NAVAL AIR WARFARE CENTER
TRAINING SYSTEMS DIVISION
ORLANDO, FL 32826-3275

NAWCTSD-TR-2019-001
30 September 2019
Experimental and Applied Human Performance Research & Development
Technical Report

Student Naval Aviation Extended Reality Device Capability Evaluation

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
	Technical Report	1 October 2018-30 September 2019

4. TITLE AND SUBTITLE

Student Naval Aviation Extended Reality Device Capability Evaluation

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Air Warfare Center Training Systems Division

8. PERFORMING ORGANIZATION REPORT NUMBER

NAWCTSD-TR-2019-001

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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10. SPONSOR/MONITOR'S ACRONYM(S)

PMA-205, ONR, NISE

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

NAWCTSD Public Release 19-ORL082 Distribution Statement A – Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Navy is considering Virtual and Mixed Reality (VR/MR) Part-Task Trainers (PTTs) to supplement existing naval aviation curricula. In support of this initiative, Naval Air Warfare Center Training Systems Division Research Psychologists conducted a device capability evaluation to explore the potential for four VR/MR devices to improve student pilot knowledge and performance. The evaluation included the Pilot Training Next (PTN) T-6B VR-PTTs, two T-45C VR-PTTs, and a Mixed Reality Visual System. In-person and online questionnaires were employed to collect student reaction and simulator sickness data. Although device utilization was infrequent, students reported them as useful for building a sight picture in spite of low realism and clarity. The PTN VR-PTT was reported as useful for Contacts training, while the T-45C devices were reported as useful for Familiarization and multiple stages of Formation. Data from the students' training events in the aircraft served as performance measures. T-6B VR-PTT usage was not associated with performance, but there were positive relations between T-45C device usage and performance. Simulator sickness returned to baseline levels within one hour after usage. Detailed VR/MR training implementation

15. SUBJECT TERMS

virtual reality, mixed reality, aviation, training, evaluation

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					19b. TELEPHONE NUMBER *(Include area code)*

Reset

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1. Acknowledgments

For acquiring the funding, coordinating across CNATRA, scheduling and supporting data collection, and providing needed expertise, we thank the following individuals:

PMA-205
CAPT Jason Lopez
CAPT Lisa Sullivan
CDR Chris Foster
LT Joseph Mercado
Michael Kennedy
Joseph Bell III

Office of Naval Research
LCDR Peter Walker

NISE 219
Dr. James Sheehy

Naval Air Warfare Center Training Systems Division
CAPT Timothy Hill
CDR Henry Phillips
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Dr. Heather Priest-Walker
Mark Thailing
Dr. Robert Seltzer
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Ronell Arceneaux
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2. Executive Summary

2.1. Problem, Objectives, and Organization

As stated in RADM Harris's letter outlining his vision for the utilization of emerging simulation technology, The Chief of Naval Air Training (CNATRA) is exploring the potential for Virtual and Mixed Reality (VR/MR) Part-Task Trainers (PTTs) to supplement the existing curriculum. In support of this initiative, Naval Aviation Training Systems and Ranges Program Office / Air Warfare Training Development (PMA-205 / AWTD), the Office of Naval Research (ONR), and Naval Innovative Science and Engineering (NISE)/ Section 219 sponsored an effort to design and execute a Training Effectiveness Evaluation (TEE) of three Virtual Reality (VR) PTTs and one Mixed Reality (MR) visual system across several CNATRA locations. Typically, a TEE involves a controlled study in which participants in the experimental group are assigned to a formal training intervention. This intervention contains the same content, delivery of instruction, training duration, and feedback across all participants in the same group. However, CNATRA was interested in the capability of the systems to train certain stages of the syllabi. To gather as much feedback on the utility of these devices, CNATRA wanted all students to have equal access to the training devices, regardless of their level of advancement in the training pipeline. Because instructor resources are limited, formal scenarios, instructor briefing, and performance feedback were not present for the VR-PTTs; therefore, students who used the devices engaged in free play or self-guided study. Due to the limitations on this study, a typical TEE was not conducted. Instead, the research team considers this study to be a device capability evaluation (DCE). The goal of this evaluation was to begin to answer the following research questions, which are based on Kirkpatrick's Learning Levels (Kirkpatrick, 1976):

Research Question 1 (**REACTIONS):** *To what degree do trainees and instructors react favorably to the devices?*

Research Question 2 (**LEARNING):** *To what degree do trainees acquire intended knowledge, skills, and attitudes based on their experience in the devices?*

For this level, the research team had three specific hypotheses on how these devices would influence outcomes.

> H2a: *VR/MR device usage is expected to have a positive relation with performance in the aircraft (Navy Standard score, re-flys, marginals, unsatisfactories, raw scores on events, and events to meet Maneuver Item File).*
>
> H2b: *Student Naval Aviator (SNA) performance is expected to differ among the three VR-PTT devices access conditions (e.g., no access, access for part of training, and access for entire training).*
>
> H2c: *Type of use (i.e., purpose of the VR-PTT session) will be associated with performance in the aircraft.*

Research Question 3 (**BEHAVIOR):** To what degree do trainees apply what they learned in the device to the operational environment?

Research Question 4 (**RESULTS):** To what degree do the targeted outcomes occur as a result of learning and reinforcement? What is the impact on CNATRA?

Research Psychologists from the Naval Air Warfare Center Training Systems Division (NAWCTSD), in collaboration with CNATRA and Aerospace Experimental Psychologists (AEPs), conducted an 8-month evaluation in FY19 of the T-6B (NAS Corpus Christi and NAS Whiting Field) and T-45C (NAS Kingsville and NAS Meridian) Extended Reality (XR) training platforms.

2.2. Method, Assumptions, and Procedures

NAWCTSD Research Psychologists, CNATRA, and PMA-205 collaborated on the experimental design of this evaluation. This DCE featured both quantitative and qualitative analyses. The goal of the qualitative feedback was to collect data from users related to a) strengths and weaknesses of the devices for training purposes, b) improvements that could be made to the devices to increase their training utility, and c) when and how the devices should be integrated into the training curriculum. During the course of the data-collection period, no official changes were made to the training syllabus to accommodate the devices being evaluated. Students used and provided feedback on the devices outside of the regular training syllabus schedule.

The research team collected feedback from 966 unique users across the four different devices: 1) Bohemia T-45C VR-PTTs, 2) Bohemia T-45C Mixed Reality Visual System (MRVS), 3) T-45C 4E18 VR-PTTs, and 4) T-6B Pilot Training Next (PTN) VR-PTTs. For in-person data collection, participants used an XR device for approximately 1 hour. Afterwards, researchers collected data via a comprehensive questionnaire (n = 304) regarding usability and training utility. Additionally, subsets of participants completed questionnaires regarding simulation sickness (pre- and post-session), automation use, trust in automation, virtual limb ownership (the feeling that virtual limbs belong to the user) and aesthetics. All other SNAs who used the XR training devices (n = 375) were requested to complete online or paper session logs. To conclude data collection, the team deployed an online wrap-up questionnaire (n = 503) to capture responses from a larger proportion of the current training cohort. In-person focus groups were conducted with instructors and stakeholders to gain additional insights on training applicability, improvements needed, and implementation strategies. It is important to note that some users participated in multiple data collection sessions (e.g., completed in-person and online flight logs) and therefore are represented in more than one n group.

Researchers examined the effect of XR system usage on performance using data derived from the Training Integration Management System (TIMS). The goal of using quantitative performance data was to measure the effects of device usage on student pilot performance in the aircraft. This was accomplished by comparing event raw scores and counts of poor performance events between participants who reported that they did or did not use the XR devices.

2.3. Results and Conclusions

2.3.1. Qualitative Results

T-6B and T-45C VR-PTTs

The qualitative analysis indicated that students and instructors see some potential benefits in some or all of the devices evaluated during the device capability evaluation (DCE). A common strength reported for all the devices was the ability to build a sight picture when preparing for upcoming events (*n* = 245 responses). Additionally, the 360° field of regard allows for more realistic visual scan not currently possible in the Operational Flight Trainers (OFTs; *n* = 61 responses). Finally, the ability to conduct networked flight was a notable strength for the VR devices (*n* = 35 responses). One limitation of the devices was the lack of visual clarity inside the cockpit (*n* = 200). While this is likely a limitation of current headset technology, it does reduce the ability of students to practice instrument flight with the devices. Another limitation for the VR devices was the unrealistic behavior of the controls (e.g., commercial off-the-shelf stick and throttle, Leap motion; *n* = 138). An inaccurate flight model was reported to be a weakness in the VR devices as well (*n* = 94). Overall, the devices could provide some training utility in their current state. Recommended upgrades and modifications should be explored to further enhance the training utility of these devices.

T-45C BISim MRVS

Participants reported having the controls and feel of the realistic OFT cockpit to be the primary strength of the T-45C BISim MRVS. The 360° field of regard was also considered to be a strength, as it allowed SNAs to maintain visuals of an artificial intelligence (AI) lead aircraft and the virtual environment (*n* = 6). Weaknesses of the MRVS included the narrow field of view and the low-resolution peripheral vision (*n* = 31) provided by the Varjo headset. Because of the narrow field of view, some participants reported that the MRVS required exaggerated head motion to complete their routine visual scan (*n* = 18). Low acuity in the cockpit video pass-through additionally made indicators difficult to read (*n* = 17).

2.3.2. Quantitative Results

Training Evaluation Level 1: Reactions

From the comprehensive questionnaire, overall positivity, training utility, usability, visibility, and realism subscales were calculated; reaction scores on these subscales tended to center around neutral reactions, indicating no strong opinion or divided opinions. Of all of the systems, the T-45C 4E18 VR-PTT was favored in overall positivity, training utility, and visibility. The PTN T-6B VR-PTT was favored in usability, and the MRVS was favored in realism. Among participants at NAS

Kingsville, the majority stated that they preferred not using any of the VR/MR devices. Participants who had their own VR devices preferred to use their own over the VR/MR devices used in this DCE.

The T-6B PTN VR-PTT was considered most useful for Contact practice, while the T-45C VR-PTTs were generally reported as useful for Familiarization, Formation, Tactical Formation, and somewhat for Basic Fighter Maneuvering stages of the syllabus. The T-45C BISim MRVS was reported as useful primarily for Familiarization and Formation stages. Building a sight picture was the highest reported potential use for both T-6B and T-45C devices. The T-6B PTN VR-PTT was also considered useful for practicing flight training instruction (FTI) procedures and building situational awareness when networked with another SNA. The T-45C BISim VR-PTT was reported to be useful for understanding aircraft positioning in joint flight operations. The research team cautions against planning to use the VR/MR devices for practice in stages beyond those mentioned above.

Training Evaluation Level 2: Learning

Performance data from the Training Integration Management System (TIMS) were provided for 357 of the SNAs who participated in the DCE (out of 902 requested). The T-45C and T-6B are training aircraft, and therefore performance within the T-45C or T-6B is more closely related to learning than it is to behavior within the operational environment. Thus, performance data were considered representative of Kirkpatrick’s Learning level of evaluation, which refers to the degree to which skills have been improved. They are less applicable to Level 3, Behavior, which refers to the degree to which the learned skills are applied (Kirkpatrick, 1976). The research team hypothesized that usage of the VR/MR devices would have a positive impact of performance in the aircraft. For the T-6B devices, there was no significant relation between device usage and aircraft performance (i.e., counts of events that indicate poor performance), although event raw scores and Maneuver Item File (MIF) data were not available.

Participants who reported using the T-45C devices had fewer poor performance events and fewer re-flys in the Formation chapter of the syllabus than participants who reported not using the devices. They also had fewer marginal flights overall. Additionally, participants who used the T-45C devices had higher event raw scores (i.e., better performance) in the Formation and Strike stages, as well as the total Formation chapter. Finally, participants who used the devices required fewer events to meet MIF (a minimum required score to advance) in the Instruments chapter. Therefore, the available evidence suggests that VR/MR device usage may be associated with improvements in aircraft performance.

XR system usage was low overall, with almost all participants stating they used them once per week or less, and the majority stating that they never used the systems. For participants who did use the XR systems, the mean usage time was approximately 3.5 to 6.5 hours across the 8-month study duration for each training wing. Thus, usage was infrequent, brief, and limited to a small subset of potential users. Mandatory compliance and incorporation into the curriculum could increase usage of the devices and associated performance changes.

Training Evaluation Level 3: Behavior

The evaluation period did not cover enough time to collect data on performance within aircraft in the operational environment (e.g., F-18, E-2, EA-18G). As a result, the research team could not directly measure long-term behavior changes as a result of exposure to the XR systems. Conclusions from Level 2: Learning suggest performance improvements are associated with usage of the XR devices, but it is not yet known if these improvements will generalize to the operational environment. Future research could address behavior by comparing operational performance in graduates who had access to XR systems throughout their training pipeline to those who did not have access to XR systems. This would require a longer evaluation period (i.e., a longitudinal study).

Training Evaluation Level 4: Results

As with Behavior-level results, the evaluation period did not cover enough time to collect data on the XR devices’ impact on CNATRA. The Learning-level data for the T-45C devices, showing a reduction in reflys and events to meet MIF, may indicate that the devices could reduce training costs and shorten the training pipeline. However, analyzing longer- term trends in training costs and training pipeline durations was outside the scope and timeline of the current evaluation.

Simulator Sickness

Although simulator sickness is generally a minor issue in commercial VR headsets, it is still a concern for pilot safety because of its potential to reduce a person's ability to operate an aircraft. Simulator sickness in student pilots could lead to required downtime for recovery. In turn, downtime requirements could increase the length of the training pipeline, thereby increasing training costs. Slight simulator sickness occurred for all XR systems, although it returned to baseline levels within 30 minutes after exposure for the T-45C 4E18 VR-PTT and T-6B PTN VR-PTT, and within one hour for the BISim systems. No participants reported delayed or relapsed simulator sickness. However, this result is based on self-report data, and further research is needed using physiological data to confirm or disconfirm the current results.

All three simulator sickness subscores (oculomotor symptoms, disorientation, and nausea) increased from baseline immediately after exposure to the VR/MR devices, but simulator sickness was primarily driven by oculomotor and disorientation scores. This result may indicate that future VR headsets with improved visuals will mitigate simulator sickness.

Simulator sickness was negatively associated with perceived usability. Given that perceived usability is known to affect intentions to use a system (Venkatesh & Davis, 1996), reducing simulator sickness may be important to increase utilization of the XR systems.

2.4. Recommendations

Recommendations provided in this report include hardware upgrades, software upgrades, and curriculum implementation. The primary hardware component that should be addressed is the lack of visual clarity in the cockpit. This limitation significantly reduces the training utility of these devices for any training event requiring use of the instruments and cockpit displays. Given that this is likely a limitation of current headset technology, investment should be made in exploring and developing improved headset capabilities. Currently, visual engineers from NAWCTSD are involved in market research to develop a novel AR/VR/MR headset that provides full-motion tracking with enhanced visuals that minimize any impacts to human-factors qualities. This headset will also allow for joint flight capabilities. Additionally, the visual engineering team is developing techniques and tools to measure performance of near-eye display systems. With these efforts and in conjunction with industry partners, the limitations of current XR headsets are being explored to improve their capability for naval aviation training.

The primary software component that should be addressed is the flight model for both the T-6B and T-45C aircraft. While not severe, the slight inaccuracies in aircraft behavior significantly reduce the training utility of these devices beyond simply building a sight picture. If the goal is to learn and practice aircraft maneuvers in the device, then the aircraft behaviors should match what would be expected in the aircraft. Lastly, focus groups conducted with instructor pilots from several CNATRA training wings provided insight into where and how these devices should be implemented into the training curriculum. These recommendations are outlined in detail in Section 7 of this report and Appendices 10.1. and 10.2.

3. Introduction

3.1. Problem

The Navy, Air Force, and Marine Corps all currently suffer from an increasing shortage of pilots, with a 26% shortage in first-tour Navy fighter pilots as of 2017 (United States Government Accountability Office, 2018). This shortage indicates a need to increase training pipeline throughput to mitigate the gap. At the same time, downward pressure on training and procurement budgets restricts the ability to increase instructor availability, to expand access to high-cost and high-fidelity simulators, and to provide more aircraft for training (e.g., Sanders, 2017).

Thus, the Navy and other branches of the military need a way to expedite new pilot training without reducing pilot performance standards. Extended reality (XR) may offer a partial solution, as some Virtual reality (VR), Augmented Reality (AR), and Mixed Reality (MR) systems can be acquired, maintained, and operated for relatively low cost. However, questions remain regarding the ability of VR/MR devices to improve student pilot performance and reduce the need for live flights. Thus, Chief of Naval Air Training (CNATRA) and Naval Aviation Training Systems and Ranges Program Office (PMA 205) are seeking information on how student pilots' performance change when given access to relatively low-cost VR/MR flight trainers.

3.2. Objectives

The purpose of this study was to assess the impact of XR on Student Naval Aviator (SNA) training performance outcomes. Specifically, the research team evaluated three Virtual Reality Part-Task Trainers (VR-PTTs) and one Mixed Reality Visual System (MRVS) on student performance in Primary, Intermediate Jet, and Advanced Strike training. Part-task trainers allow student pilots to practice specific subtasks (e.g., a portion of a flight) in isolation (Teague, Gittelman, & Park, 1994). The VR-PTTs in the current evaluation gave pilots a new means of practicing subsets of skills such as formation flight skills. The MRVS integrated with the 2F138D Operational Flight Trainer (OFT) to provide enhanced visuals compared to the traditional OFT screens. The OFT can be viewed as a PTT as well; the MRVS is differentiated here from the VR-PTTs because it specifically serves to add mixed reality visuals to an existing training system. To gain a comprehensive understanding of how these devices will impact training, researchers analyzed quantitative training performance data that were derived from the Training Integration Management System (TIMS). Using archival data from TIMS, performance data were compared to the amount of XR system usage. The researchers collected qualitative feedback on the devices usability, training utility, and simulator sickness severity and duration. Insights gathered from the data informed recommendations on hardware and software upgrades, curriculum integration, and implementation strategies.

3.3. Background

Extended Reality (XR)

Extended Reality is the umbrella term that covers the spectrum between all real and virtual combined environments and human machine interactions generated by computer technology and wearables (Milgram, Takemura, Utsumi, & Kishino, 1994). Within this spectrum, there is virtual, augmented, and mixed reality. All of these immersive technologies extend the reality we experience by either blending the virtual or “real” worlds or by creating a fully immersive experience.

Although the definition of VR varies widely between sources, it is frequently defined as the use of computerized displays and controls to present a 3-dimensional world in which interactions with objects are relatively naturalistic compared to non-VR systems (e.g., Gregory, 1991; Krueger, 1991; Taupiac, Rodriguez, & Strauss, 2018). For the purposes of this report, the research team adapted the previous definition to define VR as a 3-dimensional world presented via Head Mounted Displays (HMD), which enables interaction with at least some components of the virtual display. VR completely replaces the real-world environment with a simulated environment. The majority of the systems evaluated for this study are considered virtual reality part-task trainers.

According to Milgram et al. (1994), Augmented Reality (AR) is defined as “augmenting natural feedback to the operator with simulated cues” (p. 284). Essentially, AR consists of virtual objects overlayed onto the real-world environment (Milgram & Kishino, 1994). As compared to virtual reality, which is entirely simulated, AR has a fixed real environment with a layer of virtual enhancements.

Mixed reality (MR) is defined as "an environment…in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extrema of the RV continuum" (pg. 283, Milgram et al., 1994). In other words, an individual can interact with real and virtual objects within the

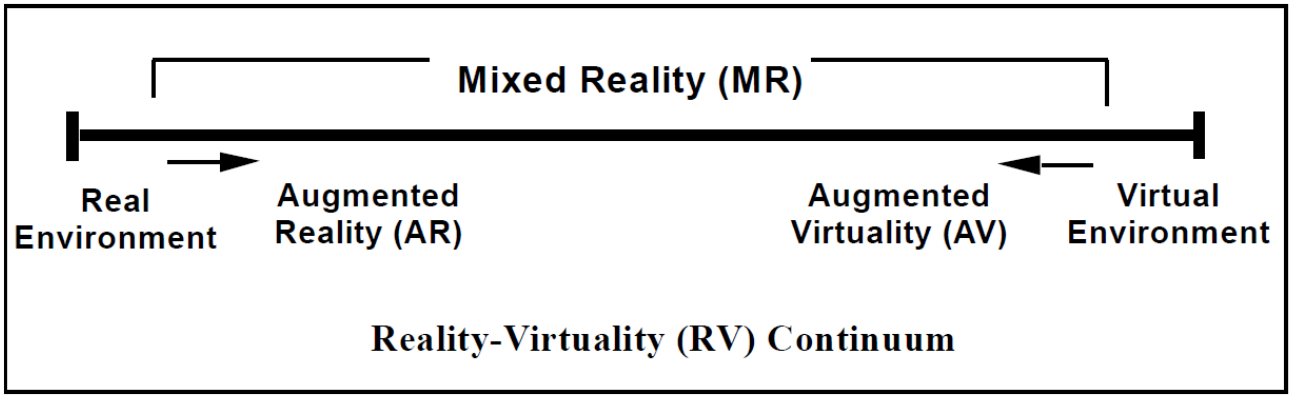

Figure 1. Simplified Representation of RV Continuum (Milgram et al, 1994)

same environment simultaneously. The differentiation between AR and MR is that in AR, the virtual and real objects do not interact with each other to create one seamless environment. In MR, a user experiences a completely blended environment as the virtual objects are anchored in the real environment. The cited researchers further distinguish types of MR, of which one describes the Mixed Reality Visual System (MRVS) device: HMD/computer-generated (CG) environment with video overlays (See Figure 1).

Potential Benefits of Extended Reality

The above definitions imply a number of potential advantages over live flights and large-scale Operational Flight Trainers (OFTs) if the goal is to expedite pilot training while remaining within the constraints of a tightening budget. The first advantage is the use of Commercial Off-The-Shelf (COTS) hardware in small-scale extended reality (XR) systems. The up-front cost of COTS hardware tends to be lower than tailored hardware designed specifically for the training system (Stone, 2008). This could reduce maintenance costs by decreasing the cost of replacement parts. In addition, widely available COTS components could be relatively easy to acquire or repair compared to tailored hardware, reducing system downtime for maintenance, and thus, increasing availability of the systems for student use. Increased system availability provides the potential for either increased volume of training per student, or increased volume of students trained.

The second potential advantage is a reduction of instructor-student ratio needed for effective training. The Department of the Air Force stated that past experience indicates the possibility of using a single instructor for four VR systems. In combination with greater system availability compared to live flights, which could decrease training time by as much as 28%, this creates the potential for up to a 97% increase in training throughput (Department of the Air Force, 2018). The current evaluation emphasized student-led learning in the absence of formal instruction, (e.g., using VR systems to prepare for their next event or to practice skills on which they received feedback during instructor-led training). The use of XR devices could allow for training more students, and with programmed virtual instruction and feedback, students could still attain expected training performance. This could increase availability for instructors for aircraft training and decrease training costs.

The third potential advantage is a smaller simulator footprint, requiring less space to house each XR headset system compared to either a live aircraft or a large-scale OFT. The smaller dimensions of the systems provide two benefits. First, housing costs can be reduced by minimizing the square footage needed and avoiding the need for special housing with high ceilings and large open spaces. For example, the space required for the VR-PTTs employed in the current report was approximately six feet by six feet of floor space in a room without special ceiling height requirements, whereas the OFTs can require much larger spaces and multistory ceiling heights. Second, a higher number of units can be installed in the same amount of space, increasing the availability of systems for students.

