without any upgrade requirement to satisfy the associated regulations. To satisfy the requirements for the FFS C/D and FNPT II flight simulator configurations, two hardware upgrades would be required. First, for the FFS C/D case, the horizontal FoV of the UR display would need to supersede a 176° specification, beyond the current 110° specification, which is technically feasible. Second, to satisfy the requirements to provide a training solution for the FNPT II configuration, the optical depth modulation of the UR display would be required to span from 6-10 m, increasing this range from the current configuration of 1.4-2.5 m. Results are summarized in Table 1.

**Table 1. Summary of compliance standards and upgrade requirements for UR integration into various flight simulator systems.**

| FTSD TYPE | STANDARDS | COMPLIANCE / UPGRADE REQUIREMENT |
|---|---|---|
| FFS A/B | "Continuous minimum collimated visual FoV of 45 degrees horizontal and 30 degrees vertical FoV simultaneously for each pilot." | COMPLIANCE: "SOC is acceptable in place of this test."<br>UPGRADE REQ: None. |
| FFS C/D | "Continuous, cross-cockpit, minimum collimated visual field of view providing each pilot with 180 degrees horizontal and 40 degrees vertical FoV. Application of tolerances require the FoV to be not less than a total of 176 measured degrees horizontal field of view (including not less than ±88 measured degrees either side of the centre of the design eye point) and not less than a total of 36 measured degrees vertical FoV from the pilot's and co-pilot's eye points." | COMPLIANCE: "Consideration shall be given to optimizing the horizontal/vertical FoV for the respective airplane cut-off angle."<br>UPGRADE REQ: Increase FoV in horizontal direction to be > 176°. |
| FNPT II | "A visual system (night/dusk or day) capable of providing a FoV of a minimum of 45 degrees horizontally and 30 degrees vertically, unless restricted by the type of aeroplane, simultaneously for each pilot, including adjustable cloud base and visibility." | COMPLIANCE: "The visual system need not be collimated but shall be capable of meeting the standards laid down in Parts (b) and (c) (Validation, Functions and Subjective Tests - See AMC1 FSTD(A).300). SOC is acceptable in place of this test."<br>UPGRADE REQ: Increase optical depth from 2.5 m to 6-10 m. |

Next, Brelyon's partners at Cayman Airways assessed the flight simulator efficacy relative to the two different solutions currently being used: an FFS and a large format curved display-based solution. The goal was to gain access to a higher efficacy training solution than what is being used at the classroom scale (curved monitor solution) to overcome their training pipeline throughput concerns due to the cost and lack of availability of FFSs in Miami. Figure 7 shows images of the platforms considered during this study.


**Figure 7. Comparison of different flight training methods to UR. (a) Physical 737 Max, (b) FFS. (c), (d) UR platform. (e) Samsung 55″ curved monitor.**

The baseline study of the comparative simulator efficacy was performed using a physical Boeing 737 Max aircraft as the “gold standard” and corresponding with an aggregate efficacy score of 100. Three different comparisons were made, leveraging the access and activity with partners at Cayman Airways: a full flight simulator (based in Miami, FL), a UR-based flight simulator, and a large, curved monitor-based flight simulator (55″ curved Samsung curved monitor). The aggregate efficacy scores for each simulator platform were based on the four (4) key metrics, described above and summarized in Table 2. UR scored a 91% average, which exceeds the required baseline score of 90%. Notably, UR has a strong “I” score, indicating that its monocular depth is beneficial for depth discernment during landing exercises. Only its ITC score is lower than the curved monitor. Further testing is necessary to determine whether this may be due to the novelty of using the UR platform compared to more common platforms.

**Table 2. Scoring of simulator effective efficacy based on observation of 4 key metrics comparing simulators (full flight simulator, UR-based, and Samsung 55″ curved monitor based) to “gold standard” physical 737 Max aircraft. Metric Symbols. E: Ergonomics. I: Image fidelity & realism. AH: Aircraft handling. ITC: Instructional tool capability. AV: Average. UR technology (91% average) surpasses the required 90% score.**

| | Physical 737 Max | | | | | FFS | | | | | UR | | | | | Samsung | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metric** | E | I | AH | ITC | AV | E | I | AH | ITC | AV | E | I | AH | ITC | AV | E | I | AH | ITC | AV |
| **Score** | 100 | 100 | 100 | 100 | **100** | 94 | 96 | 96 | 93 | **94.75** | 90 | 95 | 90 | 89 | **91** | 81 | 71 | 86 | 90 | **82** |

## BROADER IMPACT & FUTURE WORK

UR is designed to support immersive content and long interaction times with lower technical overhead. The underlying reason can be understood through analysis of depth perception itself. To mimic true volumetric depth in a virtual display system—with both stereoscopic and monocular cues—over 1700 stereoscopic depth levels, whereas only seven monocular depth levels, optimally distributed from 25 cm to infinity, are sufficient. Adding more levels offers negligible perceptual improvement (Aghasi et al., 2019). This suggests that immersion through monocular depth programming has fewer technical constraints, whereas stereoscopic cues effectively require higher bandwidth.