Finally, the fourth possible advantage is the potential for XR systems to enable evidence-based instructional methods for flight training, such as cognitive load management or adaptive training (Department of the Air Force, 2018). The use of high-efficacy training methods could reduce the amount of training time needed to reach proficiency, which could shorten the training schedule. For example, the Air Force has developed the Pilot Training Next (PTN) initiative with the intention of addressing their pilot shortage. The Air Force estimates that, VR simulators could increase training capacity by up to 97%

without increasing the number of instructor pilots (Department of the Air Force, 2018). Thus, COTS VR systems appear to be a promising avenue for addressing the pilot shortages in the Navy, Air Force, and Marine Corps, and warrant further investigation to determine their potential to improve performance outcomes and supplement more expensive training methods.

Importantly, with the benefits detailed above, XR training provides instructional efficacy without sacrificing a highly immersive system. VR headsets such as the Oculus Rift (Oculus VR, Menlo Park, CA), the HTC Vive Pro (HTC, New Taipei City, Taiwan), or Varjo (Varjo, Helsinki, Finland) can be used to provide a 360° three-dimensional visual and auditory display with a wider Field Of View (FOV) than older headsets.

Effectiveness of Virtual Reality for Pilot Training

Research suggests that COTS simulators and VR/MR systems can successfully be used to train conceptual knowledge and motor skills. For example, VR headsets can improve performance on a spatial navigation task better than non-VR training (Regian, Shebilske, & Monk, 1992), can improve knowledge about water movement patterns better than non-VR desktop training (Winn, Windschitl, & Fruland, 2002), and can improve recall of aircraft maintenance procedures better than non-VR desktop training (Bailey, Johnson, Schroeder, & Marraffino, 2017). One feature of VR/MR headsets is the fully immersive visual display. Immersive simulations have been demonstrated to increase learning over low-immersion simulations in the context of medical education (Coulter, Saland, Caudell, Goldsmith, & Alverson, 2007). However, very little research is available to show whether or not VR/MR headset-based systems are effective for training the conceptual and motor skills involved in flying (e.g., Wojton, et al., 2019). Thus, further research is needed to determine if VR trainers using XR headsets and hardware can contribute to successfully expediting pilot training.

Furthermore, although high-fidelity simulations are often assumed to provide higher training value than lower-fidelity simulations, the relationship between fidelity and training outcomes is not entirely straightforward. In some cases, higher fidelity flight trainers degrade or at least fail to improve transfer of training (Lintern, Roscoe, Koonce, & Segal, 1990; Lintern, Roscoe, & Sivier, 1990). Lower-fidelity trainers can help trainees focus on their goals better than high-fidelity trainers (Stone, 2008), and strategically choosing lower-fidelity options, where appropriate, can greatly reduce cost without reducing training effectiveness (Padron, Mishler, Fidopiastis, Stanney, & Fragomeni, 2018). Hence, it is worthwhile to examine how different levels of fidelity (e.g., FOV, quality of visual stimuli, accuracy of flight model) affect pilot training outcomes.

Toward that end, the current evaluation focused on multiple T-45C systems for Intermediate and Advanced Strike SNAs as well as a T-6B VR-PTT for Primary Student Naval Aviators (SNAs). Moreover, to assess whether the VR-PTTs and the MRVS provided a training benefit to the T-6B and T-45C, the research team leveraged Kirkpatrick’s Four Levels of Training Evaluation: 1) Reactions, 2) Learning, 3) Behavior, and 4) Results. *Reactions* measures the degree to which trainees and instructors react favorably to the devices. *Learning* measures the degree to which trainees acquire intended knowledge, skills, and attitudes based on their participation in the device. *Behavior* measures the degree to which trainees apply what they learned in the device to the operational environment. Results measures the degree to which the targeted outcomes occur as a result of learning and reinforcement. To reflect these levels within Kirkpatrick’s model, following research questions and hypotheses were investigated (Kirkpatrick, 1976):

Research Question 1 (**REACTIONS):** *To what degree do trainees and instructors react favorably to the devices?*

Research Question 2 (**LEARNING):** *To what degree do trainees acquire intended knowledge, skills, and attitudes (KSAs) based on their participation in the device?*

For this level, the research team had three specific hypotheses on how these devices would influence outcomes.

> H2a: *VR/MR device usage is expected to have a positive relation with performance in the aircraft (Navy Standard score, re-flys, marginals, unsatisfactories, raw scores on events, and events to meet MIF).*

> H2b: *SNA performance is expected to differ among the three VR-PTT devices access conditions (e.g., no access, access for part of training, and access for entire training).*

H2c: *Type of use (i.e., purpose of the VR-PTT practice session) will be associated with performance in the aircraft.*

Research Question 3 (**BEHAVIOR):** To what degree do trainees apply what they learned in the device to the operational environment?

Research Question 4 (**RESULTS):** To what degree do the targeted outcomes occur as a result of learning and reinforcement? What is the impact on CNATRA?

3.4. Organization of the Report

Section 4 of this report, “Methods, Assumptions, and Procedures,” describes the student pilot sample, the three types of VR-PTTs and one MRVS employed, the design of the study, and the types of data collected. Section 5 describes the results of data collection and analysis; Section 6 provides the Discussion in which more information is presented in context of the research questions. Section 7 is a summary of the Focus Group recommendations to include hardware/ software upgrades, XR implementation strategies, and the T-6 and T-45C curriculum analysis. Section 8 presents the conclusions on the effectiveness of VR-PTTs for improving Primary, Intermediate, and Advanced training performance. The Appendices included in this report provide additional information about the curricula recommendations, full versions of the measures employed, tables of device feedback, and an example VR syllabus.

4. Methods, Assumptions, and Procedures

4.1. Data were collected as part of a training effectiveness evaluation for the benefit of the sponsors of this effort, and was not originally considered human subjects research. However, per the Department of the Navy Human Research Protection Program (HRPP), published data are considered human subjects research. The evaluation was re-submitted to the Institutional Review Board (IRB) Chair at NAWCTSD prior to publication. It was determined to fall under the classification of exempt research and to have met the ethical standards for exempt human subjects research.

4.2. Methods

4.2.1. Participants

This DCE consisted of multiple data collection efforts, including in-person collection of the comprehensive questionnaire responses, online or in-person collection of responses to the flight log questionnaire, a wrap-up survey at the end of data collection, in-person focus groups with CNATRA stakeholders, and use of Training Integration Management System (TIMS) data from former and current trainees.

Requirements for study inclusion were that participants were SNAs, instructors, or pilots at one of the CNATRA locations selected for delivery of VR-PTTs and / or the MRVS (NAS Corpus Christi, Kingsville, Meridian, or Whiting Field). Participation in the study was not compulsory and does not reflect any alterations to the current CNATRA syllabus.

In coordination with the XR points of contact, Operations and Schedules Departments at the various sites, the research team collected responses from 304 participants for the comprehensive questionnaire. The participants included SNAs, Instructor Pilots (IPs) / Pilot Training Officer (PTO), Recently-Winged Pilots, and a Flight Surgeon. SNAs were either in or about to start the Primary curriculum (PTN T-6B VR-PTT) or were in the Intermediate Jet or Advanced Strike syllabus (T-45C VR-PTTs and MRVS). Additional details of the participants can be found in Table 1 below.

Table 1. Comprehensive Questionnaire Participant Details

	SNAs	IPs	Winged	Flight Surgeon	Total
Male	257 (84.5%)	6 (2.0%)	7 (2.3%)	1 (0.3%)	
Female	29 (9.5%)	0 (0%)	0 (0%)	0	
Not Reported	4 (1.3%)	0 (0%)	0 (0%)	0	
Total	290 (95.4%)	6 (2.0%)	7 (2.3%)	1 (0.3)	304 (100%)

On the flight log questionnaire, 375 participants responded, including 374 SNAs and 1 simulator instructor. On the wrap-up survey, 503 SNAs responded. Focus groups were also conducted with numerous Subject Matter Experts (SMEs) across all CNATRA sites.

The above participant data for the comprehensive and flight log questionnaires include those who responded to multiple questionnaires. Across all questionnaires, there were 966 unique participants (i.e., excluding duplicate Department of Defense Identification [DODIDs]), including 958 SNAs or recently-winged pilots, 6 IPs or PTOs, 1 flight surgeon, and 1 simulator instructor. The total data are from 966 participants; however, some SNAs participated multiple times, provided a total 1107 data points. Combining TW4 and TW5 data, the majority of the participation was for the T-6B devices (n = 757). The research posits that because of the visibility of the Air Force’s PTN program, the T-6B leadership was more invested and instructors advocated in exploring its training capabilities. Additional details on SNA participation from each training wing can be found in Table 2.

Table 2. Training Wing Participation

	TW1	TW2	TW4	TW5	Total
Comprehensive	42 (14%)	92 (30%)	62 (20%)	107 (35%)	303 (27%)
Flight Log	12 (4%)	39 (13%)	56 (19%)	194 (64%)	301 (27%)
Wrap-Up	68 (14%)	97 (19%)	235 (47%)	103 (20%)	503 (45%)
Total	122 (11%)	228 (21%)	353 (32%)	404 (36%)	1107 (100%)

Finally, TIMS data were pulled for a subset of active participants (n = 357) in the current evaluation (no gender information).

4.2.2. Materials

Self-report feedback data were collected using three different questionnaires: 1) comprehensive questionnaire, 2) flight log measure, and 3) wrap-up survey. The comprehensive questionnaire was used during in-person data collection sessions to obtain self-report data on user attitudes towards the system, realism, visual clarity, usability, and training utility. Items within the comprehensive survey were similar in nature to the following: “The limited width of view in the VR-PTT compared to the OFT may not allow for training certain tasks” (1 = Strongly Disagree to 5 = Strongly Agree). See Table 3 for measure descriptions.

In addition to the self-report feedback questionnaires, subsets of in-person participants completed secondary questionnaires, which are provided in Appendices 10.3-10.7. A leading concern from CNATRA regarding these devices was examining if XR practice provided any physiological responses that would affect a subsequent flight in the aircraft. Thus, the research team utilized the Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993) before and after use of a XR device (for up to two hours). An example item within the SSQ is “Select how each symptom below is affecting you right now” (1 = *None* to 4 = *Severe*).

Questions about embodiment illusion were also asked as part of the secondary questionnaires. This was of interest because past research indicates that inaccuracies in virtual avatars could have residual effects on training outcomes (e.g., negative training; Toothman & Neff, 2019). Embodiment illusion is defined as when a person’s body part and motion are represented by an avatar in a fully-immersive environment (Gonzalez-Franco & Peck, 2018). Embodiment illusion is affected by the perceived limb ownership. For the current evaluation, limb ownership is defined as the sense that one or both virtual limbs belong to the user. Because the SNAs’ arms and hands were virtually represented by Leap Motion in the BISim T-45C VR-PTTs (i.e., Image 1) and via a video stream in the MRVS, the influence on limb embodiment to other variables (e.g., simulator sickness, positivity toward the systems) was a research objective. To examine if limb ownership was experienced by participants in the two BISim devices, a limb ownership questionnaire was adapted from Gonzalez-Franco and Peck (2018). Items in the limb ownership questionnaire were similar to the following: “The movements of the limb in my field of view did not correlate with the movements of my actual limb” (1 = *Strongly Disagree* to 5 = *Strongly Agree*).

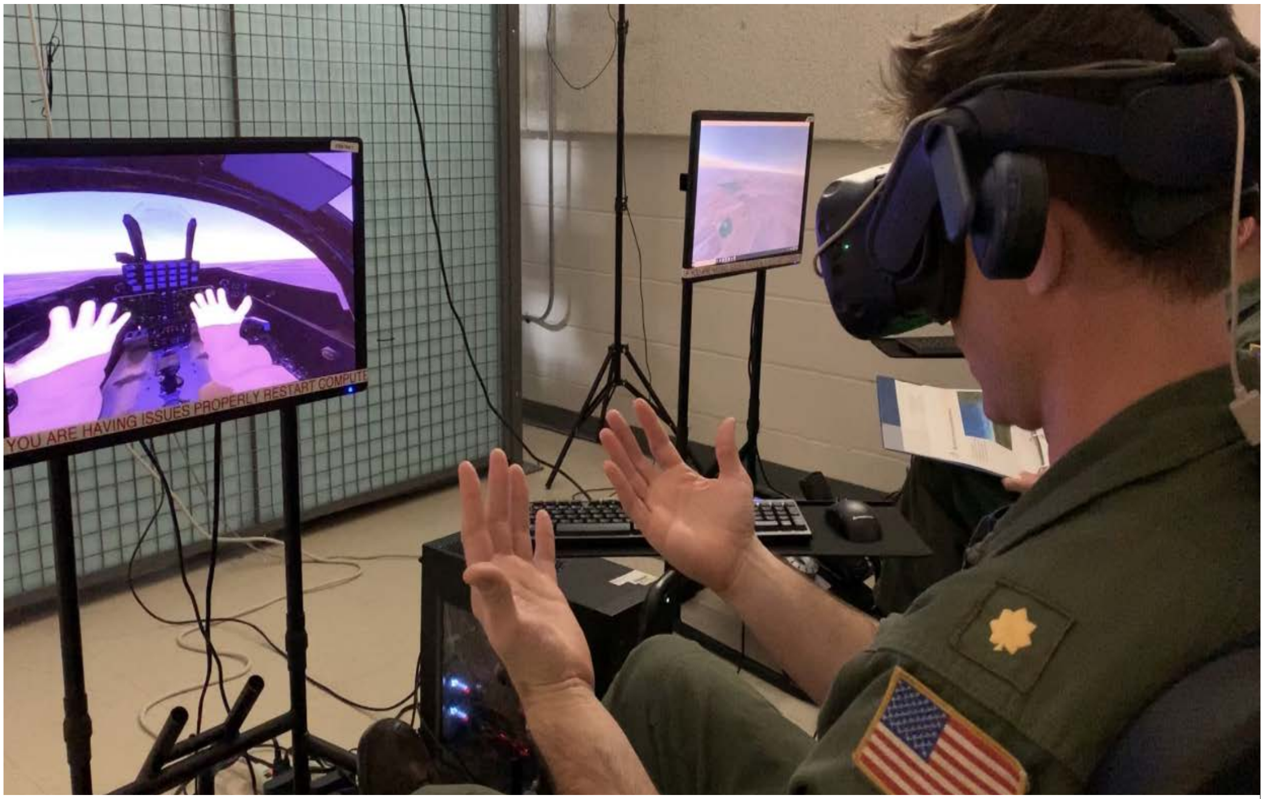

Image 1. Leap Motion Virtual Limb in T-45C BISim VR-PTTs

Trust in automation was an individual difference variable examined to investigate its relevance in XR training. Hence, questions of automation use, trust in automation generally, and trust in the XR devices were asked. Items related to trust in automation were similar to the following: “I am likely to trust automation even when I have little knowledge about it” (1 = *Strongly Disagree* to 5 = *Strongly Agree*). The full surveys are provided in Appendices 10.3-10.10.

A SurveyMonkey flight log measure was used to collect data on system usage (SurveyMonkey Inc., San Mateo, CA). This measure was used to gather data on practice session duration, reasons for using the devices, and flight practice with multiple networked simulators. The full flight log questionnaire is provided in Appendix 10.9. Due to the lack of participation on the SurveyMonkey measure (e.g., lack of signal in the building, forgetting after departure), the research team sent survey lock boxes to each site and emailed the paper-version to be printed and placed next to the data collection boxes. Although the printed version was more successful than the online questionnaire for some sites, it required personnel from the bases and the research team to transcribe the responses.

Finally, a wrap-up questionnaire was employed toward the end of the DCE, and is provided in Appendix 10.10. This was a mitigation measure to capture data that were not collected due to low participation completing the flight log measure. This measure detailed questions regarding total amount of device usage, effects of the devices on training behavior, potential uses of the devices, and device preference.

Performance measures were obtained from the TIMS. These included event raw scores for aircraft and flight simulator events, number of re-flys, unsatisfactory scores, marginal scores per event, number of warmup and supplemental sorties, number of progress checkrides, and number of elimination checkrides.

Table 3. Data Collection Measures

Measure Title	Measure Details
Comprehensive Questionnaire	Capture demographic, training utility, fidelity, curriculum placement, and training outcomes information for the VR/MR devices.
Online Flight Log	Capture demographic, training utility, fidelity, curriculum placement, and training outcomes information for the VR/MR devices.
Simulator Sickness Questionnaire	Capture simulator sickness symptoms post VR/MR exposure.
Virtual Limb Ownership Questionnaire	Capture perceptions of any sensations, movements, and/or characteristics of the hands you see displayed in the HMD versus your real hands.
Automation Use in Everyday Life	Capture exposure and use of automation in everyday life.
Trust in Automation Questionnaire	Capture general propensity to trust automation and trust in the VR/MR devices used.
Aesthetics Questionnaire	Capture whether aesthetics influences VR/MR device experience and usage.
Wrap-Up Questionnaire	Capture demographic, device usage, generalized training utility.

4.2.3. Apparatus

Three different VR-PTTs and one MRVS were included in this evaluation.

BISim created a VR-PTT for the T-45C Goshawk Jet (Bohemia Interactive Simulations, Inc., Prague, Czech Republic) with the developmental intention to respond to training needs in the Formation, Tactical, BFM, Operational Navigation, and Carrier Qualification. The system consisted of an HTC Vive Pro Head Mounted Display (HMD; HTC, New Taipei City, Taiwan) connected to a desktop computer powered by a i7-8700k hecta-core processor with a NVIDIA GTX 1080Ti 11GB video card run on a Windows 10 operating system. The Vive Pro HMD includes a display resolution of 1440 x 1600 per eye and a 105° horizontal and 110° vertical FOV. Visual content was supported by BISim's image generator, Virtual Battlespace (VBS) Blue IG v18.3. Additional hardware components included a Thrustmaster Warthog Hands on Throttle and Stick and rudder pedals (HOTAS; Guillemot Corporation, Chantepie, France). The HMD provides a 360° view of the cockpit with working multi-functional displays (MFDs). Users actuated virtual cockpit MFDs, buttons, switches, and dials using hand gestures captured using a Leap Motion hand tracking device (Leap Motion, San Francisco, CA) mounted to the front of the HMD. Users sat in a Volair Sim flight simulation cockpit seat (Volair Sim, Carmel, IN). The two BISim VR-PTTs had networked capabilities to support joint flight operations. They were developed to support Formation, Basic Fighter Maneuvers, Tactical formation, Low-Level (Operational Navigation), and Carrier Qualification. These VR-PTTs were delivered and evaluated at NAS Kingsville.

Image 2. BISim T-45CVR-PTTs at NAS Kingsville

To ensure accuracy in the T-45C BISim VR-PTT flight model, the research team from NAWCTSD facilitated interaction between IPs and leadership from CNATRA and the BISim development team during much of the development process. Feedback obtained from CNATRA SMEs played a significant role in validating the flight model used in the T-45C BISim VR-PTT to ensure that it would be a close representation of the T-45C Goshawk, see Image 2.

BISim also created the MRVS, which consisted of a Varjo (Varjo, Helsinki, Finland) HMD and was designed to be integrated with the 2F138D OFT at NAS Kingsville. The Varjo HMD includes a peripheral display resolution of 1440 x 1600 per eye and a 90° horizontal and 90° vertical FOV. For the high-resolution inset display, the resolution was 1920 x 1080 per eye and a 35° horizontal and 20° vertical FOV. It also features a pass-through camera capability allowing the user to see their actual hands and real cockpit overlaid on the virtual outdoor environment. One MRVS device was temporarily installed at NAS Kingsville for a two-month evaluation, see Image 3 and 4.

Image 3. BISim T-45C MRVS at NAS Kingsville

Image 4. T-45C BISim MRVS Instructor Station at NAS Kingsville

In addition, CNATRA provided a second VR-PTT for the T-45C Goshawk Jet based on a prototype device developed by two marine pilots. The T-45C 4E18 VR-PTT consists of an Oculus Rift HMD connected to a desktop computer. Flight model and visuals are supported by Prepar3D simulation software (Lockheed Martin, Bethesda, MD). The Oculus Rift HMD includes a display resolution of 1080 x 1200 and a 90° horizontal x 100° vertical FOV. As with the T-45C BISim VR-PTT, the HMD provides a 360° view of the cockpit with functional indicators and gauges. The device also includes a Thrustmaster Warthog HOTAS (Guillemot Corporation, Chantepie, France). In addition to the stick, throttle, and rudder pedals, actuation of functional buttons, dials, and switches located in the virtual cockpit are controlled by using the HMD gaze function in combination with left clicking a mouse located on the device chair. Alternatively, functional virtual cockpit components can also be selected and actuated by using the mouse (i.e., trackball and left click). During device operation, SNAs are seated in a height adjustable, standard rolling office chair with mouse and trackball mounted to the right side of the chair. Four T-45C 4E18 VR-PTTs were delivered to NAS Kingsville and four were delivered to NAS Meridian, see Image 5.

Image 5. T-45C 4E18 VR-PTTs at NAS Meridian

Finally, CNATRA provided 10 VR-PTTs for the Beechcraft T-6B Texan II aircraft, which were developed by SAIC in partnership with The United States Air Force (USAF) Air Education and Training Command (AETC) in support of the Pilot Training Next (PTN) program. The T-6 VR-PTT system consisted of an HTC Vive Pro (HTC Corporation, New Taipei City, Taiwan) connected to a desktop computer powered by an Intel Core i7 6-core processor with NVIDIA GeForce GTX 1080 8GB graphics card. Hardware components include a Thrustmaster Warthog Hands on Throttle and Stick and rudder pedals (HOTAS; Guillemot Corporation, Chantepie, France) and a Guitammer Buttkicker 2 haptic feedback seat attachment (The Guitammer Company, Westerville, OH). The HTC Vive Pro HMD includes a display resolution of 1440 x 1600 pixels per eye and a 105° horizontal x 110° vertical FOV. Six T-6B VR-PTTs were delivered to NAS Whiting Field and four delivered to NAS Corpus Christi, see Image 6.

Image 6. T-6B PTN VR-PTTs at NAS Corpus Christi

Table 4 provides a summary of the capability features of all of the devices within this evaluation. “Unknown” information include data that were not provided to the research team.

Table 4. XR System's Capability Matrix

Capability		System			
		T-45C BISim VR-PTT	T-45C BISim MRVS*	T-45C 4E18 VR-PTT	T-6B PTN VR-PTT
Visual Display Characteristics	**HMD**	• Vive Pro	• Varjo	• Oculus Rift	• HTC Vive Pro
	HMD resolution	• 1440 x 1600	• 1920 x 1080 center, 1440 x 1600 peripheral	• 1080 x 1200	• 1440 x 1600
	HMD instantaneous field of view	• 105°h x 110°v	• 90°h x 90°v • High resolution inset: 35°h x 20°v	• 90°h x 100°v	• 105°h x 110°v
	HMD refresh rate	• 90 Hz	• 90 Hz	• 90 Hz	• 90 Hz
	Scene update and refresh rate	• Cockpit updates at 90 frames per second (FPS) • Terrain updates at 45 FPS	• Cockpit updates at 90 frames per second (FPS) • Terrain updates at 45 FPS	• Unknown	• Unknown
	Field of regard	• 360° • High resolution	• 360° • High resolution	• 360° • High resolution	• 360° • High resolution
	Image generation	• Real-time, realistic scene with 3D visual cues • Sufficient for a wide range of flying tasks, including takeoff, landing, FRM, BFM, carrier landing	• Real-time, realistic scene with 3D visual cues • Sufficient for a wide range of flying tasks, including takeoff, landing, FRM, BFM, carrier landing	• Real-time, realistic scene with 3D visual cues • Sufficient for a wide range of flying tasks, including formation and tactical tasks	• Real-time, realistic scene with 3D visual cues • Sufficient for a wide range of tasks, including takeoff, landing, formation, and emergency procedures
	Instructor display	• Desktop monitor allows instructor to view HMD display in real time	• Secondary desktop monitor allows instructor to view HMD display in real time	• Desktop monitor allows instructor to view HMD display in real time	• Desktop monitor allows instructor to view HMD display in real time, along with real-time physiological data
Auditory Display Characteristics		• Spatially accurate sounds including engine, wind, flaps, landing gear, warning cues, and button clicks	• Standard OFT audio cues	• Spatially accurate sounds including engine, wind, and warning cues	• Realistic sounds relevant to the T-6B aircraft

Capability		T-45C BISim VR-PTT	T-45C BISim MRVS*	T-45C 4E18 VR-PTT	T-6B PTN VR-PTT
		System			
User Interface	Out-the-window scene	• Displayed in virtual cockpit canopy	• Displayed outside the physical cockpit of the 2F138D Operational Flight Trainer (OFT)	• Displayed in virtual cockpit canopy	• Displayed in virtual cockpit canopy
	Cockpit interior	• Contents of cockpit replicated in visual display • COTS hardware to replicate seat, stick, throttle, and rudders	• Contents of 2F138D Operational Flight Trainer (OFT) viewed through the visual display • Relies on 2F138D (OFT) for physical cockpit	• Contents of cockpit replicated in visual display • COTS hardware to replicate stick, throttle, and rudders	• Contents of cockpit replicated in visual display • COTS hardware to replicate seat, stick, throttle, and rudders • iPad Mini to replicate kneeboard • Vibratory haptic feedback
	Object cueing	• Programmable capability that magnifies designated models at preset ranges to compensate for current HMD visual resolutions	• Programmable capability that magnifies designated models at preset ranges to compensate for current HMD visual resolutions	• No object cueing	• No object cueing
	Interaction with controls	• Virtual controls: Gaze tracking + hand tracking • Hardware controls: HMD display correlates with inputs	• HMD display correlates with actions taken in the physical cockpit of the 2F138D OFT	• Virtual controls: Gaze tracking + mouse click OR mouse trackball + mouse click • Hardware controls: HMD display correlates with inputs	• Hardware controls: HMD display correlates with inputs
	Instructor Operator Station (IOS)	• No IOS; system and scenarios are controlled from the desktop that hosts the HMD and cockpit hardware	• Interface to the 2F138D OFT IOS controls that supports system start and restart, changes in weather, time of day, and sea-states	• No IOS; system and scenarios are controlled from the desktop that hosts the HMD and cockpit hardware	• No IOS; system and scenarios are controlled from the desktop that hosts the HMD and cockpit hardware
Multi-Ship Operations		• Links with other BISim T-45C VR-PTTs • Expected to link with BISim T-45C MRVS	• Correlates with scenarios simulated by the 2F138D OFT • Links with BISim T-45C VR-PTTs	• Links with other CNATRA T-45C 4E18 VR-PTTs, but visual jitter and poor location calibration between the systems degrades parade and close formation flying	• Links with other CNATRA T-6B PTN VR-PTTs, but visual jitter and lag degrade close formation flying
Aircraft Positioning	Geographic position	• Within 0.1 foot of the geographic position as computed by the host flight simulator	• Simulated geographic position in x,y,z coordinates is within ±0.1 foot of the geographic position in the 2F138D OFT flight simulation	• Unknown	• Unknown
	Angular position	• Within 0.1° of simulated angular position as computed by the host flight simulator	• Within ±0.1° of simulated angular position as computed by the 2F138D OFT flight simulation	• Unknown	• Unknown

Capability		System: T-45C BISim VR-PTT	T-45C BISim MRVS*	T-45C 4E18 VR-PTT	T-6B PTN VR-PTT
Terrain Database		• BISim's synthetic imagery database covers the area around Kingsville, TX approximately 100 miles out in any direction	• BISim's synthetic imagery database covers the area around Kingsville, TX approximately 100 miles out in any direction	• Database of terrain satellite imagery covers the continental US	• Imagery database covers the area around Austin, TX
Flight Model		• Basic flight dynamics package representative of the T-45C aircraft, including hydraulics, engine performance, and fuel flows	• Correlates with the 2F138D OFT for flight dynamics	• Flight model representative of the T-45C aircraft, including hydraulics, engine performance, and fuel flows, except: • Overpowered compared to the T-45C • Inaccuracies in the Angle of Attack (AOA)	• Flight model representative of the T-6B aircraft
Avionics		• Simulates T-45C avionics suite, including basic flight gauges, engine and radio controls, system warning and status annunciators, HUD, data entry panel, MFD system, and TACAN	• Visually replicates the 2F138D OFT cockpit interior	• Simulates T-45C avionics suite, including basic flight gauges, engine controls, system warning and status annunciators, HUD, data entry panel, and MFD system • Simulates Automatic Direction Finder (ADF) rather than TACAN • Simulates radios that differ from T-45C radios	• Simulates T-6B avionics suite, but not all task-relevant controls and gauges are functional
Trainee Performance Measurement		• Six degrees of freedom data (roll, pitch, yaw, latitude, longitude, altitude) • Primary flight control inputs (stick, rudder, throttle) • AOA • CSV file output • Graphical data output	• None specified	• TACView debrief tool tracks aircraft position, lift vector placement, airspeed, altitude, and many other variables and provides graphical data output •	• Flight and gauge data • Gaze tracking data • Real-time cognitive load measurement (pupil diameter, heart rate, heart rate variability, respiratory rate)
Adaptive Simulation		• Not adaptive	• Not adaptive	• Not adaptive	• Simulation adapts based on real-time measures of cognitive load • Intelligent tutor provides real-time performance feedback

4.3. Assumptions

The researchers conducted the study with minimal to no impact on training schedule and no formal changes to syllabus. All students were provided access to devices during the evaluation. During the sessions, it was assumed that the SNAs were actually engaging in flight practice, not engaging in idle play. For data analyses, as we do not know the exact date that each participant began using the systems, a rough cutoff date of 01 December 2018 was selected as the criterion for including participant scores in data analysis. Scores after 01 December 2018 were considered relevant, and earlier scores were discarded. Researchers are not confident that the dates associated with event grades were accurate.

4.4. Procedures

Study Design and Practice Sessions

The TIMS analyses was conducted as a concurrent assessment of the three different VR-PTT systems and the MRVS. For all of the systems, data on system usage were collected after the devices were installed at the respective training locations. At each location, CNATRA required that all SNAs be given free access to the XR devices. Instructor support was not built into the delivery of the devices; therefore, SNAs did not participate in structured training events with the VR-PTTs. Instead, they engaged in free play or self-guided study sessions with the devices as they desired. The MRVS required instructor presence to operate the OFT with which it was integrated, so participants who used the MRVS received traditional OFT instructor guidance during MRVS sessions.

TIMS data were pulled for SNAs who indicated that they used or did not use the devices. Hence, the usage of the XR devices could be compared to objective performance measures.

For the self-report components of the evaluation, students were instructed to use the available VR-PTTs or MRVS as frequently as desired. For the purposes of this evaluation, students were not required to use the VR-PTT or MRVS as a part of the CNATRA training syllabus. Therefore, students were able to choose when, why, and how the devices were used. Following each voluntary practice session, students were instructed to fill out the post-practice flight log questionnaire online or hard-copy version.

In addition, some students were scheduled to participate in a practice session for approximately 1 hour with researchers present, and then complete either the comprehensive questionnaire or the flight log questionnaire. For the MRVS sessions, the presence of a contracted flight instructor was required to operate the OFT, and pre-existing training events were used for their session, but the instructor did not evaluate participant performance. For the T-45C VR-PTTs, participants completed their session without a flight instructor. They were instructed to network their simulators for formation flights when the session contained more than one participant, but they were allowed to choose the events or skills they wished to practice. The T-6B PTN VR-PTTs SNAs were also instructed to remove their headsets and practice instrument flying with the dual-monitor configuration.

A subset of the in-person participants also completed the SSQ. They completed a baseline SSQ before beginning their VR or MR practice session, and then completed further SSQs immediately after, 30-, 60-, 90-, and 120 minutes after the end of their practice session. Due to time constraints and low incidence of symptom reporting, most participants departed after their 60-minute SSQ. At times, the training wings Aerospace Operational Physiologist was present during data collection to examine symptoms. Contact information for the training wings Aerospace Operational Physiologist was provided to the SNAs upon departure in case of delayed effects.

After completing the comprehensive questionnaire, a subset of participants also completed the limb ownership, automation use, trust in automation, and aesthetics questionnaires. The limb ownership questionnaire was given only to participants who evaluated the two systems developed by BISim; the remaining questionnaires included participants from all three T-45C systems. For efficiency, these questionnaires were completed by SNAs during the 30 (i.e., comprehensive questionnaire) and 60 minute (secondary questionnaires) waiting periods for the SSQ.

A curriculum analysis was conducted with instructors online and via teleconference on their perspective of the training utility of the XR devices. This approach was employed to complement the feedback provided by the SNAs from the comprehensive questionnaire, providing a balanced assessment on the devices' training utility. Instructors have an expert perspective on the entire training curriculum, and therefore, can parse the learning objectives for each stage. On the other hand, SNAs have a narrow focus on what is needed for their current training stage. The combination of their feedback provides a comprehensive analysis of the devices' capability to respond to training gaps.

In the final month of data collection, SNAs at NAS Corpus Christi, Kingsville, Meridian, and Whiting Field were asked to complete the wrap-up questionnaire. Concurrently, focus groups were conducted with instructors and stakeholders at each training site. Participants in these focus groups were asked to discuss strengths and weaknesses of the VR/MR systems, potential training utility, upgrades needed, and recommendations for implementation in the training pipeline, see Table 5. These recommendations are summarized in Section 7.

Table 5. Data Collection Trip Summary

Trip Location	Trip Dates	Purpose
NAS Meridian	13-15 NOV 2018	T-45C 4E18 VR-PTT Data Collection
NAS Kingsville	4-5 DEC 2019	T-45C BISim VR-PTT
NAS Kingsville	15-17 JAN 2019	T-45C BISim VR-PTT and T-45C 4E18 VR-PTT Data Collection
NAS Meridian	28-31 JAN 2019	T-4C5 4E18 VR-PTT Data Collection
NAS Kingsville	26-29 MAR 2019	MRVS Delivery
NAS Kingsville	2-4 APR 2019	T-45C BISim MRVS and T-45C BISim VR-PTT Data Collection
NAS Whiting Field	9-11 APR 2019	T-6B PTN VR-PTT Data Collection
NAS Kingsville	16-18 APR 2019	T-45C BISim MRVS Data Collection
NAS Corpus Christi	29 APR – 1 MAY 2019	T-6B PTN VR-PTT Data Collection
NAS Whiting Field	7-8 MAY 2019	T-6B PTN VR-PTT Data Collection
NAS Kingsville	14-16 MAY 2019	T-45C BISim MRVS Data Collection
NAS Kingsville	21 MAY 2019	T-45C BISim MRVS Demonstration for PMA-205 / AWTD
NAS Kingsville	21-24 MAY 2019	T-45C BISim MRVS Data Collection
NAS Whiting Field	30 MAY – 2 JUN 2019	T-6B PTN VR-PTT Data Collection
NAS Corpus Christi	4-5 JUN 2019	T-6B PTN VR-PTT Data Collection
NAS Whiting Field	14 JUN 2019	T-6B PTN VR-PTT Focus Group Discussion
NAS Corpus Christi	26 JUN 2019	T-6B PTN VR-PTT Focus Group Discussion
NAS Meridian	26-28 JUN 2019	T-45C 4E18 VR-PTT Data Collection & Focus Groups
NAS Kingsville	27 JUN 2019	T-45C BISim MRVS /T-45C BISim VR-PTT / T-45C 4E18 VR-PTT Focus Group Discussion

Analysis

Questionnaire data were examined to determine trends in usability, realism, visibility, training utility, and overall positivity of reactions across the devices. Due to a variety of data types collected, nonparametric and parametric tests are included; the results section provides the type of test used for each separate analysis.

In order to evaluate the relation between device usage and aircraft performance, Spearman rank-order correlation coefficients were calculated for count data (i.e., reflys, marginals, unsatisfactories, warmup sorties, supplemental sorties, progress checkrides, and elimination checkrides). Correlations between event raw scores and device usage were also calculated.

Finally, written free-response feedback from the comprehensive questionnaire were analyzed for response trends. Responses were counted and the most common responses are summarized with counts provided in Appendices 10.11 through 10.14.

5. Results

Due to the multi-pronged approach to data collection, results are broken down into several sections with sub-sections. A brief summary paragraph at the end of each subsection provides the overall conclusion from each analysis or set of analyses.

Data were analyzed using International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) 22 (IBM Corporation, Armonk, NY) with default settings. For Likert-type questions, items with negative wording were reverse-coded such that scores corresponded to positivity of responses (1 = *Not Positive*, 2 = *Slightly Positive,* 3 = *Moderately Positive*, 4 = *Very Positive*, 5 = *Extremely Positive*. For example, if the SNA chose the “4 – Agree” to the question “The view outside the cockpit was not clear enough…”, the research team would convert that score to a “2” to indicate slight positivity. Except where noted below, participants who evaluated multiple systems were excluded from between-systems analyses.

5.1. Participants

The research team collected feedback data from SNAs and instructors from various stages within the training syllabus. The tables below (i.e., Table 9-11) outline the demographic data for both the SNA and instructors who offered feedback for the four devices included in the evaluation. If no SNAs from a particular block provided feedback, that block is not represented in the tables. Similarly, if no instructor provided feedback for a particular device, those tables are not included.

Table 6. T-45C BISim MRVS Demographics

T-45C BISim MRVS Student Naval Aviator Participants																
	Current Stage of Training															
	Contacts			Contacts Total	Instruments			Instruments Total	Formation			Formation Total	Tactical Total	Winged Pilots	Total	
	FAM	FCL	CO		RI	AN	IR		FRM	DIV	NFR					
Male	7	3	0	**10**	1	3	4	**8**	11	3	2	**16**	**1**	**3**	**38**	**40**
Female	1	0	0	**1**	0	0	0	**0**	1	0	0	**1**	**0**	**0**	**2**	

Table 7. T-45C BISim VR-PTT Demographics

T-45C BISim VR-PTTs Student Naval Aviator Participants																				
	Current Stage of Training																			
	Contacts				Contacts Total	Instruments				Instruments Total	Formation		Formation Total	Tactical				Tactical Total	Winged Pilots	Total	
	FAM	NFM	FCL	CO		BI	RI	AN	IR		FRM	DIV		ON	TAC	BFM	CQL				
Male	10	3	4	1	**18**	1	1	0	1	**3**	6	2	**8**	2	2	1	1	**6**	**3**	**38**	**44**
Female	3	0	0	0	**3**	0	0	1	0	**1**	2	0	**2**	0	0	0	0	**0**	**0**	**6**	

Table 8. T-45C 4E18 VR-PTT Demographics

T-45C 4E18 VR-PTTs Student Naval Aviator Participants																		
	Current Stage of Training																	
	Contacts			Contacts Total	Instruments		Instruments Total	Formation	Formation Total	Tactical					Tactical Total	Winged	Total	
	FAM	NFM	FCL		BI	IR		FRM		ON	STK	BFM	SEM	CQL				
Male	8	2	2	**12**	1	1	**2**	12	**12**	3	4	4	1	1	**13**	**5**	**44**	**45**
Female	1	0	0	**1**	0	0	**0**	**0**	**0**	0	0	0	0	0	**0**	**0**	**1**	

Table 9. T-6B PTN VR-PTT Demographics

	T-6B Student Naval Aviator Participants																	
	Current Stage of Training																	
	Ground School		Ground School Total	Contacts				Contacts Total	Instruments		Instruments Total	Formation	Formation Total	Other		Other Total	Total	
	Indoc	Course Rules		Contact Flight	Cockpit Procedures	Contact	Day Contact		BI	RI		FRM		Stage Not Designated	Pool/Stash			
Male	16	1	**17**	2	3	7	15	**27**	1	1	**2**	4	**4**	17	25	**42**	**92**	**96**
Female	1	0	**1**	0	0	0	0	**0**	0	0	**0**	1	**1**	1	1	**2**	**4**	

Table 10. T-45C 4E18 VR-PTT Instructor Demographics

	4E18 Instructors		Total	
	Contractor	Uniformed		
Male	4	0	**4**	**4**
Female	0	0	**0**	

Table 11. T-45C BISim VR-PTT Instructor Demographics

	T-45C BISim VR-PTT Instructors		Total	
	Contractor	Uniformed		
Male	1	4	**5**	**5**
Female	0	0	**0**	

5.2. HMD Evaluation

There were multiple HMDs involved in this evaluation, providing an opportunity for a capability comparison. A FOV comparison among the average human eye, aviation helmet, and XR HMDs was conducted by a NAWCTSD Visual Engineer. The headsets included in this FOV evaluation were the Oculus Rift, Varjo, and Vive Pro. The average human eye FOV was provided by the literature (e.g., Walker, Hall, & Hurst, 1990). For the aviation helmet, the Visual Engineer examined the scan pattern of an Instructor Pilot SME at NAS Kingsville to understand the FOV limitations for pilots in a helmet, as compared to the average human eye (see Table 12). The data reported for the helmet FOV was measured by the Visual Engineer analyzing the FOV of another individual wearing a fixed-winged aviation helmet. The FOV was calculated from the geometric distortion measurement pattern analyses in the NAWCTSD DOME room. The data can be found in Table 12.

Table 12. FOV Comparisons

Human Eye	Aviation Helmet	Oculus Rift	Vive Pro	Varjo
Horizontal FOV ~ 210° Stereo H FOV ~ 114° Vertical FOV ~135°	Horizontal FOV ~ 200° Vertical Up FOV ~40° Vertical Down FOV not impaired by helmet.	Horizontal FOV ~90° Vertical 100°	Horizontal 105° Vertical 110°	Horizontal 90° Vertical 90°

Image 7. FOV Measurement

As demonstrated in Figure 2, the average horizontal FOV for the human eye is 210 degrees. The horizontal FOV for the fixed-wing aviation helmet was just short of the human eye with 200 degrees. Of the HMDs, the Oculus Rift and Varjo provide the least horizontal FOV of 90 degrees. Although the Vive Pro offers a slightly wider FOV of 105 degrees, both HMDs are approximately half the horizontal FOV utilized by pilots in the helmet. Although the headset needs are different for first-person gaming, which may not need a wide FOV, this evaluation underscored that there is a requirement for the HMD developers to explore amplifying the horizontal FOV to better support XR aviation training.

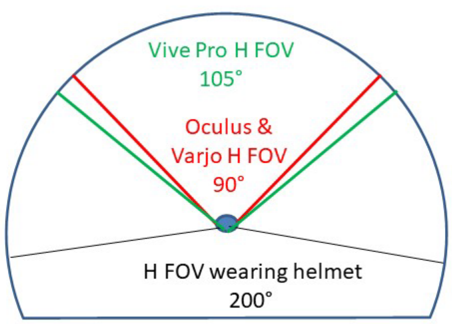

Figure 2. FOV Comparison

5.3. Hypothesis Testing

To provide a comprehensive evaluation, the research team leveraged the four levels of Kirkpatrick's Training Evaluation model (1976): (1) Reactions, (2) Learning, (3) Behavior, and (4) Results. As such, the research team identified hypotheses for each of the levels. The following subsections will address all of the hypotheses proposed.

5.3.1. Research Question 1 (Reactions)

Level 1 of Kirkpatrick Training Evaluation seeks to understand the "To what degree do trainees and instructors react favorably to the devices?" The following subsections detail overall reactions to the VR/MR devices.

5.3.2. Overall Positivity

Responses to all Likert-type questions in the comprehensive questionnaire were combined to create an overall score indicating the degree to which the user reacted positively to the systems. Since participants were not required to respond to all questions and the number of relevant questions varied between systems, overall positivity was calculated as a mean score (range: *1 = Strongly Disagree* to *5 = Strongly Agree*) rather than a summed score. All of the devices had an above neutral score on agreement of device positivity, except for the T-6B PTN VR-PTT. The mean positivity scores are presented in ascending score order in Table 13.

Table 13. Mean Positivity Scores

Device	Mean Overall Positivity Score	Standard Deviation
T-6B PTN VR-PTT	2.94	0.58
T-45C BISim VR-PTT	3.12	0.45
T-45C BISim MRVS	3.18	0.54
T-45C 4E18 VR-PTT	3.23	0.50

Overall positivity was then compared between systems in a one-way between-subjects ANOVA with 4 levels (PTN T-6B VR-PTT, T-45C 4E18 VR-PTT, T-45C BISim VR-PTT, and T-45C MRVS), and with hours of previous experience with VR as a covariate. The effect of system was significant, $F(3,203) = 3.34$, $p = .020$, indicating that overall positivity of users' reactions differed between the systems. In general, reactions to the T-45C 4E18 VR-PTT were the most positive, followed by the T-45C MRVS, then the T-45C BISim

VR-PTT, and then the PTN T-6B VR-PTT. Post-hoc tests of the effect of system indicated that responses to the PTN T-6B VR-PTT were significantly less positive than responses to the T-45C 4E18 VR-PTT, $p = .002$. No other differences were significant, *p*s > .216.

In summary, reactions to the four devices differed and those to the T-6B VR-PTT were less positive than reactions to the T-45C 4E18 VR-PTT. Other comparisons did not show a significant difference between systems. Responses are further broken down in the following sections. Overall positivity and subscale scores are displayed in in Figure 3.

5.3.3. Training Utility

Responses to Likert-type questions pertaining to perceived training utility of the systems (questions 17, 19, and 36-38) of the comprehensive questionnaire) were averaged to create a training utility mean score. The mean score for T-6B PTN VR-PTT was lower than neutral, whereas the mean scores for the other devices indicated greater than neutral agreement of their training utility. The mean training utility scores are presented in ascending score order in Table 14.

Table 14. Mean Training Utility Scores

Device	Mean Training Utility Score	Standard Deviation
T-6B PTN VR-PTT	2.97	0.83
T-45C BISim MRVS	3.27	0.64
T-45C BISim VR-PTT	3.29	0.83
T-45C 4E18 VR-PTT	3.67	0.65

Training utility was then compared between systems using a one-way between-subjects ANOVA with 4 levels and with hours of past VR experience as a covariate. The effect of system was significant, $F(3,203) = 7.35$, $p < .001$. The T-45C 4E18 VR-PTT was rated the highest on training utility, and the T-6B VR-PTT was rated the lowest. Post-hoc tests indicated that the T-6B VR-PTT was seen as having significantly less training utility than the 4E18 VR-PTT, $p < .001$. No other comparisons were significant, *p*s > .157.

In summary, perceived training utility was lower for the T-6B PTN VR-PTT than for the T-45C 4E18 VR-PTT. Other comparisons were not significant. This difference in perceived training utility, along with differences in visibility ratings (below), seems to have been the driving factor in lower overall positivity ratings for the T-6B PTN VR-PTT.

5.3.4. Visibility

Responses to Likert-type questions pertaining to perceived visibility within the systems (questions 19-21, 35, and 40 of the comprehensive questionnaire) were averaged to create a mean visibility score. All of the devices scored below neutral to agreement of visibility. The mean visibility scores are presented in ascending score order in Table 14.