Therefore, it is worthwhile to explore how UR may address several capability gaps in different use cases, specifically those where the operator must interact with large swaths of visual data in high-precision tasks:

1. Mitigating CL in C2 configurations: Extended screen use causes visual fatigue (Rosenfield, 2011)—with closer standoff distances exacerbating asthenopia symptoms (Sheedy et al., 2023)—and visual fatigue leads to lower productivity (task completion rate) in cognitively demanding scenarios (Beeson et al., 2024). Although the exact causal relationships between visual fatigue, cognitive load, and display ergonomics is an open question, reduced eye strain may mitigate CL and improve operator effectiveness.
2. Increasing visualization capabilities while reducing size, weight, and power (SWaP) constraints in tactical vehicles: There is a growing need for greater visual information access while minimizing SWaP budgets for vehicular computational systems (Lafontaine, 2018), but traditional screens increase visual real estate only by simultaneously increasing SWaP. UR generates a 122″ virtual image through a 30″ aperture, providing increased image size in a smaller system and with lower power requirements, offering a potential solution.
3. Increasing situational awareness (SA): Improved visual comfort and (virtual) image size can increase SA for mission-critical operations. In particular, depth-based content provides persistently available data without requiring fixing on the data (Fox and Lehmkuhle, 1978).

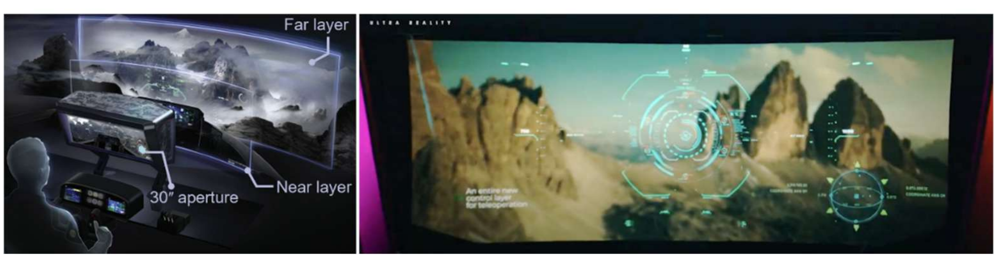


**Figure 8. Dual layer extensions of UR provide multi-depth flight simulation training. Left: Concept rendering showing a synthetic environment on the far layer and HUD content on the near layer. The true-depth (monocular) image content spans a maximum of 122″ and the depth ranges from 70 cm to 2.5 m. Right: Photograph of prototype, focusing on HUD content (in focus), with out-of-focus synthetic environment.**

Future work will leverage multiple layers of depth and generative content. Dual-layer extensions of UR can render imagery at different monocular depths and generates content overlaid on existing video streams, games, and data visualizations (Figure 8). In flight simulation training, with a realistic synthetic environment shown on the farther virtual layer, it can generate, for example, HUD imagery or a digital kneeboard on the closer virtual layer. This functionality provides a path to improve realism and streamline skills transfer.

## CONCLUSION

Addressing the USAF's critical pilot shortage requires scalable, immersive, and physiologically sustainable training methods. Although VR headsets initially appeared promising for enhancing pilot training, their significant drawbacks have limited their effectiveness and accessibility. UR is an alternative immersive technology that avoids headsets and harmonizes monocular and binocular depth cues, reducing eye strain and enhancing both physical and psychological fidelity. Empirical results demonstrate UR's training efficacy and regulatory compliance potential. Importantly, the viewable zone, image size, immersion level, etc., are adjustable with different optical designs. For example, a larger unit can replicate a half-dome simulator while conforming to a desk-sized form factors or be improved using eye tracking methods (Van Benthem et al., 2016) or to train for vection effects (Temme et al., 2024). Therefore, UR has potential to serve as a comprehensive flight simulation platform at all levels of training and complexity.

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