Table 15. Mean Visibility Scores

Device	Mean Visibility Score	Standard Deviation
T-6B PTN VR-PTT	2.41	0.66
T-45C BISim MRVS	2.60	0.81
T-45C BISim VR-PTT	2.73	0.61
T-45C 4E18 VR-PTT	2.90	0.70

Perceived visibility was then compared between systems using a one-way, between-subjects ANOVA with four levels. Hours of previous VR experience was not used as a covariate, as previous VR experience was not expected to have an effect on participants’ ability to see within the VR/MR headsets. The effect of system was significant, $F(3,276) = 8.61$, $p < .001$. Post-hoc tests indicated that the PTN T-6B VR-PTT had significantly worse visibility than the T-45C 4E18 VR-PTT, $p < .001$. All other comparisons were not significant, $ps > .337$.

In summary, visibility in the PTN T-6B was rated lower than visibility in the T-45C 4E18 VR-PTT. Visibility did not significantly differ between the T-45C systems.

5.3.5. Usability

Responses to Likert-type questions pertaining to usability of the systems (questions 15, 16, 18, 26, and 29 of the comprehensive questionnaire) were averaged to create a mean usability score. The mean usability scores ranged from slightly below to slightly above neutral. The mean usability scores are presented in Table 16.

Table 16. Mean Usability Scores

Device	Mean Usability Score	Standard Deviation
T-45C BISim VR-PTT	2.85	0.82
T-45C 4E18 VR-PTT	3.07	0.59
T-45C BISim MRVS	2.60	0.81
T-6B PTN VR-PTT	3.38	0.67

Usability was then compared among the four systems using a one-way, between-subjects ANOVA with four levels, and with hours of previous VR experience as a covariate. The effect of system was significant, $F(3,203) = 5.01$, $p = .002$. Post-hoc tests indicated that usability ratings for the PTN T-6B VR-PTT were significantly higher than usability ratings for the T-45C VR-PTTs, *p*s < .010. All other comparisons were not significant, *p*s > .310.

In summary, usability was actually highest for the T-6B PTN VR-PTT compared to the other devices. No other comparisons were significant. Thus, usability of the system did not drive the differences in overall positivity, where the T-6B VR-PTT scored the lowest of the four systems.

5.3.6. Realism

Responses to Likert-type questions pertaining to realism of the systems (questions 22-25 and 27-33 of the comprehensive questionnaire) were averaged to create a mean realism score. All realism mean scores were slightly above neutral except for the T-6B PTN VR-PTT. The mean realism scores are presented in ascending score order in Table 17.

Table 17. Mean Realism Scores

Device	Mean Realism Score	Standard Deviation
T-6B PTN VR-PTT	2.92	0.61
T-45C 4E18 VR-PTT	3.24	0.54
T-45C BISim VR-PTT	3.28	0.42
T-45C BISim MRVS	3.39	0.53

Realism was then compared between systems using a one-way, between-subjects ANOVA with four levels. Hours of previous VR experience was not included as a covariate, as it was not expected to have an effect on perceived realism compared to the aircraft. The effect of system was significant, $F(3,274) = 8.93$, $p < .001$. Post-hoc tests indicated that the T-6B PTN VR-PTT was rated significantly lower on realism than all of the T-45C systems, *p*s < .014. Realism did not significantly differ between the T-45C systems, *p*s > .751.

In summary, the T-6B PTN VR-PTT was rated significantly lower on realism than the T-45C VR-PTTs and MRVS. This may indicate actual lower realism, or it may indicate that certain types of realism, such as realistic control feel, are considered more important for early-stage trainee pilots than for more advanced pilots.

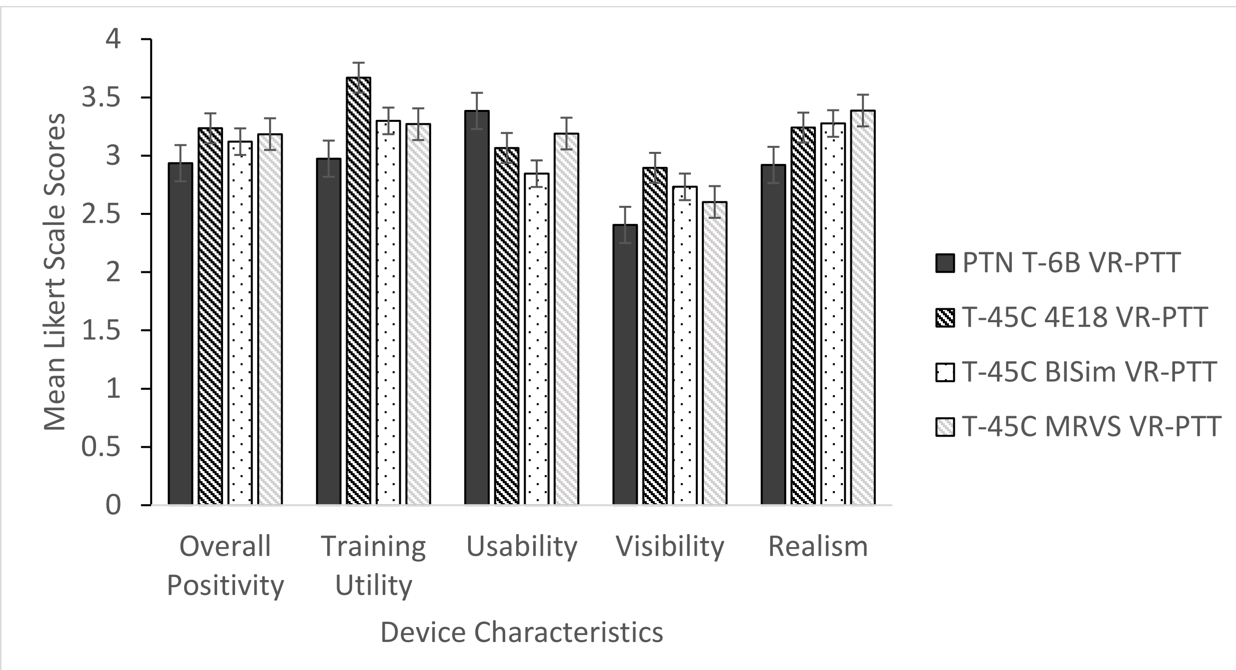

Figure 3. Mean Scores on Device Characteristics

5.3.7. XR System Preference

In the wrap-up questionnaire, participants who owned their own VR flight simulators were asked whether they preferred the VR devices evaluated in this study, or their own device. Preference for own device or squadron device was compared between T-6B sites (NAS Corpus Christi and Whiting Field) and T-45C sites (NAS Kingsville and Meridian) using a Chi Squared (χ^2) test. A

Chi Squared test compares the distribution of two categorical variables to determine if they differ. The test was not significant, $\chi^2(1, N=104) = 3.63$, $p = .057$, but the trend towards SNAs preferring their own devices should be acknowledged, although the trend was not as pronounced for the T-6 sites as for the T-45C sites.

Additionally, SNAs at NAS Kingsville were asked whether they preferred to use the MRVS, T-45C BISim VR-PTT, T-45C 4E18 VR-PTT, or no VR/MR device. A χ^2 test indicated significant differences between responses, $\chi^2(3) = 15.02$, $p = .002$. Follow-up χ^2 tests comparing each system to each other indicated that the majority of respondents preferred to use none of the VR/MR devices, all χ^2 (1,N=95)> 5.49, all ps < .020. None of the other comparisons were significant, all $\chi^2 < 1.60$, all ps > .205. In conjunction with the preference for one’s own VR device from the T-6 vs T-45C comparison, this suggests that acceptance and voluntary usage of the VR/MR systems is somewhat low.

In summary, device preference results from the wrap-up questionnaire indicate that respondents prefer not to use the VR/MR systems, suggesting low acceptance and indicating that usage of VR/MR systems may remain somewhat low if usage compliance is not mandatory from leadership.

5.3.8. Training Value

Usefulness for Stages or Phases of Training

In the comprehensive questionnaire, participants were asked to mark the stages of training for which the system would be useful. Although a similar question was asked in the wrap-up questionnaire, the online version of the questionnaire did not contain a complete list of training stages. Therefore, only the item from the comprehensive questionnaire is reported here. Frequency of responses to the different stages was analyzed separately for each system using Cochran’s *Q* test (test of differences in a dichotomous variable among three or more groups). Post-hoc McNemar tests were conducted to compare stages of interest, using exact McNemar tests for comparisons with fewer than 25 discordant pairs. For the T-6B PTN VR-PTT, the question asked whether or not the system was useful for the phases Contacts, Instruments, Navigation, and Formation; post-hoc tests were conducted for all four phases compared to each other. For the T-45C systems, Formation (FRM), Tactical Formation (TAC), Basic Fighter Maneuvering (BFM), and Carrier Qualification Landing (CQL) stages were compared to each other and to the Basic Instruments (BI) block, and Familiarization (FAM) was compared to FRM and BI. FRM, TAC, and BFM are all stages that require multi-aircraft flight skills, and were therefore expected to be a strength of the networkable T-45C systems. Additionally, the T-45C trainers included an aircraft carrier for carrier landing practice, and were therefore originally expected to be useful for CQL stages. However, after acquisition of the systems, it was found that IFLOLS was not functional and the carrier was stationary, two complaints which limited CQL practice; therefore, it was uncertain whether or not the T-45C systems would actually be useful for CQL. The expectation that the T-45C systems would be useful for FAM was developed through informal conversation with SNAs. The systems were expected to be less specifically useful for instruments training stages; therefore, the other stages of interest were compared to BI.

For all four systems, frequency of "useful" responses significantly differed between stages or phases, all $\chi^2 > 117.98$, all *p*s < .001.

For the T-6B VR-PTT, post-hoc McNemar tests indicated that the VR-PTT was considered useful for Contacts practice significantly more often than for Instruments, Navigation, and Formation, all $\chi^2 > 40.55$, all *p*s < .001. The difference between Instruments and Formation was not significant, $\chi^2(1, N=148) = 3.52$, $p = .061$. Additionally, the differences between Instruments and Navigation, and between Navigation and Formation, were not significant, $\chi^2 < 2.62$, *p*s > .105.

Table 18. Frequency of "Useful" Responses to Primary Training Phases

Phase	Useful[a]	Not Useful
Contacts	122	25
Instruments	57	90
Navigation	44	103
Formation	41	106

[a] *Frequency of responses that the T-6B VR-PTT is useful for each phase of Primary training.*

For the T-45C 4E18 VR-PTT, post-hoc McNemar tests indicated that the T-45C 4E18 VR-PTT was considered useful for FRM, BFM, and FAM significantly more often than for BI, all $\chi^2(1,N=64) > 11.28$, all *p*s < .002. Additionally, the T-45C 4E18 VR-PTT was considered useful for FRM, TAC, and FAM significantly more often than for CQL, all *p*s < .001. The other comparisons were not significant, all *p*s > .142.

For the T-45C BISim VR-PTT, post-hoc McNemar tests indicated that it was considered useful for FRM and FAM significantly more often than for BI, *p*s < .002. It was also considered useful for FRM, TAC, BFM, and FAM significantly more often than for CQL, *p*s < .007; and considered useful for FRM and FAM more often than for BFM, *p*s < .024. Finally, it was considered useful for FRM significantly more often than for TAC, *p* = .007. All other differences were not significant, all *p*s > .088.

Finally, the MRVS was considered useful for FRM and FAM significantly more often than for BI, TAC, BFM, or CQL, *p*s < .002. All other comparisons were not significant, all *p*s > .069.

Frequencies of "useful" responses for each block or phase are provided below in Table 19.

Table 19. Frequency of "Useful" Responses to Stages of Intermediate or Advanced Training.

Block	T-45C 4E18 VR-PTT		T-45C BISim VR-PTT		T-45C BISim MRVS	
	Useful[a]	Not Useful	Useful[a]	Not Useful	Useful[a]	Not Useful
FAM	33	31	25	20	25	9
OCF	12	52	8	37	9	25
NFM	15	49	7	38	12	22
FCL	8	56	8	37	12	22
CO	16	48	13	32	15	19
BI	8	56	10	35	6	28
RI	8	56	7	38	4	30
AN	7	57	3	42	5	29
IR	6	58	2	43	5	29
FRM	37	27	29	16	31	3
DIV	19	45	18	27	14	20
NFR	18	46	11	34	16	18
ON	21	43	9	36	8	26
RR	22	42	6	39	7	27
STK	18	46	7	38	11	23

TAC	35	29	15	30	10	24
BFM	28	36	13	32	8	26
SEM	19	45	7	38	6	28
CQL	5	59	3	42	4	30

[a] Frequency of responses that the T-45C system is useful for each block of training in an intermediate or advanced syllabus.

In summary, the T-6B VR-PTT was considered useful for Contact practice more often than for other phases of training. The T-45C systems were generally considered useful for Familiarization, Formation, Tactical Formation, and somewhat for Basic Fighter Maneuvering stages; and, as expected, were considered useful less often for Basic Instruments stages. Additionally, the T-45C trainers were not often considered useful for Carrier Qualification Landing, suggesting that the lack of function in IFLOLS and lack of movement in the carrier prevents the VR-PTTs from being usefully practiced for CQL. Finally, the MRVS was most often considered useful for Familiarization and Formation stages, and was not often considered useful for Tactical Formation, Basic Fighter Maneuvering, Basic Instruments, or Carrier Qualification Landing. Thus, The T-45C VR-PTTs fall short in expectations with regard to CQL, and the MRVS falls short in expectations with regard to CQL and tactical stages. However, the VR-PTTs may cover the current gaps in good practice tools for formation and tactical flying, and the MRVS may cover the gap in formation flying specifically.

5.3.9. Potential Uses

In addition to the question about usefulness for specific stages or phases of training, participants were asked to rank the value of the VR/MR systems for six potential uses: preparing for the next event, remediation on items for which instructors provided feedback, learning new content, building a sight picture, free play, or other uses. Usefulness rankings were transformed to a 1 – 7 scale, with 1 being most useful, 6 being least useful, and 7 being not useful at all, and then were compared using a Friedman's test with potential use as the independent variable. The difference in ranking between potential uses was significant, $\chi^2(5, N=32) = 26.95$, $p < .001$. Building a sight picture was ranked the highest of the potential uses, and post-hoc sign tests indicated that it was ranked significantly higher than preparing for the next event, remediation on items for which instructors gave feedback, learning new content, and free play, all ps $< .001$. Remediation was the lowest-ranked potential use, and was ranked significantly lower than preparing for the next event, learning new content, and free play, all ps $< .034$. Finally, free play was ranked significantly higher than learning new content, $p = .006$. All other comparisons were not significant, all ps $> .073$.

Finally, respondents to the wrap-up questionnaire were asked to rank the value of the systems for building a sight picture, practicing communications, practicing FTI procedures, building situational awareness, understand aircraft positions, and flying with another student. Response rankings were compared separately for the T-6B VR-PTT and the T-45C devices, using Friedman's tests with potential use as the independent variable. Both Friedman tests were significant, $\chi^2 > 77.46$, ps $< .001$.

For the T-6B VR-PTT, building a sight picture was ranked the highest, and post-hoc sign tests indicated that building a sight picture had a significantly higher ranking than all other potential uses, all ps $< .001$. Flying with another student was ranked the lowest, and post-hoc sign tests indicated that it was ranked significantly lower than all other potential uses, all ps $< .001$.

For the T-45C systems, building a sight picture was also ranked the highest, and post-hoc sign tests indicated that it was ranked significantly higher than all other potential uses, all ps $< .001$. Practicing communications was ranked the lowest, but post-hoc sign tests indicated that the only significant differences were with building situational awareness, $p = .004$, and building a sight picture, $p < .001$. All other comparisons with practicing communications were not significant, ps $> .059$.

In summary, the greatest potential use of the T-6B and T-45C systems is building a sight picture. These systems were perceived as less useful for remediation for items on which instructors gave feedback. Additionally, the T-6B is not considered highly useful for networked flying with another SNA, and the T-45C systems are considered somewhat less useful for practicing communications than for other purposes. The fact that the T-6B is not considered highly useful for flying with another SNA may explain why T-6B users did not usually network their VR-PTTs for multi-aircraft practice.

5.3.10. Value in Networking

Respondents to the flight log questionnaire who had networked their system with another student were asked to select the valuable aspects about practicing with another student, including building a sight picture, practicing communications, building situational awareness, practicing FTI procedures, and understanding aircraft positions. Although “Other” was also an option, “Other” responses were extremely rare and were excluded from analysis. Differences in frequencies between these response options were compared separately for each VR-PTT using Cochran’s Q tests with aspect of practicing as the independent variable (5 levels), and post-hoc McNemar tests were conducted for significant Cochran’s tests.

For the T-6B VR-PTT, the difference between aspects of practicing was significant, $\chi^2(5, N=74) = 15.77$, $p = .003$. Post-hoc tests indicated that building a sight picture, practicing FTI procedures, and building situational awareness were considered valuable significantly more often than practicing communications, all *p*s < .004. All other comparisons were not significant, all *p*s > .091.

For the T-45C 4E18 VR-PTT, the difference between aspects of practicing was not significant, $\chi^2(4, N=15) = 2.40$, $p = .663$.

For the T-45C BISim VR-PTT, the difference between aspects of practicing was significant, $\chi^2(4, N=12) = 14.48$, $p = .006$. Post-hoc tests indicated that understanding aircraft positions was considered valuable significantly more often than practicing communications and practicing FTI procedures, *p*s < .032. The differences between building a sight picture and practicing communications, and between building situational awareness and practicing FTI procedures, were not significant, $p = .070$ for both.

In summary, users of the T-6B VR-PTT considered it valuable for building a sight picture, practicing FTI procedures, and building situational awareness when networked with another SNA. They considered the T-6B VR-PTT less valuable for practicing communications. By contrast, users of the T-45C BISim VR-PTT considered it valuable for understanding aircraft positions when practicing with another SNA, although they also considered it somewhat less valuable for practicing communications. Different aspects of practicing with another student did not significantly differ in value for the T-45C 4E18 VR-PTT. Responses about the value of aspects of practicing with another SNA are presented in Table 20 below.

Table 20. Frequency of "Valuable" Responses to Aspects of Practicing with another SNA

System	Building a Sight Picture	Practicing Comms	Practicing FTI Procedures	Building Situational Awareness	Understanding Aircraft Positions
T-6B PTN VR-PTT	25	7	19	26	14
T-45C 4E18 VR-PTT	6	4	4	6	7
T-45C BISim VR-PTT	7	1	2	2	8

5.3.11. Free Response Questionnaire Feedback

T-45C BISim MRVS

The MRVS received overall positive feedback in terms of the realism of the cockpit and virtual environment, the flight model, and training utility. The most commonly reported strength of the MRVS was the fact that the user is able to see and interact with a real T-45C cockpit in the OFT rather than a virtual cockpit. Combined with the 360° degree field of regard and superior outside visuals, students reported confidence that the MRVS could provide additional training capabilities beyond what the OFT currently provides. Due to the realistic cockpit and virtual environment, students reported the device being useful for building a sight picture, preparing for upcoming events, remediation, and learning new content.

Negative feedback regarding the MRVS was generally related to the quality of the visuals within the cockpit as well as the restricted field of view within the HMD. For example, while the students were able to see the real T-45C OFT cockpit via the pass-through camera capability, the instruments and gauges were frequently reported as being too blurry to read without significant focusing or straining. Additionally, students also reported alterations to their typical scan pattern as a result of the restricted field of view inside the HMD. Both of these characteristics led to students reporting that the MRVS would not be useful for instruments practice. Lastly, use of the MRVS requires a knowledgeable instructor to start and run the system. Students reported this requirement as a potential drawback to the device because it limits their ability to use the device without prior scheduling. Counts of common responses are provided in Appendix 10.11.

T-45C BISim VR-PTT

Feedback towards the T-45C BISim VR-PTT was generally positive with respect to training utility, networking capabilities, the visual fidelity of the virtual environment, and the realism of the avionics and cockpit displays. For example, students indicated that the 360° degree field of regard offered by the T-45C BISim VR-PTT is a significant improvement compared to what is currently available in the OFT. Further, students also commonly cited the ability to network with another student for formation flights as strong reason to utilize the device. When asked how the T-45C BISim VR-PTT could impact training, students commonly reported that the device could increase mission readiness and performance through its usefulness in building a sight picture and preparing for upcoming events.

Negative feedback towards the T-45C BISim VR-PTT was typically associated with issues of system usability, blurriness of objects in the HMD, and some inaccurate aircraft behaviors associated with the flight model. For example, students indicated that system setup can be difficult and complex for novice users. Furthermore, students also reported difficulty with the hand tracking controls making it difficult or impossible to articulate certain controls in the cockpit (e.g., TACAN). While the avionics were generally reported as being accurate, students reported difficulty in reading certain displays due to blurriness in the HMD. The difficultly in reading many of the displays and gauges in the cockpit led the majority of the students to report that the T-45C BISim VR-PTT would not be suitable for instruments practice. Counts of common responses are provided in Appendix 10.12.

T-45C 4E18 VR-PTT

Feedback towards the T-45C 4E18 device was generally favorable in terms of system usability, environmental appearance, networking capabilities, and training utility. With respect to usability, students generally found the T-45C 4E18 VR-PTT to be simple and relatively easy to setup and start without significant guidance. Students also felt that the visual quality of the virtual environment as well as the 360° degree field of regard was a significant strength of the device compared to the OFT. In addition, students responded favorably to the ability to complete networked flights with other students in the device. Given the quality of the virtual environment and networking capabilities, students generally reported that the 4E18 devices would be most useful for building a sight picture and preparing for the next event.

Negative feedback towards the T-45C 4E18 VR-PTT was generally focused on the flight model, the behavior of other aircraft when networked, and poor visuals inside the cockpit. The most commonly reported issue with the flight model was that the rotation speed at takeoff was noticeably higher than what would be expected in the real aircraft. Additionally, students reported the virtual aircraft behaving more similarly to a fighter aircraft rather than a T-45C. Further, students reported a noticeable jitter in companion aircraft during close formation flights. This jitter was only reported during in-close configurations. Lastly, the blurriness of most instruments and gauges in the cockpit made reading most cockpit displays difficult or not possible. Due to the inaccuracies in flight model and aircraft behaviors, students generally reported the devices as not being useful for initial or intermediate stage students. Counts of common responses are provided in Appendix 10.13.

T-6B PTN VR-PTT

The T-6B PTN device received positive feedback in several areas, including overall usability, cockpit avionics, environmental appearance, flight model, networking capabilities, and training utility. Students reported that overall system is user-friendly and relatively easy to set up. The cockpit layout and outside visuals were both reported as being realistic. The flight model was not perfect, but was generally reported as being accurate. Students responded favorably to being able to complete formation flights with other students while networked in the device. The T-6B PTN device would most likely be useful for building a sight picture and learning new content and as such, could increase performance in the aircraft.

Negative feedback regarding the T-6B PTN device was generally focused on visual clarity inside the cockpit, lack of realism in the HOTAS compared to the actual T-6B, and a lack of realism in virtual landmarks used for checkpoints. Students indicated the stick and throttle currently used in the T-6B PTN is not representative of the stick and throttle in the actual T-6B aircraft. In terms of visual clarity, students reported difficulty in reading some of the instruments and gauges in the cockpit due to blurriness. Additionally, lack of visual clarity in key landmarks in the virtual environment made certain navigation flights requiring visual checkpoints difficult. Counts of common responses are provided in Appendix 10.14.

Research Question 1 (Reactions) Summary

To understand the first level of Kirkpatrick’s Training Evaluation of Reactions, the researchers proposed the following hypothesis: *“To what degree do trainees and instructors react favorably to the devices?”* The research team analyzed data collected from the comprehensive questionnaire. Generally, there were differences in reactions among the systems and their mean scores centered slightly below and above neutral. Specifically, the T-6B PTN VR-PTTs ranked the lowest on overall positivity, perceived utility, visibility, and realism as compared to the T-45C devices. Interestingly, the T-6B PTN VR-PTT was ranked highest for usability. Considering that most participants preferred not to use the devices, the SNAs reported that both the T-6B and T-45C devices were useful for building a site picture. The T-6B participants considered that their VR devices were useful for Contacts stage. Although conducting multi-ship operations were ranked the lowest for T-6B PTN VR-PTT potential use, building a sight picture, practicing FTI procedures, and developing situational awareness were ranked highest for valuable uses when networked with another SNA. For the T-45C participants, The MRVS was most often considered useful for Familiarization and Formation stages. Additionally, the SNAs generally considered their VR-PTTs useful for Familiarization, Formation, Tactical Formation, and somewhat for Basic Fighter Maneuvering stages. When networked, understanding the other aircraft’s positioning was considered a strength and practicing communications as a challenge. All feedback considered, the SNAs’ reactions were neutrally favorable to the devices. With upgrades to the systems and mandatory incorporation in the syllabus, these reactions may become more positive and universal usage may increase.

5.3.12. Research Question 2: Learning

The T-45C and T-6B are training aircraft, and therefore performance within these aircraft is more closely related to learning within the training environment than it is to behavior within the operational environment. Thus, performance data were considered representative of Kirkpatrick's Learning level of evaluation. Performance data from the Training Integration Management System (TIMS) were requested for all SNAs who responded to at least one questionnaire and provided a DODID. From the pool of 966 participants, data were requested for 902 (those who provide a DODID) and archival data for 100 non-participants who graduated or attrited (left the training program) before the systems were delivered. However, CNATRA personnel only delivered data for 341 participants, including a mix of T-45C system users, T-6B system users, and respondents who indicated that they did not use the systems. Prior to data collection, a sample of archival TIMS data from intermediate and advanced syllabi were provided for 178 SNAs who had not had access to the VR/MR systems. To compensate for not receiving the requested archival TIMS data, the research team planned to use the sample dataset during analysis for T-45C devices. However, a comparison of archival SNAs to participants who did not use the VR/MR devices indicated that event raw scores were higher for archival than current SNAs, archival mean = 1.06, current mean = 1.03, $t(54.37) = 6.09$, $p < .001$. This suggests that performance for the archival sample was better overall than for the evaluation participants without any intervention. Therefore, archival SNAs were not comparable to current SNAs, and including them in analyses could obscure any effects of the VR/MR systems. As a result, the research team did not include the archival sample in data analysis.

As we do not know the exact date that each participant began using the systems, a rough cutoff date of 01 December 2018 was selected as the criterion for including participant scores in data analysis. Scores after 01 December 2018 were considered relevant, and earlier scores were discarded. Researchers are not confident that the dates associated with event grades were accurate.

The TIMS data included item grades, maneuver item file scores (MIFs; which correspond to the cutoff for a passing grade), and several types of count data. SNAs’ overall grade, the Navy Standard Score (NSS), was not included.

From these raw data, several scores were calculated:

(a) Event Raw Score (sum of item grades divided by sum of minimum acceptable item grades for the event) was calculated for graded events. A passing Event Raw Score is 1. An Event Raw Score below 1 indicates poor performance, and an Event Raw Score above 1 indicates better than acceptable performance. Event raw score data were insufficient for T-6B system users, due to the provided event dates being before the cutoff date of 1 December 2018. However, event raw scores were available for participants who used the T-45C devices. For the purposes of data analysis, Event Raw Score was not calculated separately for each repetition of an event. Instead, an overall Event Raw Score was calculated for all repetitions of an event, in order to provide an overall picture of event performance.

(b) Re-fly Count: For 4000-level events (aircraft flights), the number of re-flys that did not result from an incomplete flight were calculated. Incomplete flights can be due to non-performance factors such as weather, so that re-flys that follow incompletes may be irrelevant to performance measures.

(c) Marginal Count: For 4000-level events, the number of events graded as Marginal were calculated. Marginal performance is performance that borders on passing, but is not entirely satisfactory.

(d) Unsatisfactory Count: For 4000-level events, the number of events graded as Unsatisfactory were calculated.

(e) Overall Count of Poor Performance Events: For 4000-level events, the total number of events that indicated poor performance was calculated. This included Re-flys, Marginal Flights, Unsatisfactory Flights, Warmup Sorties, Supplemental Sorties, Progress Checkrides, and Elimination Checkrides. Warmup sorties are not graded, and are conducted after a break in training, but may be treated as a graded event if the performance is acceptable, or marked as a warmup sortie if performance is unacceptable. Supplemental sorties are not graded, and are conducted to address deficiencies in performance. Progress checkrides are graded, and are conducted to check progress when progress has been unsatisfactory. Finally, elimination checkrides are graded, and are conducted when performance has been unsatisfactory; failing an elimination checkride results in elimination from the training program. Thus, an increased number of any of the above-listed events can indicate a decrease in performance.

(f) Number of Events Needed to Reach MIF: SNAs have to complete a number of items (i.e. maneuver or task) to complete each event. The Maneuver Item Files (MIFs) contain this list of items for each event and the minimum score needed for each item. Generally, if SNAs do not satisfy the minimum score for each critical item, then they will be required to repeat the event until the minimum score is met. To analyze the number of events needed to meet MIF, researchers would need to a) identify all critical items for each event, b) determine if the item met the minimum score, and c) count the number of times they had to complete an event to meet the minimum score for all items. It is possible to receive an Event Raw Score above 1 without meeting MIF for each individual item within the event. However, the computing power needed for these calculations exceeded the technology available to the research team. As a proxy, researchers counted the number of times an SNA had to complete an event to receive an event raw score of 1 or greater. The definition of event raw score is the sum of item grades divided by sum of minimum acceptable item grades for the event.

Performance among participants who had used the systems was compared to performance among those who indicated in the wrap-up questionnaire that they had not used the systems.

VR/MR Usage and Performance in the Aircraft

Hypothesis 2a:

VR/MR device usage is expected to have a positive relation with performance in the aircraft (Navy Standard Score, re-flys, marginals, unsatisfactories, raw scores on events, and events to meet MIF).

T-6B PTN VR-PTT Usage and Overall Poor Performance

Archival data for T-6B SNAs prior to 01 December 2018 were not delivered to the team for analyses. From the data that were collected in the wrap-up questionnaire, there were TIMS data from 45 SNAs who reported using the T-6B PTN device and 25 SNAs who reported not using the devices. To test if there was a relation between T-6B PTN device usage and performance, the research team compared Overall Count of Poor Performance Events in Contact, Instruments, Navigation, and Formation stages of the primary syllabus (Naval Air Training Command, 2017) between participants who did and did not use the T-6B VR-PTT. Spearman's rank-order correlation was utilized to examine those relations. For these analyses, T-6B PTN VR-PTT usage was dummy coded such that those who reported not using the devices were coded as 0 and SNAs who reported using the devices were coded as 1. A positive correlation would suggest that the use of the devices is associated with poor performance (i.e., more negative events). Conversely, a negative correlation would suggest that the use of the devices is associated with better performance (i.e., fewer negative events). A p-value of less than .05 would indicate a statistically significant relation between the variables. For overall poor performance events across all stages, there was no statistically significant relation between device usage and poor performance ($\rho = -0.22$, $p = .075$). That is, there was no association between using the T-6B devices and poor performance in the aircraft for the SNAs that participated in this evaluation. Although the p-value was greater than .05, the trend for a negative correlation (the use of the devices being related to positive performance in the T-6B aircraft) may indicate that a significant relation would have been observed with a larger sample size. The same analyses were conducted separately for each of the four stages. For these analyses, the poor performance composite score was calculated for each stage. There were no significant correlations observed between using the devices and poor performance for Contact, Instruments, or Formation (see Table 21). However, a weak negative correlation for the Contact stage may suggest that the usage of the T-6B PTN devices could be associated with better performance in the T-6B aircraft, although not at the statistically significant level of .05 or less. This analysis could not be performed for Navigation because there was an insufficient number of SNAs with poor performance.

Table 21. T-6B PTN VR-PTT Usage and Overall Poor Performance Flight Data in the T-6B

T-6B	***N***		**Minimum**		**Median**		**Maximum**		**Mean**		**Std. Dev**		**Correlation**
	Used	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	
Overall Count	45	25	0	0	2	4	27	22	3.69	5.88	4.85	5.59	ρ = -0.22, p = .075
C_Count	43	25	0	0	2	4	26	22	3.58	5.56	4.85	5.41	ρ = -0.21, p = .084
I_Count	44	25	0	0	0	0	2	3	0.14	0.16	0.46	0.62	ρ = 0.02, p = 0.899
N_Count	41	25	0	0	0	0	0	0	0.00	0.00	0.00	0.00	–
F_Count	40	24	0	0	0	0	2	2	0.15	0.17	0.53	0.48	ρ = -0.07, p = .569

T-45C VR/MR Device Usage and Overall Poor Performance

To analyze if there was a relation observed for the T-45C VR-PTT and MRVS usage and overall poor performance, the research team conducted independent-samples *t* tests for overall poor performance between current SNAs who did and did not use the devices. Where Levene's test for equality of variances was significant at $p < .05$, the *t* test was corrected for unequal variances.

From the TIMS data provided, there were 73 SNAs who reported using the devices and 18 who reported not using the devices. T-45C analyses employed the same approach as T-6B analyses (Spearman rank order correlation). Overall Count of Poor Performance Events was compared to each of the four chapters (i.e., Contacts, Instruments, Formation, and Tactical) and all 21 stages in the T-45C Master Curriculum Guide (Naval Air Training Command, 2014). The only relation that was statistically significant was for poor performance in the Formation chapter (ρ = -0.33, p = 0.002). This negative relation suggests that usage of the T-45C VR/MR device was associated with fewer negative events (better performance) in the aircraft for Formation (see Table 22Table 22; statistically significant results are denoted in bold).

Table 22. T-45C VR/MR Usage and Overall Poor Performance Flight Data in the T-45C

T-45C	*N*		Minimum		Median		Maximum		Mean		Std. Dev		Correlation
	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	
Overall Count	73	18	0	2	8.00	10.00	32	32	9.16	11.67	7.38	7.90	ρ = -0.14, p = 0.179
AN Count	57	15	0	0	0.00	0.00	6	0	0.61	0.00	1.46	0.00	ρ = 0.22, p = 0.067
BFM Count	18	3	0	0	0.00	0.00	8	4	1.50	1.33	2.18	2.31	ρ = 0.03, p = 0.914
BI Count	6	4	0	0	0.00	0.00	2	4	0.33	1.00	0.82	2.00	ρ = -0.15, p = 0.675
CO Count	0	0	-	-	-	-	-	-	-	-	-	-	-
CQL Count	22	5	6	6	8.00	10.00	21	13	10.32	10.20	4.30	2.63	ρ = -0.08, p = 0.689
DIV Count	50	15	0	0	0.00	0.00	3	2	0.14	0.40	0.54	0.83	ρ = -0.17, p = 0.18
EP Count	2	2	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-

FAM Count	51	15	0	0	2.00	2.00	10	7	2.59	2.07	2.56	2.02	*ρ* = 0.07, *p* = 0.603
FCL Count	52	15	0	0	0.00	0.00	4	6	0.75	0.73	1.12	1.62	*ρ* = 0.07, *p* = 0.570
FRM Count	47	13	0	0	0.00	2.00	8	12	0.89	2.38	1.52	3.40	*ρ* = -0.24, *p* = 0.071
IR Count	42	12	0	0	0.00	0.00	2	2	0.24	0.17	0.62	0.58	*ρ* = 0.07, *p* = 0.622
NFM Count	51	15	0	0	0.00	0.00	3	4	0.39	0.40	0.83	1.21	*ρ* = 0.05, *p* = 0.668
NFR Count	20	5	0	0	0.00	2.00	6	4	1.05	2.00	1.91	2.00	*ρ* = -0.235, *p* = 0.258
OCF Count	30	11	0	0	0.00	0.00	2	0	0.07	0.00	0.37	0.00	*ρ* = 0.10, *p* = 0.552
ON Count	19	3	0	0	0.00	0.00	2	2	0.16	0.67	0.50	1.16	*ρ* = -0.245, *p* = 0.272
RI Count	11	6	0	0	0.00	0.00	4	2	0.36	0.67	1.21	1.03	*ρ* = -0.27, *p* = 0.304
RR Count	18	3	0	0	0.00	0.00	1	0	0.11	0.00	0.32	0.00	*ρ* = 0.13, *p* = 0.567
SEM Count	18	3	0	0	0.00	0.00	1	0	0.06	0.00	0.24	0.00	*ρ* = 0.09, *p* = 0.694
STK Count	18	3	0	0	0.00	0.00	1	1	0.11	0.33	0.32	0.58	*ρ* = -0.22, *p* = 0.333
TAC Count	18	3	0	1	1.00	2.00	6	2	1.72	1.67	1.99	0.58	*ρ* = -0.7, *p* = 0.760
Contacts Chapter	54	15	0	0	3.00	2.00	14	9	3.57	3.20	3.29	2.93	*ρ* = 0.04, *p* = 0.754
Instruments Chapter	60	15	0	0	1.60	0.00	6	4	0.85	0.67	1.60	1.23	*ρ* = 0.03, *p* = 0.806
Formation Chapter	67	18	0	0	1.71	2.00	9	12	1.04	2.61	1.71	2.85	***ρ* = -0.33, *p* = 0.002**
Tactical Chapter	24	5	1	10	6.37	13.00	26	15	12.21	12.60	6.37	2.5	*ρ* = -0.10, *p* = 0.591

There was a specific interest in the relations among VR device usage and (a) NSS, (b) re-flys, (c) marginals, (d) unsatisfactories, (e) raw scores on events, and (f) events to meet MIF. However, as stated above, NSS was not included in the TIMS data. Results for re-flys, marginal, unsatisfactories, raw scores on events, and events to meet MIF are presented in separate sections below.

T-6B PTN VR-PTT Usage and Re-flys

The research team conducted Spearman rank-order correlations between T-6B PTN VR-PTT usage and re-flys summed across all stages, and then separately for each stage. None of the relations were statistically significant. However, as reflected in the previous analyses, there were negative trends between T-6B PTN VR-PTT usage and total re-flys and Contact re-flys (see Table 23).

Table 23. T-6B PTN VR-PTT Usage and Re-flys

T-6B	***N***		**Minimum**		**Median**		**Maximum**		**Mean**		**Std. Dev**		**Correlation**
	Used	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	
Total Re-flys	45	25	0	0	1.00	2.00	15	13	2.04	3.60	2.68	3.57	ρ = -.21, p = .080
C Re-flys	43	25	0	0	1.00	2.00	14	13	1.98	3.40	2.61	3.40	ρ = -.22, p = .075
I Re-flys	44	25	0	0	0.00	0.00	1	1	0.09	0.08	0.29	0.28	ρ = .02, p = .879
N Re-flys	41	25	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
F Re-flys	40	24	0	0	0.00	0.00	1	1	0.08	0.13	0.27	0.34	ρ = -.08, p = .514

T-45C VR/MR Device Usage and Re-flys

To investigate if there was a relation between T-45C VR/MR device usage and re-flys, the research team conducted Spearman rank order correlations for total re-flys and for each of the four chapters (i.e., Contacts, Instruments, Formation, and Tactical) and all 21 stages. Among all of the re-fly analyses, the only statistically significant finding was for Formation re-flys (ρ = -.326, p = .002). This negative relation indicates that VR/MR device usage was associated with fewer poor performance events in the aircraft while conducting Formation events. That is, T-45C VR/MR device usage was associated with better performance in the aircraft for Formation events (see Table 24; statistical significant results are denoted in bold).

Table 24. T-45C VR/MR Usage and Re-flys

T-45C	*N*		Minimum		Median		Maximum		Mean		Std. Dev		Correlation
	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	
Total Re-flys	73	18	0	1	3.00	3.50	17	10	4.40	4.72	3.62	3.18	ρ = -.06, p = .567
AN Re-flys	57	15	0	0	0.00	0.00	3	0	0.32	0.00	0.74	0.00	ρ = .22, p = .067
BFM Re-flys	18	3	0	0	0.00	0.00	4	2	0.78	0.67	1.11	1.16	ρ = .04, p = .871
BI Re-flys	6	4	0	0	0.00	0.00	1	2	0.17	0.50	0.41	1.00	ρ = -.15, p = .675
CO Re-flys	0	0	-	-	-	-	-	-	-	-	-	-	-
CQL Re-flys	22	5	3	3	4.00	5.00	11	7	5.23	5.20	2.18	1.48	ρ = -.09, p = .641
DIV Re-flys	50	15	0	0	0.00	0.00	1	1	0.08	0.20	0.27	0.41	ρ = -.16, p = .194
EP Re-flys	2	2	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
FAM Re-flys	51	15	0	0	1.00	1.00	5	4	1.41	1.07	1.28	1.10	ρ = .12, p = .353
FCL Re-flys	52	15	0	0	0.00	0.00	2	1	0.37	0.27	0.56	0.46	ρ = .06, p = .613
FRM Re-flys	47	13	0	0	0.00	1.00	4	6	0.49	1.23	0.78	1.69	ρ = -.23, p = .075
IR Re-flys	42	12	0	0	0.00	0.00	1	1	0.14	0.08	0.35	0.29	ρ = .07, p = .597
NFM Re-flys	51	15	0	0	0.00	0.00	2	2	0.24	0.20	0.51	0.56	ρ = .06, p = .636
NFR Re-flys	20	5	0	0	0.00	1.00	3	2	0.55	1.00	1.00	1.00	ρ = -.24, p = .258
OCF Re-flys	30	11	0	0	0.00	0.00	1	0	0.03	0.00	0.18	0.00	ρ = .10, p = .552
ON Re-flys	19	3	0	0	0.00	0.00	1	1	0.11	0.33	0.32	0.58	ρ = -.228, p = .307
RI Re-flys	11	6	0	0	0.00	0.00	2	1	0.18	0.33	0.60	0.52	ρ = -.27, p = .304
RR Re-flys	18	3	0	0	0.00	0.00	1	0	0.11	0.00	0.32	0.00	ρ = .13, p = .567
SEM Re-flys	18	3	0	0	0.00	0.00	1	0	0.06	0.00	0.24	0.00	ρ = .09, p = .694
STK Re-flys	18	3	0	0	0.00	0.00	1	1	0.11	0.33	0.32	0.58	ρ = -.22, p = .333
TAC Re-flys	18	3	0	1	0.50	1.00	3	1	0.89	1.00	1.02	0.00	ρ = -.107, p = .643

Contacts Chapter Re-flys	54	15	0	0	2.00	1.00	8	5	1.93	1.53	1.76	1.51	*ρ* = .09, *p* = .448
Instruments Chapter Re-flys	60	15	0	0	0.00	0.00	3	2	0.45	0.33	0.81	0.62	*ρ* = .04, *p* = .749
Formation Chapter Re-flys	67	18	0	0	0.00	1.00	5	6	0.57	1.33	0.91	1.41	***ρ* = -.326, *p* = .002**
Tactical Chapter Re-flys	24	5	1	5	5.50	7.00	14	7	6.33	6.60	3.35	1.52	*ρ* = -.12, *p* = .531

T-6B PTN VR-PTT Usage and Marginals

The research team was not able to conduct correlational analyses because there were no marginals recorded for the SNAs in this study.

T-45C VR/MR Usage and Marginals

To evaluate if there is a relation between the usage of the T-45C VR/MR devices and marginal events, the research team analyzed the total count of marginals, as well as counts of marginals for the four syllabus chapters and 21 stages. The relation for T-45C VR/MR usage and total marginals was statistically significant (ρ = -.21, p = .043). That is, the SNAs who reported usage of the devices had fewer marginal events than those who reported no usage. FCL was the only stage that had marginals recorded for the SNAs in this evaluation. Though the relation was not statistically significant at the .05 threshold, the FCL marginal has a negative trend indicating more device usage linking to fewer FCL marginals (see Table 25; statistical significant results are denoted in bold).

Table 25. T-45C VR/MR Usage and Marginal Events

T-45C	***N***		**Minimum**		**Median**		**Maximum**		**Mean**		**Std. Dev**		**Correlation**
	Used	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	
Total Marginals	73	18	0	0	0.00	0.00	0	4	0.00	0.22	0.00	0.94	***ρ* = -.21, *p* = .043**
AN Marginals	57	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-

BFM Marginals	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
BI Marginals	6	4	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
CO Marginals	0	0	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
CQL Marginals	22	5	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
DIV Marginals	50	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
EP Marginals	2	2	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
FAM Marginals	51	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
FCL Marginals	52	15	0	0	0.00	0.00	0	4	0.00	0.27	0.00	1.03	$\rho = -.23$, $p = .062$
FRM Marginals	47	13	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
IR Marginals	42	12	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
NFM Marginals	51	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
NFR Marginals	20	5	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
OCF Marginals	30	11	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
ON Marginals	19	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
RI Marginals	11	6	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
RR Marginals	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
SEM Marginals	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
STK Marginals	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
TAC Marginals	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
Contacts Chapter Marginals	54	15	0	0	0.00	0.00	0	4	0.00	0.27	0.00	1.03	$\rho = -.23$, $p = .057$
Instruments Chapter Marginals	60	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
Formation Chapter Marginals	67	18	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-

Tactical Chapter Marginals	24	5	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-

T-6B PTN VR-PTT Usage and Unsatisfactory Events

To evaluate if there were relations between T-6B PTN VR-PTT device usage and unsatisfactory events, the research team conducted Spearman rank order correlations for overall unsatisfactory event count and for unsatisfactory event count in each stage. None of these relations were significant, indicating that there was no association between using the T-6B PTN VR-PTT devices and unsatisfactory events in the T-6B aircraft. Analyses for Navigation and Formation Chapters could not be conducted due to insufficient unsatisfactory events among the SNAs in this evaluation (see Table 26).

Table 26. T-6B PTN VR-PTT Usage and Unsatisfactory Events in the T-6B Aircraft

T-6B	***N***		**Minimum**		**Median**		**Maximum**		**Mean**		**Std. Dev**		Correlation
	Used	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	**Used**	**Not Used**	
Overall Unsats	45	25	0	0	0.00	0.00	1	1	0.02	0.04	0.15	0.20	$\rho = -.05, p = .674$
C Unsats	43	25	0	0	0.00	0.00	1	0	0.02	0.00	0.15	0.00	$\rho = .09, p = .450$
I Unsats	44	25	0	0	0.00	0.00	0	0	0.00	0.04	0.00	0.20	$\rho = -.16, p = .187$
N Unsats	41	25	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
F Unsats	40	24	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-

T-45C VR/MR Usage and Unsatisfactory Events

The research team completed multiple correlational analyses to examine if there was an association between T-45C VR/MR device usage and total unsatisfactory events, as well as unsatisfactory events for the four syllabus Chapters, and for the 21 stages. None of those Spearman rank order correlations were statistically significant; there was no relation between using the T-45C devices and unsatisfactory events (see Table 27).

Table 27. T-45C VR/MR Usage and Unsatisfactory Events

T-45C	*N*		Minimum		Median		Maximum		Mean		Std. Dev		Correlation
	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	
Overall Unsats	73	18	0	0	0.00	0.00	1	0	0.03	0.00	0.164	0.00	ρ = -.074, p = .483
AN Unsats	57	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
BFM Unsats	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
BI Unsats	6	4	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
CO Unsats	0	0	-	-	-	-	-	-	-	-	-	-	-
CQL Unsats	22	5	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
DIV Unsats	50	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
EP Unsats	2	2	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
FAM Unsats	51	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
FCL Unsats	52	15	0	0	0.00	0.00	1	0	0.02	0.00	0.139	0.00	ρ = .066, p = .595
FRM Unsats	47	13	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
IR Unsats	42	12	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
NFM Unsats	51	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
NFR Unsats	20	5	0	0	0.00	0.00	1	0	0.05	0.00	0.224	0.00	ρ = .102, p = .627
OCF Unsats	30	11	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
ON Unsats	19	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
RI Unsats	11	6	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
RR Unsats	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
SEM Unsats	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
STK Unsats	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
TAC Unsats	18	3	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
Contacts Chapter Unsats	54	15	0	0	0.00	0.00	1	0	0.02	0.00	0.136	0.00	ρ = .064, p = .602
Instruments Chapter Unsats	60	15	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-
Formation Chapter Unsats	67	18	0	0	0.00	0.00	1	0	0.01	0.00	0.122	0.00	ρ = 0.57, p = .607
Tactical Chapter Unsats	24	5	0	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	-

T-6B PTN VR-PTT Usage and Event Raw Score

All of the event item data provided for primary syllabus participants were from before 01 December 2018. Therefore, the data were recorded before participants had access to the T-6B PTN VR-PTT. The Event Raw Score analyses depend on event item data. Thus, the research team was unable to conduct these analyses for the T-6B PTN VR-PTTs.

T-45C VR/MR Usage and Event Raw Score

To determine if there were relations between T-45C VR/MR device usage and Event Raw Score (EVR), the research team conducted independent-samples *t* tests for overall EVR, and for EVR in each chapter and stage. Where Levene's test for equality of variances was significant at $p < .05$, the *t* test was corrected for unequal variances. All of the significant comparisons were in the Formation chapter, and in the FRM and STK stages (See Table 28Table 28; statistically significant results are denoted in bold). In all three cases, mean EVR was higher for participants who used the T-45C devices than for participants who did not use them. That is, SNAs who used the T-45C devices performed better in FRM and STK stages and the Formation chapter than those who did not.

Table 28. T-45C VR/MR Usage and Event Raw Score

T-45C	Mean		Standard Deviation		Mean Difference (Used-Not Used)
	Used	Not Used	Used	Not Used	
Overall EVR	1.037	1.028	0.022	0.016	0.009, $t(89) = 1.62$, $p = .109$
AN EVR	1.038	1.030	0.025	0.023	0.008, $t(71) = 1.95$, $p = .291$
BFM EVR	1.009	1.011	0.022	0.047	-0.002, $t(2.15) = 1.12$, $p = .964$
BI EVR	1.060	1.081	0.044	0.031	-0.021, $t(9) = 0.05$, $p = .398$
CO EVR	-	-	-	-	-
CQL EVR	1.008	0.985	0.048	0.068	0.023, $t(20) = 0.73$, $p = .473$
DIV EVR	0.989	0.990	0.034	0.037	0.001, $t(63) = 0.07$, $p = .946$
EP EVR	1.069	1.037	0.027	0.042	0.032, $t(2) = 0.92$, $p = .456$
FAM EVR	1.051	1.035	0.053	0.028	0.016, $t(36.54) = 1.38$, $p = .175$
FCL EVR	1.006	1.001	0.059	0.025	0.005, $t(62) = 0.14$, $p = .892$
FRM EVR	1.043	1.011	0.032	0.035	**0.032, $t(59) = 3.14$, $p = .003$**
IR EVR	1.002	1.000	0.015	0.009	0.002, $t(51) = 0.53$, $p = .601$
NFM EVR	1.052	1.043	0.032	0.035	0.009, $t(64) = 0.92$, $p = .359$
NFR EVR	1.067	1.075	0.035	0.029	-0.008, $t(24) = 0.47$, $p = .643$
OCF EVR	1.087	1.061	0.073	0.072	0.026, $t(58) = 1.17$, $p = .247$
ON EVR	1.022	1.028	0.033	0.014	-0.006, $t(19) = 0.30$, $p = .768$

RI EVR	1.088	1.046	0.061	0.034	0.042, $t(15) = 1.53$, $p = .147$
RR EVR	1.001	0.989	0.016	0.008	0.012, $t(19) = 1.30$, $p = .210$
SEM EVR	1.009	1.014	0.040	0.052	-0.005, $t(19) = 0.18$, $p = .860$
STK EVR	1.056	1.030	0.027	0.010	**0.026, $t(8.14) = 1.64$, $p = .016$**
TAC EVR	1.021	1.012	0.019	0.007	0.009, $t(19) = 0.80$, $p = .432$
Contacts Chapter EVR	1.062	1.054	0.058	0.046	0.008, $t(87) = 0.56$, $p = .580$
Instruments Chapter EVR	1.032	1.026	0.023	0.017	0.006, $t(73) = 0.97$, $p = .335$
Formation Chapter EVR	1.040	1.019	0.036	0.034	**0.021, $t(84) = 2.20$, $p = .030$**
Tactical Chapter EVR	1.027	1.020	0.017	0.018	0.007, $t(27) = 0.83$, $p = .411$

T-6B PTN VR-PTT Usage and Events to Meet MIF

All of the event item data provided for primary syllabus participants were from before 01 December 2018. Therefore, the data were recorded before participants had access to the T-6B PTN VR-PTT. As with Event Raw Score, MIF analyses depend on event item data, and the research team was unable to conduct MIF analyses for the T-6B PTN VR-PTT.

T-45C VR/MR Usage and Events to Meet MIF

To determine if usage of the T-45C VR/MR devices affected how many events were required to reach the MIF, the research team conducted Spearman rank order correlations on the sum of events required to meet the MIF. Correlations were calculated for overall events, as well as events for each chapter and stage. There were no data for the CO stage, and there was no variation between groups for the EP and FCL stages, so statistical testing could not be completed for these stages. For all other comparisons, the only significant relation was with the Instruments chapter. The number of events needed to reach MIFs in the Instruments chapter was negatively correlated with device usage; that is, people who used the T-45C VR/MR devices needed fewer events to reach MIFs (indicating better performance). Although not statistically significant at the $p = .05$ level, there was also a trend for the FRM stage to be positively correlated with device usage, such that people who used the T-45C VR/MR devices needed more events to reach MIFs (indicating worse performance; see Table 29).

Table 29. T-45C VR/MR Usage and Events to Meet MIF

T-45C	*N*		Minimum		Median		Maximum		Mean		Std. Dev		Correlation
	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	Used	Not Used	
Overall Count	73	18	2	6	47.00	46.00	77	82	41.84	46.89	20.12	21.76	ρ = -.10, p = .357
AN Count	58	15	1	1	9.50	10.00	12	12	8.66	8.93	3.12	2.82	ρ = -.01, p = .913
BFM Count	18	3	1	1	9.00	12.00	12	13	8.06	8.67	2.92	6.66	ρ = -.20, p = .374
BI Count	6	5	2	3	3.50	5.00	11	11	5.67	7.00	4.18	3.74	ρ = -.299, p = .372
CO Count	0	0	-	-	-	-	-	-	-	-	-	-	-
CQL Count	5	2	1	2	3.00	2.00	3	2	2.40	2.00	0.89	0.00	ρ = .34, p = .453
DIV Count	49	15	1	2	3.00	3.00	5	5	3.33	3.13	1.20	0.92	ρ = .10, p = .434
EP Count	2	2	3	3	3.00	3.00	3	3	3.00	3.00	0.00	0.00	-
FAM Count	37	12	1	1	12.00	12.50	20	20	10.54	12.08	6.67	6.24	ρ = -.09, p = .541
FCL Count	3	2	2	2	2.00	2.00	2	2	2.00	2.00	0.00	0.00	-
FRM Count	48	13	1	6	13.00	10.00	16	14	13.00	10.38	3.69	2.40	ρ = .23, p = .073
IR Count	41	12	1	3	5.00	4.50	7	6	5.00	4.58	1.30	1.08	ρ = .19, p = .163
NFM Count	51	15	2	2	3.00	3.00	7	6	3.37	3.53	0.96	0.99	ρ = -.04, p = .735
NFR Count	21	5	1	4	5.00	5.00	7	6	4.86	5.00	1.62	1.00	ρ = -.01, p = .974
OCF Count	44	12	1	1	1.50	1.00	2	2	1.50	1.25	0.51	0.45	ρ =.21 , p = .127
ON Count	17	3	2	7	7.00	7.00	9	8	6.41	7.33	2.45	0.58	ρ = -.03, p = .917
RI Count	11	6	3	8	12.00	11.50	13	14	10.09	11.17	3.73	2.48	ρ = -.14, p = .588
RR Count	18	3	1	1	3.00	2.00	4	3	2.56	2.00	0.86	1.00	ρ = .22, p = .349
SEM Count	16	3	2	2	3.00	3.00	4	4	3.06	3.00	0.85	1.00	ρ = .03, p = .910
STK Count	18	3	8	10	14.00	12.00	16	15	13.78	12.33	2.07	2.52	ρ = .25, p = .269
TAC Count	18	3	3	4	8.00	7.00	10	8	7.78	6.33	1.93	2.08	ρ = .26, p = .251

Contacts Chapter	68	18	1	1	4.00	9.00	27	27	8.53	11.06	8.66	9.14	ρ = -.12, p = .266
Instruments Chapter	60	15	1	7	13.50	16.00	39	45	12.80	19.80	8.51	12.39	**ρ = -.23, p =.044**
Formation Chapter	68	18	1	2	13.00	13.00	19	17	11.69	11.50	5.75	4.77	ρ = .07, p =.519
Tactical Chapter	24	5	1	2	37.00	3.00	49	48	29.33	9.20	17.77	23.23	ρ = .19, p = .344

Effects on Training Behavior

Changed Approaches to Studying and Instruction

Respondents to the wrap-up questionnaire were asked whether or not their usage of the VR/MR systems changed their approach to studying. For both T-45C and T-6B systems, SNAs were more likely to report that the devices did not change their approach to studying than to report that it did, T-6B $\chi^2(1, N=320) = 126.50$, $p < .001$; T-45C $\chi^2(1, N=154) = 57.32$, $p < .001$. For the T-6B SNAs, 30 participants reported that they changed their approach to studying, while 290 participants reported no change. For T-45C SNAs, 16 participants reported affirmatively, whereas 138 reported no changes to their study approach. This did not differ between T-45C and T-6B systems, $\chi^2(1, N=474) = 0.12$, $p = .727$.

Respondents were also asked to report whether or not the VR/MR systems enabled them to change the focus of their time with instructors. For both T-45C and T-6B systems, SNAs were again more likely to say that the systems did not change their focus with instructors than to say that it did, T-6B $\chi^2(1, N=320) = 110.95$, $p < .001$; T-45C $\chi^2(1, N=154) = 48.89$, $p < .001$. This did not differ between the SNAs who used T-45C and T-6B systems, $\chi^2(1, N=474) = 0.20$, $p = .655$, 37 yes and 283 no responses for T-6B, 20 yes and 134 no responses for T-45C.

In summary, SNAs generally believed that the VR/MR systems did not change the way they approached studying, and did not change the focus of their sessions with instructors. However, study and instruction behavior outside the VR/MR systems could remain the same while performance overall could improve due to use of VR/MR.

Changed Behavior during Training Flights

Respondents to the wrap-up questionnaire were asked if the VR/MR systems changed their visual scan head movements compared to other trainers or the live aircraft. For both T-6B and T-45C systems, respondents were more likely to report that the systems did not change their scan head movements than that they did, T-6B $\chi^2(1,N=227) = 83.57$, $p < .001$; T-45C $\chi^2(1,N=111) = 23.74$, $p < .001$. However, this tendency differed between T-6B and T-45C systems, $\chi^2(1,N=338) = 4.50$, $p = .034$, 24 yes and 203 no responses for T-6B, 21 yes and 90 no responses for T-45C, such that T-45C users were more likely than T-6B users to say that the systems had changed their scan head movements.

Finally, respondents to the wrap-up questionnaire were asked to indicate how strongly they agreed that the VR/MR systems improved their performance in training, on a scale from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). A Mann-Whitney U test was conducted to determine if the responses differed between the T-6B VR-PTT and the T-45C systems. There was no significant difference between T-6B and T-45C systems, U = 23469.50, $p = .411$, T-6B Mdn = 3, $M = 2.93$; T-45C Mdn = 3, $M = 3.06$. Thus, for both T-6B and T-45C systems, responses tended to cluster around the “Neutral” response.

Device Access Conditions and SNA Performance

The research team tested the following hypothesis:

H2b: *SNA performance is expected to differ among the three VR-PTT devices access conditions (e.g., no access, access for part of training, and access for entire training).*

Although archival data were requested, the research team was not given access to archival TIMS data as originally intended. Without archival data, it was not possible to analyze performance data as three distinct groups based on SNAs access to the device (e.g., no access, access for part of training, and access for entire training). As such, the research team could only analyze data from current SNAs who would have a combination of access for part or all of training. However, without the ability to apply any experimental controls to current student’s access to the devices the research team was also unable to analyze current SNAs as two distinct groups (e.g. access for part of training, and access for entire training).

XR System Usage

H2c: *Type of use (i.e., purpose of the VR-PTT practice session) will have a relation on performance in the aircraft*

Frequency and Duration of Use

Respondents to the wrap-up questionnaire were asked how often they used the VR/MR devices. The most common responses were never (202 out of 326 responses for sites with T-6B VR-PTTs; 98 out of 162 responses for sites with T-45C systems), once per month (93 for T-6B VR-PTTs; 57 for T-45C systems), and once per week (31 for T-6B VR-PTTs; 7 for T-45C VR-PTTs). The frequency of these three response categories was compared between T-6B VR-PTTs and T-45C systems using a χ^2 test. The test was not significant, $\chi^2(2,N=488) = 5.34$, $p = .069$. Post-hoc tests were not conducted, but the general trend indicated that T-45C users were more likely to use the systems weekly, whereas the T-6B users were more likely to use the VR-PTT monthly.

There were two questions relevant to duration of each practice session. In the flight log questionnaire, respondents were asked to record the duration of each practice session they logged. In the wrap-up questionnaire, respondents were asked to report their average time spent on all practice sessions conducted with the systems under evaluation. Although the flight log questionnaire was completed shortly after each session and may provide more accurate responses than the retrospective question in the wrap-up questionnaire, no MRVS practice sessions were recorded in the flight log. Therefore, both the flight log and the wrap-up questionnaire results are reported here.

For the use duration question of the flight log, responses were analyzed using a one-way, between-subjects ANOVA with system as the three-level independent variable (T-6B PTN VR-PTT, T-45C 4E18 VR-PTT, T-45C BISim VR-PTT). The effect of system was significant, $F(2,252) = 7.90$, $p < .001$. Post-hoc tests indicated that the T-45C 4E18 VR-PTT sessions tended to be longer than the T-6B VR-PTT sessions, $p = .001$. The other comparisons were not significant, ps > .188. VR-PTT session duration is presented in Figure 4.

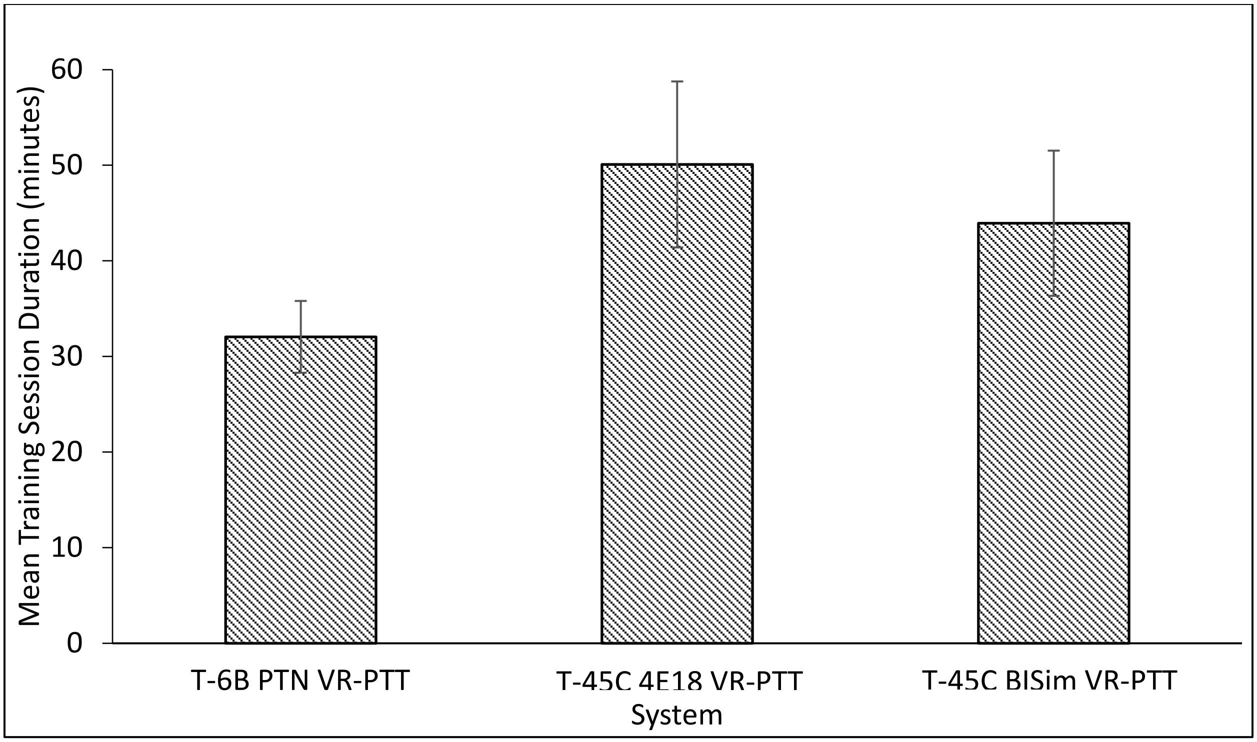

Figure 4. Mean Practice Session Duration in the VR-PTTs.

Mean duration was significantly shorter for the T-6B VR-PTT than for the T-45C 4E18 VR-PTT. Error bars represent 2 standard errors above and below the mean.

For the average session duration question of the wrap-up questionnaire, only participants who did not record their average duration as zero minutes were included, and use duration was compared between sites with the T-6B VR-PTT and the T-45C systems using a one-way, between-subjects ANOVA. The difference between T-6B sites and T-45C sites was not significant, $F(1, 233) = 0.05$, $p = .820$, T-6B $M = 40.08$ minutes, T-45C $M = 39.28$ minutes.

Finally, respondents to the wrap-up questionnaire were asked to estimate the total amount of time they had spent using the VR/MR systems. The total number of different systems differed between sites, with one type of system available at NAS Corpus Christi, Meridian, and Whiting Field, whereas NAS Kingsville had three different types of systems. Therefore, two different ANOVAs were conducted, one comparing the training sites that had a single type of VR-PTT, and one comparing total time using the three different systems available at NAS Kingsville. For single VR-PTT types, a one-way, between-subjects ANOVA was conducted with site

(NAS Corpus Christi, Meridian, and Whiting Field) as the independent variable and total time using as the dependent variable. The effect of training site was not significant, $F(2,219) = 0.18$, $p = .837$, Corpus Christi $M = 6.49$ hours, Meridian $M = 4.91$ hours, Whiting Field $M = 6.02$ hours. For the T-45C VR-PTTs and MRVS at Kingsville, a one-way, within-subjects ANOVA was conducted with system (T-45C 4E18 VR-PTT, T-45C BISim VR-PTT, and T-45C BISim MRVS) as the independent variable and total time using the system as the dependent variable. The effect of system was not significant, $F(1.49, 116.84) = 0.17$, $p = .780$, T-45C 4E18 VR-PTT $M = 1.37$ hours, T-45C BISim VR-PTT $M = 1.00$ hours, T-45C BISim MRVS $M = 1.09$ hours. Thus, the mean total time using the VR/MR systems was a few hours per user, and the total time did not significantly differ between systems.

In summary, the VR/MR systems were used with fairly low frequency, with the most common responses being that the respondent never used them, followed by once per month and once per week. When used, the practice sessions tended to last between half an hour and an hour, and the T-6B VR-PTT practice sessions may have been somewhat shorter than the T-45C 4E18 VR-PTT sessions. Finally, total time using the available VR/MR systems during the roughly 8-month duration of the study tended to be a few (mean of roughly 3.5 to 6.5) hours, and did not differ between training wings or between different systems at NAS Kingsville. These results indicate that use of the systems was infrequent and short.

Reasons for Use

Respondents to the flight log questionnaire were asked to provide their primary reason for using a system each time they used one. Participants who used paper copies of the flight log questionnaire occasionally gave more than one primary reason; for the purposes of this analysis, only the first-listed primary reason was used. As with use duration, only VR-PTT responses are available, as no flight log entries were made for T-45C MRVS session. For each VR-PTT, a χ^2 analysis was conducted on observed vs expected response frequencies, with expected response frequencies being an equal number of responses for each reason for use. For the T-6B VR-PTT, there were significant differences in the frequency of reasons for use, $\chi^2(5, N=408) = 106.90$, $p < .001$. Free play was the most-listed response, and working on items for which the user received feedback from instructors was the least-listed response. Free play was a significantly more frequent response than learning new content, the second-highest frequency, $\chi^2(1,N=246) = 44.8$, $p < .001$. Additionally, working on feedback items was a significantly less frequent response than building a sight picture, the second-lowest frequency, $\chi^2(1,N=59) = 10.01$, $p = .002$. Frequency of responses did not significantly differ for the T-45C 4E18 VR-PTT, $\chi^2(5,N=35) = 7.90$, $p = .162$, or the T-45C BISim VR-PTT, $\chi^2(5,N=26) = 3.93$, $p = .559$. Frequency of primary reasons for use of each VR-PTT is represented in Figure 5. Significant differences occurred only for the T-6B PTN VR-PTT.

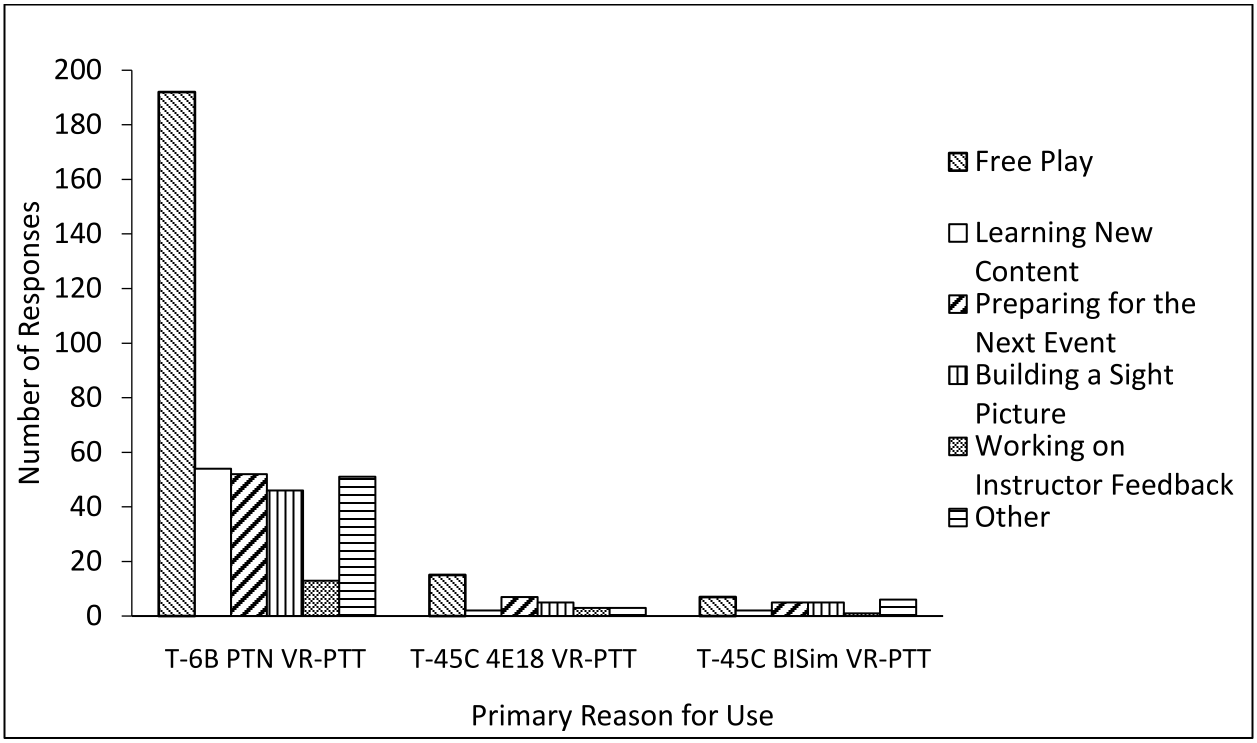

Figure 5. Frequency of Primary Reasons for Using the VR-PTTs.

One of the intended advantages of the VR/MR systems was their ability to network with each other to enable multiple SNAs to practice formation flying. Due to this intention, the flight log questionnaire asked respondents whether or not they networked their system with another SNA during their practice session. The frequency of “yes” vs “no” responses was compared between the three VR-PTTs using a χ^2 test. The difference in proportion of responses between VR-PTTs was significant, $\chi^2(2,N=458) = 55,83$, $p < .001$. Post-hoc χ^2 tests indicated that users of the T-6B VR-PTT networked the VR-PTTs less often than users of the T-45C VR-PTTs, T-45C 4E18 VR-PTTs $\chi^2(1,N=432) = 34.57$, $p < .001$; T-45C

BISim VR-PTTs $\chi^2(1, N=423) = 31.72$, $p < .001$. The difference between the T-45C 4E18 and T-45C BISim VR-PTTs was not significant, $\chi^2(1, N=61) = 0.07$, $p = .791$. The proportion of “yes” and “no” responses to the networking question is displayed in Figure 6.

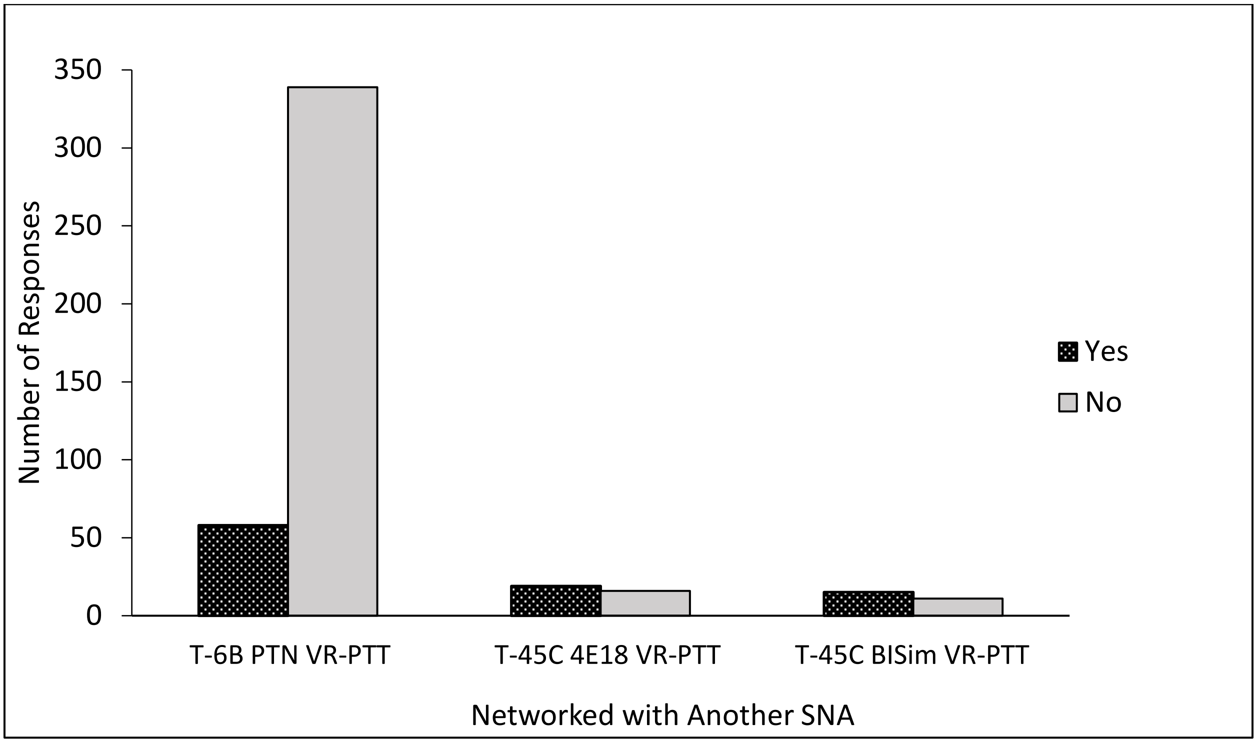

Figure 6. Frequency of Networking the VR-PTTs.

Users of the T-6B VR-PTT were most inclined to use it for free play, and least inclined to use it to practice items on which instructors gave feedback. Middling frequencies included learning new content, preparing for the next event, building a sight picture, and various reasons not listed by the researchers. No significant difference occurred between the response categories for the T-45C VR-PTTs. Additionally, users of the T-45C VR-PTTs were more likely than T-6B users to network their systems for formation flying. This may have been because T-6B users were more concerned with practicing basic flight skills; however, as discussed in the Training Utility section (see 5.3.3), respondents to the wrap-up questionnaire did not consider the T-6B VR-PTTs highly useful for flying with another SNA, suggesting that they may have chosen not to network their VR-PTTs because they did not see any value in doing so.

Reasons for Refraining from Use

In the wrap-up questionnaire, respondents who indicated that they did not use the VR/MR devices were asked why they did not use them. For both the T-6B VR-PTT and the T-45C systems, the most common response was that the respondent did not consider them useful [T-6B: 96/203 (47%) responses, T-45C: 31/98 (32%) responses]. A χ^2 test was employed to compare proportion of “not useful” responses vs other responses for T-6B vs T-45C systems. The difference was significant, $\chi^2(1, N=301) = 6.64$, $p = .010$, indicating that the proportion of SNAs who did not see the value in the systems was significantly higher for potential T-6B VR-PTT users than for potential T-45C system users.

In summary, people who did not use the T-6B VR-PTTs were more likely to see no training value in them than people who did not use the T-45C system. This may indicate either that these COTS VR/MR flight trainers are less valuable for basic flight skills than for more advanced skills, or it may indicate a difference in the way the VR/MR trainers were introduced.

Research Question 3 (Behavior) Summary

The research team hypothesized that usage of the VR/MR devices would have a positive impact on performance in the aircraft (e.g. Navy Standard Score, re-flys, marginals, unsatisfactories, raw scores on events, and events to meet MIF).

For the T-6B devices, there was no statistically significant association between device usage and aircraft performance. There were trends, however, higher usage of the T-6B devices was associated with positive overall performance (fewer negative events) in the Contact stage as well as fewer number of re-flys. The lack of statistical significance found in T-6B device usage and aircraft performance could be a result of the low sample size and/or lack of requested archival data.

For the T-45C devices, as usage of the devices increased, poor performance decreased in the Formation chapter compared to SNAs who did not use the device. In addition, higher device usage was associated with lower re-flys during the Formation chapter, and overall marginals when compared to no device usage. Furthermore, students who used the T-45C devices had higher event raw scores in the FRM and STK stages as well as the Formation chapter compared to students who reported no usage of the devices. Lastly, SNAs reporting usage of the T-45C devices also had a lower number of events required to meet MIF during the Instruments chapter compared to SNAs who reported no usage of the devices.

Most respondents did not think that the VR/MR systems changed their scan head movements, although T-45C users were more likely to notice a change in scan head movements than T-6B users. This result may be due to the types of skills used in more advanced training. For example, informal conversation with users at NAS Kingsville indicated that pilots rely heavily on scanning outside the cockpit for formation flights. Given the limited field of view in the existing VR/MR headsets, increased head movement may be needed to view a sufficient portion of the outside world in formation flying using the VR/MR systems. Additionally, users of both T-6B and T-45C systems tended to remain neutral about whether or not their use of the systems improved their performance in training. The “neutral” responses indicate uncertainty about the effectiveness of the systems in the users’ own experience.

The research team hypothesized that *type of use (i.e., purpose of the VR-PTT practice session) will have a relation on performance in the aircraft*

For the T-6B devices, the most commonly reported reason for use of the device was free play while working on instructor feedback was the least reported reason for use. Learning new content, preparing for the next event, building a site picture, and other reason were all reported with no significant difference in frequency.

For the T-45C devices, there was no significant difference in frequency of responses for reason for use of the devices, although free play was the most frequent response for both the T-45C 4E18 and BISim VR-PTTs.

Due to the lack of significant differences in reason for use across all devices, the researchers were unable to conduct meaningful analysis on the impact of the SNAs purpose of use and aircraft performance.

5.3.13. Research Question 3: Behavior

As referenced in the previous section, the T-45C and T-6B are training aircraft, and therefore are not directly relevant to the operational environment. Instead, performance in the T-45C and T-6B is performance within the training environment, making it most relevant to Kirkpatrick’s Learning level of training evaluation. An evaluation of the Behavior level would require the research team to evaluate performance in aircraft that are used within the operational environment. This would require a longer evaluation period, such that both exposure to VR/MR systems during training and performance in the operational aircraft after graduation could be measured. The ideal duration of the jet pilot training pipeline is roughly 16 months, indicating that approximately 2 years may be required for a direct Behavior-level evaluation of the VR/MR devices (Navy Installations Command, n.d.).

Conclusions from the previous section suggest that exposure to VR/MR devices is associated with improved performance in the training aircraft. However, it is not yet known if these performance improvements would transfer to the operational environment. Future research could address the Behavior level by tracking SNAs who used VR/MR devices throughout their training pipeline and those who did not use VR/MR devices. Performance within the operational environment could be then be compared between the two groups after graduation.

5.3.14. Research Question 4: Results

The fourth level of the Kirkpatrick’s model addresses the degree to which the targeted outcomes occurred as a result of learning and reinforcement. As with Behavior-level data, Results-level data collection would require a longer evaluation period than was available for the current report. Learning-level data from the T-45C VR/MR devices suggested that they may reduce reflys and events needed to meet MIF, indicating their potential to reduce the number of flights needed in the live training aircraft. This reduction could assist CNATRA both in reducing costs and in shortening the mean time to move each SNA through the training pipeline. Conversely, simulator sickness (discussed in the next subsection) could extend the training pipeline, although preliminary results from the Simulator Sickness Questionnaire indicate mild and brief symptoms overall. However, analyzing longer-term trends in training costs and training pipeline durations was outside the scope and timeline of the current evaluation.

5.3.15. Simulator Sickness

One potential hidden cost of VR/MR training devices is simulator sickness. Although the acquisition cost and footprint of these devices are well-known benefits, little is known about their physiological effects after exposure (i.e., simulator sickness).

Therefore, post-session simulator sickness was of primary importance to CNATRA to inform policy on the delay between XR practice and aircraft operations. If the VR/MR devices tend to cause simulator sickness, they may require downtime for SNAs to recover from VR/MR exposure before they conduct aircraft training events. This downtime could lead to delays in the training pipeline and resultant increases in training cost; thus, simulator sickness serves as a proxy for Results-level data. Simulator Sickness was measured by responses to the Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993) up to five times: right before entering the device (i.e., baseline), 30-, 60-, 90- and 120-minutes post practice. This measure consists of 16 symptoms, which load onto three subscales: Oculomotor (eyestrain, difficulty in focusing, blurred vision, and headache), Disorientation (dizziness and vertigo), and Nausea (salivation, nausea, stomach awareness, and burping). The SSQ checklist requires respondents to rate the severity of the symptoms on a four-point scale (0 = *None*, 1 = *Slight*, 2 = *Moderate*, 3 = *Severe*). The total average indicates the “troublesomeness” of a simulator is a weighted average of all three subscales, with the maximum score of being approximately 300 (see Table 30) for SSQ Total Score Definitions; Kennedy, Drexler, Compton, Stanney, & Harm, 2003).

Table 30. SSQ Total Score Definitions

SSQ SCORE	CATEGORIZATION
0	No symptoms
<5	Negligible symptoms
5 – 10	Minimal symptoms
10 – 15	Significant symptoms
15 – 20	Symptoms are a concern
>20	A problem simulator

The following tables represent mean severity of simulator sickness symptoms from SNAs across the XR devices. The results regarding symptom severity, simulator sickness over time, subscales, comparison across the devices, and the association with SNA reactions will be discussed in the following sections.

Symptom Severity

The tables below provide descriptive statistics of mean severity scores (i.e., 0 = None, 1 = Slight, 2 = Moderate, 3 = Severe) for each device across time sessions (baseline SSQ, +0 minute post-session SSQ, +30-minute SSQ, and +60-minute SSQ). Most symptoms remained within the slight severity range post scenario with fatigue, stomach awareness, and burping reaching moderate levels in some cases. These scores illustrate that there were symptoms reported across all four XR devices immediately post scenario through an hour timeframe.

Table 31. Average SSQ Results for the T-45C MRVS (NAS Kingsville)

T-45C MRVS																
	Discomfort	***Fatigue***	***Headache***	***Eye Strain***	***Difficulty Focusing***	***Salivation***	***Sweating***	***Nausea***	***Difficulty Concentrating***	***Fullness of the Head***	***Blurred Vision***	***Dizziness with Eyes Open***	***Dizziness with Eyes Closed***	***Vertigo***	***Stomach Awareness***	***Burping***
Baseline ***(n= 37)***	1.00	1.10	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
0-min Post (n= 38)	1.22	1.06	1.08	1.59	1.20	1.00	1.08	1.13	1.00	1.25	1.00	1.11	1.11	1.17	1.13	1.00
30-min Post ***(n= 36)***	1.20	1.17	1.25	1.14	1.20	1.00	1.00	1.50	1.33	1.20	1.67	1.00	1.25	1.25	1.33	1.00
60-min Post ***(n= 32)***	1.00	1.20	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00

Group N = 38: Male = 36 (95%), Female = 2 (5%) *SSQ Severity Rating Scale (0 = None, 1 = *Slight*, 2 = *Moderate*, 3 = *Severe*)

Table 32. Average SSQ Results for T-45C Part-Task Trainers (NAS Kingsville)

T-45C BISim VR-PTT																
	Discomfort	Fatigue	Headache	Eye Strain	Difficulty Focusing	Salivation	Sweating	Nausea	Difficulty Concentrating	Fullness of the Head	Blurred Vision	Dizziness with Eyes Open	Dizziness with Eyes Closed	Vertigo	Stomach Awareness	Burping
Baseline ***(n= 12)***	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0-min Post (n= 12)	1.00	1.00	1.00	1.45	1.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00
30-min Post ***(n= 12)***	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00
60-min Post ***(n= 12)***	0.00	2.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00

Group N = 12: Male = 9 (75%), Female = 3 (25%) *SSQ Severity Rating Scale (0 = None, 1 = *Slight*, 2 = *Moderate*, 3 = *Severe*)

Table 33. Average SSQ Results for the T-45C 4E18 VR-PTTs (NAS Kingsville and NAS Meridian)

T-45C 4E18 Part-Task Trainers																
	Discomfort	Fatigue	Headache	Eye Strain	Difficulty Focusing	Salivation	Sweating	Nausea	Difficulty Concentrating	Fullness of the Head	Blurred Vision	Dizziness with Eyes Open	Dizziness with Eyes Closed	Vertigo	Stomach Awareness	Burping
Baseline *(n= 14)*	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00
0-min Post (n= 14)	1.00	1.00	0.00	1.22	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.50	0.00
30-min Post *(n= 14)*	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.00
60-min Post *(n= 14)*	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00	2.00	1.00

Group N = 14: Male = 13 (93%), Female = 1 (7%) *SSQ Severity Rating Scale (0 = None, 1 = *Slight*, 2 = *Moderate*, 3 = *Severe*)

Table 34. Average SSQ Results for T-6B PTN VR-PTTs (NAS Corpus Christi and NAS Whiting Field)

T-6B Pilot Trainer Next Devices																
	Discomfort	***Fatigue***	***Headache***	***Eye Strain***	***Difficulty Focusing***	***Salivation***	***Sweating***	***Nausea***	***Difficulty Concentrating***	***Fullness of the Head***	***Blurred Vision***	***Dizziness with Eyes Open***	***Dizziness with Eyes Closed***	***Vertigo***	***Stomach Awareness***	***Burping***
Baseline *(n= 61)*	1.33	1.00	1.00	1.00	1.00	1.00	1.00)	1.00	1.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00
0-min Post (n= 60)	1.08	1.18	1.08	1.28	1.25	1.00	1.11	1.00	1.00	1.17	1.22	1.00	1.14	1.00	1.00	2.00
30-min Post *(n= 58)*	1.00	1.00	1.07	1.11	1.50	1.00	1.00	0.00	1.00	1.00	1.17	1.00	1.00	1.00	1.00	0.00
60-min Post *(n= 31)*	1.00	1.00	1.00	1.14	1.33	1.00	1.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00

Group N = 61: Male = 54 (89%), Female = 7 (11%) *SSQ Severity Rating Scale (0 = None, 1 = *Slight*, 2 = *Moderate*, 3 = *Severe*)

Simulator Sickness over Time

The trend in SSQ responses over time was examined separately for each system using a Friedman test with 4 levels of the independent variable (baseline SSQ, +0 minute post-session SSQ, +30-minute SSQ, and +60-minute SSQ). Friedman test is a non-parametric (does not assume data are derived from a normal distribution) test for finding differences in treatments across multiple attempts (i.e., repeated measures). Post-hoc sign tests were conducted to compare +0 minute, +30 minute, and +60 minute SSQ scores to the baseline SSQ score. Sign tests compare difference between two attempts for the same group of people. One-tailed significance values are reported for the sign tests, as the primary interest was in determining whether the SSQ was higher than baseline at each post-session time point.

Friedman tests were significant for all four systems, all $\chi^2(3) > 13.48$, all ps < .005. For the T-6B PTN VR-PTT and the T-45C 4E18 VR-PTT, only the post-session SSQ showed significantly higher scores than the pre-session SSQ, ps < .011. The later SSQs did not significantly differ from the pre-session SSQ, ps > .359, indicating that simulator sickness due to exposure to the T-6B PTN VR-PTT or the T-45C 4E18 VR-PTT subsided within 30 minutes of completing a practice session.

By contrast, both T-45C BISim systems showed significant levels of simulator sickness at both the +0 minute and the +30 minute mark, ps < .016 for all. Simulator sickness did not differ from baseline at +60 minutes, ps > .999. Thus, both the T-45C BISim VR-PTT and the MRVS caused simulator sickness that lasted more than 30 minutes beyond the end of the practice session, but had subsided within an hour.

Additionally, per the Physiologist report, no participants reported delayed feelings of simulator sickness after they had completed the evaluation for any of the four devices, indicating that long-term simulator sickness may not be a problem with the systems. Simulator sickness as function of time is displayed in Figure 7. (Note: error bars represent 2 standard errors above and below the mean) and total scores definitions are detailed in Table 30.

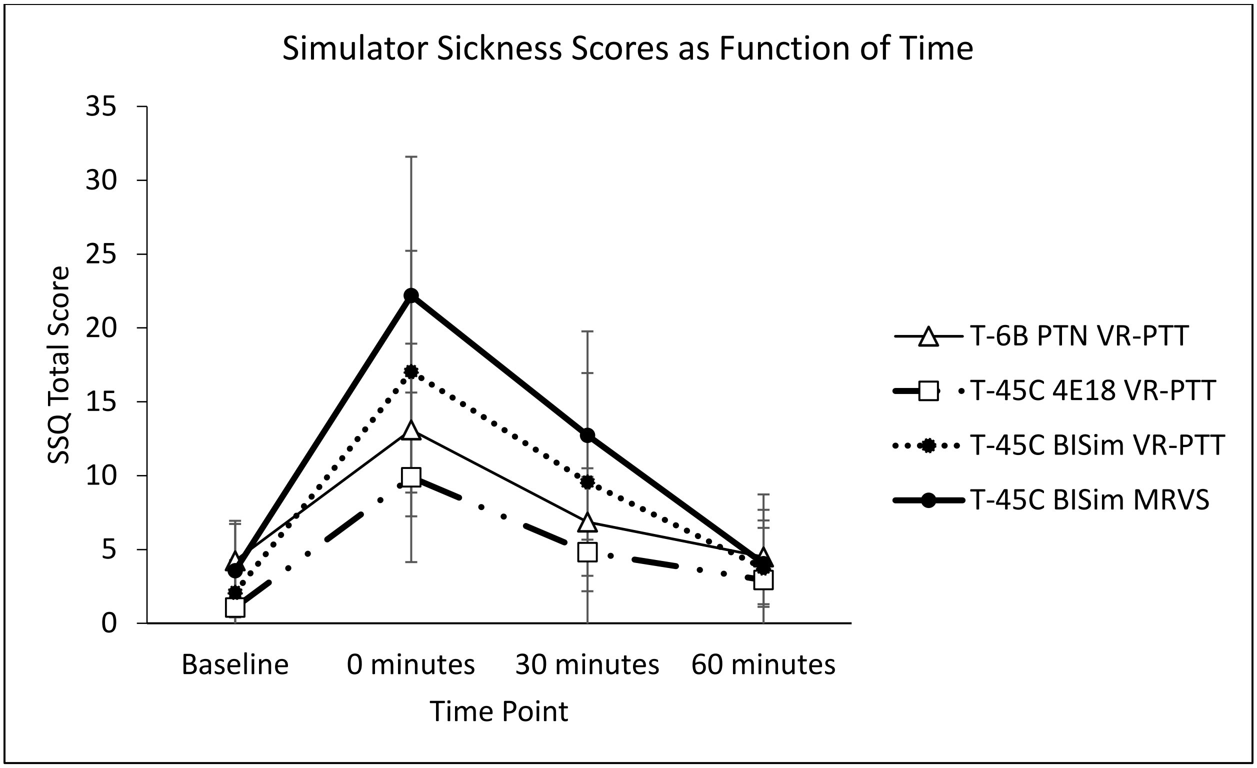

Figure 7. Simulator Sickness Scores as Function of Time

Simulator Sickness Subscales

The SSQ consists of three subscales that contribute to the overall score, including oculomotor, disorientation, and nausea subscales. Due to frequent complaints about the blurriness of the HMDs, it was expected that simulator sickness would mostly be driven by oculomotor symptoms such as eyestrain and blurred vision. To explore this concern, a 3(subscale) x 2(time point; baseline SSQ vs +0 minute SSQ) within-subjects factorial ANOVA was conducted. Factorial ANOVA compares the means of multiple variables simultaneously. The main effect of time point was significant, $F(1,109) = 45.29$, $p < .001$, indicating a tendency for simulator sickness to occur during a session with the systems, as discussed in the previous subsection. The effect of subscale was also significant, $F(1.62,176.22) = 10.99$, $p < .001$. However, post-hoc tests were not conducted on the main effect of subscale, because the primary interest is change from baseline. Most importantly, the interaction between time point and subscale was significant, $F(1.64,178.63) = 21.00$, $p < .001$. Post-hoc tests of the simple main effect of subscale indicated that nausea and oculomotor symptoms were significantly higher than disorientation at baseline, *p*s < .001, but did not differ from each other, $p = .891$. After the practice session, oculomotor symptoms and disorientation were both significantly higher than nausea, *p*s < .001, but did not significantly differ from each other, $p = .864$. Post-hoc tests of the simple main effect of time indicated that all three subscales were higher than baseline after the practice session, all *p*s < .001. Thus, results indicate that simulator sickness was primarily driven not only by oculomotor symptoms, but also by disorientation. Nausea symptoms were present, but less severe. SSQ subscale scores as a function of time point illustrate these findings in Figure 8 (Note: error bars represent 2 standard errors above and below the mean).

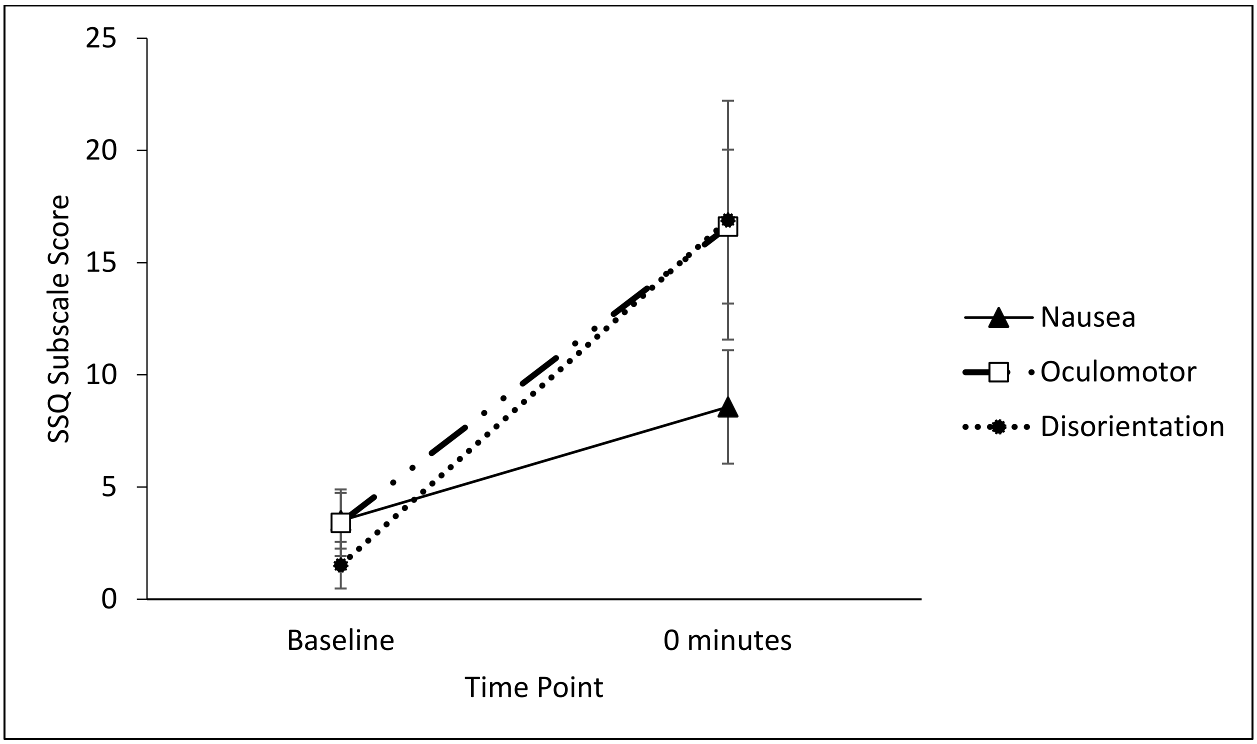

Figure 8. Simulator Sickness Subscale Scores at Baseline and 0 Minutes.

Simulator Sickness Severity Comparison among XR Systems

The difference between +0 minute SSQ scores and baseline SSQ scores was calculated for each participant, and was compared between systems using a Welch's ANOVA. Welch's ANOVA is a parametric test of mean differences across groups. The effect of system was not significant, $F(3,30.25) = 2.50$, $p = .078$ indicating that there were not severity differences between devices. Post-hoc tests were not conducted, but the trend was for simulator sickness to be highest for the MRVS based on SSQ total score and lowest for the T-6B and T-45C 4E18 VR-PTTs, indicating that the T-45C BISim systems caused the worst simulator sickness, see Figure 7. MRVS was the only system that exceeded the threshold of greater than 20 total SSQ score, indicating a troublesome device.

Simulator Sickness and Reaction Scores

It was expected that increases in simulator sickness would be associated with decreases in positivity of reactions. To explore this idea, +0 minute post-session SSQ scores were correlated to overall positivity, training utility, and usability scores from the comprehensive questionnaire. One-tailed significance values are reported. Simulator sickness was not significantly associated with overall positivity or training utility; positivity $\rho = -.03$, $p = .387$, training utility $\rho = .035$, $p = .360$. However, simulator sickness was negatively associated with usability, $\rho = -.34$, $p < .001$. This indicates that higher simulator sickness was associated with lower usability scores.

In summary, simulator sickness occurred for all four XR systems, but severity differences were not found between them. Results also show that MRVS elicited the most symptoms with a score of 22 out of 300 placing it within the “troublesome” range. Although simulator sickness was present, symptoms faded within 30 minutes after the practice session for the T-6B PTN and T-45C 4E18 VR-PTTs and faded within an hour for the T-45C BISim devices. These findings indicate that simulator sickness is not long lasting for any of the systems. It is also important to note that, even though severity differences were absent, results indicate a slight advantage for the T-6B and T-45C 4E18 VR-PTTs based on symptom duration as compared to the T-45C BISim VR-PTTs and MRVS.

Additional results from the subscale analyses may indicate that an improvement in visual clarity could decrease simulator sickness by decreasing oculomotor symptoms; however, the presence of disorientation and, to a lesser extent, nausea symptoms indicates that visual clarity will not be sufficient to eliminate simulator sickness as a whole. In addition, reaction data were analyzed and simulator sickness was found not to be associated with general positivity towards the systems or with perceived training utility. However, correlation data show that those who reported higher simulator sickness also reported lower perceptions of usability for the system. Although simulator sickness was slight and subsided after an hour, its effects should impact the devices that are acquired and the time delay between XR practice and live flights. These considerations should influence CNATRA's decisions to incorporate XR devices within its curriculum.

5.3.16. Device Aesthetics

For the T-45C devices, the research team provided a subset of the SNAs with a questionnaire on aesthetics of the devices and general beliefs about the training utility of aesthetics. For this evaluation, aesthetics is defined as pleasure derived from the experience of an object independent of pleasure derived from its usefulness (Blijlevens et al., 2017; Dutton, 2009). Attractiveness of the device was only captured by SNAs (n = 62) who used the T-45C BISim VR-PTTs or MRVS. For the T-45C BISim VR-PTTs, the overall mean agreement of attractiveness was 4.76 out of a maximum score of 7, suggesting that the SNAs found the system moderately attractive. Similarly, the MRVS overall mean agreement of attractiveness was 4.84 out of 7, indicating moderate attractiveness. These data were not collected for the T-45C 4E18 VR-PTTs. Additionally, SNAs were asked about how strongly they agreed that attractiveness would affect their (a) training motivation, (b) ability to learn, and (c) training performance. SNAs (n = 30) rated the degree of agreement of attractiveness for training motivation as 3.9 out of 5, ability to learn as 3.6 out of 5, and training performance as 3.6 out of 5, indicating moderate agreement for attractiveness of the T-45C BISim devices.

The degree of agreement for color scheme for (a) training motivation, (b) intention to continue using a system, and (c) ability to learn more from a system were asked of the T-45C SNAs. For the degree of agreement for color scheme, only the SNAs (n = 32) who trained in the T-45C BISim MRVS and T-45C 4E18 devices responded. SNAs rated motivation as 2.52 out of 5, intention to continue using the system as 2.31 out of 5, and ability to learn as 2.03 out of 5, indicating a belief that color scheme does not influence motivation, training intention, or learning.

SNAs were provided the opportunity to provide an open-ended response regarding the visual appeal of systems and its effect on training. Of 62 participants, 31 (50%) provided a response. The relevant comments are summarized in Table 35.

Table 35. Relevant Comments Regarding Aesthetics of Devices

Comment	Number of SNAs
Not important or other things more important.	12(39%)
Makes training appealing/motivating/enjoyable.	8(26%)
Makes training easier, faster, or more effective.	4(13%)
Increases trust and morale.	1(3%)

Although the SNAs reported that the devices were moderately attractive, there are mixed beliefs on its effects on the training experience. However, previous research suggests that aesthetic appeal does matter for the overall training experience. For example, aesthetically pleasing systems can decrease cognitive load (Miller, 2011), increase attention to important content (Pace, 2004), increase trust in the system (Hoff & Bashir, 2015), and increased willingness to continue using the system (Miller, 2011). Additionally, aesthetically appealing design can improve performance in systems with usability issues, suggesting that aesthetics can compensate for low usability (Moshagen, Musch, & Göretz, 2009; Reppa & McDougall, 2015). Finally, appealing color specifically can increase time spent using the system and memory of the system (Bonnardel, Piloat, & Le Bigot, 2011). All of these previous findings suggest that the aesthetic appeal of the T-45C BISim devices may provide a benefit for training utility and system usage.

5.3.17. Limb Ownership

Difference in Limb Ownership between T-45C BISim Systems

Limb ownership scores were compared between the two systems developed by BISim, the T-45C BISim VR-PTT and the T-45C BISim MRVS. The MRVS employed pass-through video of users’ hands, whereas the T-45C BISim VR-PTT employed virtual limbs controlled by Leap Motion hand tracking. The Leap Motion virtual limbs were considered difficult to control by users in free response feedback and informal comments, especially when trying to actuate the virtual TACAN. Thus, it was expected that the MRVS would give users a higher sense of limb ownership than the T-45C BISim VR-PTT.

This idea was tested using a one-way ANOVA with system as the independent variable (T-45C BISim MRVS vs T-45C BISim VR-PTT) and mean limb ownership score as the dependent variable. As expected, limb ownership was higher for the T-45C BISim MRVS than for the T-45C BISim VR-PTT, $F(1,35) = 38.71$, $p < .001$. Additionally, responses to Question 10 of the limb ownership questionnaire, “The movements of the limb in my field of view did not correlate with the movements of my actual limb (i.e., movements were delayed, not in the same location in space, different length, etc...),” were separately evaluated using a one-way ANOVA with system as the independent variable. Again, Question 10 scores were higher for the T-45C BISim MRVS than for the T-45C BISim VR-PTT, $F(1,28) = 6.94$, $p = .014$.

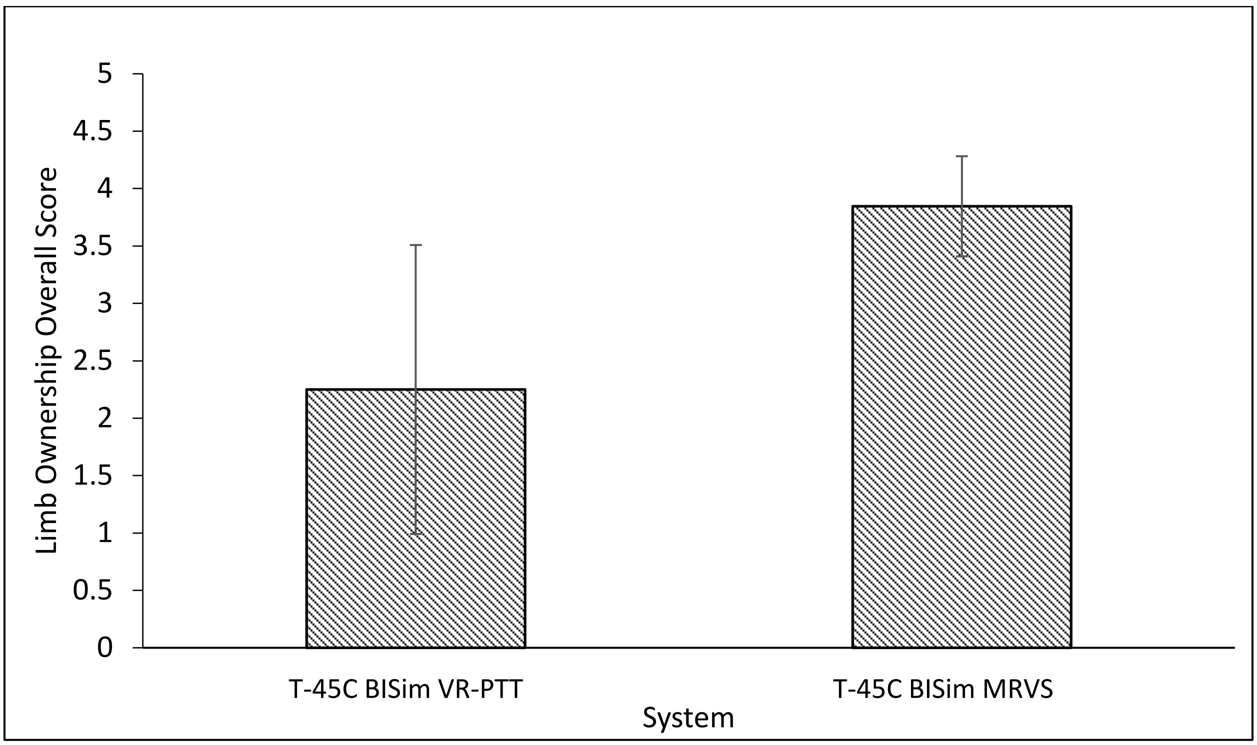

Figure 9. Limb Ownership in the T-45C BISim VR-PTT and T-45C BISim MRVS.

Limb Ownership and Reaction Scores

When examining the relation between limb ownership and SNA reaction scores, it was expected that limb ownership would affect positivity of reactions in the comprehensive questionnaire, such that higher limb ownership would be associated with more positive reactions. To test this, Spearman's rank-order correlation coefficient was calculated separately for limb ownership and overall positivity, training utility, usability, and realism scores. Overall positivity (ρ = .45, p = .003), training utility (ρ = .34, p = .019), usability (ρ = .48, p = .002), and realism (ρ = .29, p = .039) were all positively related to limb ownership, suggesting that increases in limb ownership were associated overall positive reactions to T-45C devices (See Figure 9).

Simulator Sickness and Limb Ownership

It was expected that lower limb ownership would be associated with increases in simulator sickness. To test this idea, the mean of all response values was calculated for each participant on the limb ownership questionnaire, and limb ownership was then correlated to overall +0 minute post-session SSQ scores using Spearman's rank order correlation coefficient. Limb ownership and simulation sickness were not significantly correlated, ρ = -0.12, p = .244. It was also expected that responses to question 10 alone might correlate to simulator sickness. This notion was not supported, ρ = -.030, p = 438.

In summary, limb ownership was not associated with simulator sickness. Limb ownership was higher for the MRVS than for the T-45C VR-PTT. This suggests that Leap Motion control of virtual limbs is currently somewhat unnatural and that the ability to view one's own limbs should be considered in VR/MR flight trainers, given that higher limb ownership increases positivity towards the systems. Overall limb ownership scores for each system are represented in Figure 9. Error bars represent 2 standard errors above and below the mean.

5.3.18. Use of and Trust in Automation

Overall mean scores were calculated for each participant on the automation use questionnaire, general trust in automation (items 1 through 6 of the trust in automation questionnaire), and trust in the system (items 7 – 10 of the trust in automation questionnaire). It was expected that a greater tendency to use automation, higher tendency to trust automation, and higher trust in the VR/MR systems would all associate with higher overall positivity, training utility, and usability scores for the systems.

To test this, Spearman's rank order correlation coefficients were calculated. There were a significant positive correlations among all three automation trust scales and overall positivity. Additionally, there were significant positive relationships between trust in automation and training utility and usability. Finally, for trust in the VR/MR systems, there was a significant positive relation with usability (see Table 36; statistically significant results are denoted in bold).

Table 36. Correlations among Automation Trust Scales

Automation Trust Scale	Overall Positivity	Training Utility	Usability
Use of Automation	**ρ = .40, p = .003**	ρ = .23, p = .054	ρ = .17, p = .109
Trust in Automation	**ρ = .43, p = .001**	**ρ = .29, p = .020**	**ρ = .32, p = .011**
Trust in Training System	**ρ = .51, p = .006**	**ρ = .37, p = .019**	ρ = .32, p = .065

In summary, higher levels of automation use in everyday life, general trust in automation, and trust in the VR/MR systems were all significantly associated with increases in overall positivity towards the systems. Increases in both trust scores were also significantly associated with increases in perceived training utility. Further, general trust was associated with higher usability ratings. The fact that general tendencies to trust and use automation were associated with attitudes towards the systems further indicates that individual differences between SNAs will play a role in their attitudes towards the systems and potentially their acceptance of the systems.

The Discussion section below will offer additional information about the results found, exploratory analyses, and recommendations on utilizing XR devices for training.

6. Discussion

This evaluation was conducted to examine the potential training value of four different systems, including a T-6B VR-PTT, two T-45C VR-PTTs, and an MR system that connects to an existing OFT to provide improved visuals. It is important to note that participation varied across all devices due to time constraints and data collection priorities. Among the four devices, the T-45C BISim VR-PTT and T-45C 4E18 VR-PTT had lower sample sizes. Fortunately, the lower participation rate of the two devices did not interfere with the investigation of the training-utility differences of the VR and MR modalities. Although the modality evaluation was conducted across two different platforms, T-6B and T-45C, which practice slightly different maneuvers, the researchers believe that the technology comparison is valid as the training intention is universal for the devices in this evaluation. Another discussion point regarding this study refers to the participant pool. Although the team was able to recruit SNAs for this study, there was a disparity between male and female participants. Therefore, data collected were heavily influenced by male SNAs. This can typically bring up some reliability issues for researchers, but in this case, the dataset is representative of the actual population (i.e., Male 80%, female 20%).

The following sections will provide additional insight into the Four Levels of the Kirkpatrick (1976) Training Evaluation: Reactions, Learning, Behavior, and Results.

6.1. Training Evaluation Level 1: Reactions

The reactions to the systems centered around neutral. With upgrades, mandatory compliance, and curriculum incorporation, SNA reactions could become more positive. The following sub-sections provide additional details of the SNAs' perceptions of the devices and their training utility.

6.1.1. Positivity of Reactions

In most cases, participants reacted least positively to the T-6B VR-PTT; overall positivity, training utility, and visibility were lower for the T-6B VR-PTT than the T-45C 4E18 VR-PTT; and the T-6B VR-PTT was rated worse on realism than all of the T-45C systems. The one exception to this was in usability, where the T-6B VR-PTT received a higher rating than either T-45C VR-PTT. Thus, in spite of higher usability, the T-6B VR-PTT suffered compared to T-45C systems not only in training utility but also in the usefulness of visuals and in having a sufficient level realism. These results may indicate further differences between novice and more advanced pilots, whereby novices have more difficulty than advanced pilots in compensating for unrealistic or unclear simulations.

6.1.2. Individual Differences in Positive Reactions

General tendency to use automation was positively correlated with overall positivity of reactions to the XR systems. However, it was not correlated with usability or training utility. This indicates that people who are more prone to using automation in their lives are also more prone to reacting positively to the systems, although the effect is not driven by any changes in perceived usability or usefulness. If overall positivity affected intentions to use, then positive reactions could encourage high automation users to use XR systems more than their peers. However, the relationship between positivity and usage was not tested here, due to the small sample of participants responding to automation use questionnaire and the low practice system usage in general.

Additionally, an increased general tendency to trust automation was associated with increases in overall positivity, perceived usability, and perceived training utility of the XR systems. Trust in the specific systems being evaluated was also associated with increases in overall positivity and training utility. The correlations between trust in and overall attitudes towards the systems may indicate that increasing perceived trustworthiness of the systems will increase acceptance; however, low positivity towards the systems may have reduced trust rather than low trust reducing positivity. The fact that general tendencies to trust and use automation were associated with attitudes towards the systems further indicates that individual differences between SNAs will play a role in their attitudes towards the systems and potentially their acceptance and usage of them.

6.1.3. Training Utility

Participants in the evaluation considered the T-6B VR-PTT to be useful primarily for the Contacts phase of the Primary syllabus, and not as useful for later phases. This may indicate that early familiarization with the aircraft is the most useful aspect of a VR-PTT for Primary students. However, many of the SNAs evaluating the T-6B VR-PTT had not begun the Primary syllabus, or had begun it recently. These participants may have been unable to see the training utility, or felt that they did not have enough knowledge to comment on the utility, of the VR-PTT for later phases of training.

By contrast, participants considered the T-45C systems to be useful both early on in the intermediate/advanced syllabi during familiarization, and later on in formation training.

Additionally, the two T-45C VR-PTTs were considered useful for tactical training stages, although the MRVS was not. Qualitative feedback also indicated that the ability of all four devices to allow for a full, 360° field of regard was cited as a considerable strength compared to the current capabilities of the OFTs. Combined with the ability to perform networked flights with others students and outside visuals comparable to the OFT, the T-45C VR-PTTs and MRVS were considered to potentially provide the most training benefit during formation and some contacts flights, including familiarization. These responses are consistent with the quantitative results.

None of the T-45C systems were considered useful for instruments or carrier landing practice. Responses to the free-response questions and within the focus groups suggest that poor visuals contributed to the perception of low utility for instruments stages. Qualitative feedback indicated that the lack of visual clarity inside the cockpit was a limitation across all four XR systems, and respondents were almost unanimous in their opinion that the systems would not provide benefit for instruments practice given the inability to read cockpit displays and gauges without considerable eyestrain. Additional qualitative feedback and focus groups suggested that the non-functional Improved Fresnel Lens Optical Landing System (IFLOLS) and the stationary aircraft carrier contributed to the perception of low utility for carrier landing practice.

Participants were also asked about the potential reasons that SNAs could use the XR systems and how they could be useful for practice with another SNA; answers were obtained for the VR-PTTs. Their responses suggested that the greatest utility of the VR-PTTs was building a sight picture, and they were considered less useful for practicing communications or for remediation on items for which instructors gave feedback. The T-45C BISim VR-PTT was also considered useful for understanding aircraft positions in formation flight, and the T-6B VR-PTT was considered useful for practicing FTI procedures and building situational awareness when flying with a companion. However, T-6B participants considered the T-6B VR-PTT to be least useful for practicing with another student compared to other potential reasons for use. The results suggest that the VR-PTTs are considered useful for gaining a general awareness of what a flight should look like. The fact that they are not useful for practicing communications is not surprising, given that three of the XR systems have no option for communicating between headsets, and the T-45C 4E18 VR-PTT had long transmission delays when users attempted to communicate via the headsets. Thus, the only current option for voice communications is in-person communication with a nearby companion.

The T-6B VR-PTT’s lack of perceived usefulness for practicing with another student was unexpected. However, as discussed at the beginning of this section, many of the T-6B participants had not reached formation flying portions of the syllabus yet, and may have been unable to find training utility for formation flying because of a lack of knowledge. The more advanced SNAs and instructors who evaluated the T-45C systems considered them useful for formation flying, suggesting that networkable VR-PTTs do have utility for formation practice.

6.1.4. Differences in Training Utility

The previous section presents some of the differences in training utility between the XR systems. The T-6B VR-PTT was considered useful for the Contacts phase of Primary training and less useful for later phases, whereas the T-45C systems were considered useful both early on for familiarization, as well as later in the intermediate/advanced syllabi for formation skills. The T-45C systems were not considered useful for instruments or carrier landing practice. Furthermore, participants considered practicing with another student to be the least useful application of the T-6B VR-PTT and were less likely to network with another student than T-45C VR-PTT users.

There were also differences between the T-45C systems, with the VR-PTTs additionally being considered useful for tactical practice, and the MRVS not being useful for tactical practice. The MRVS’s low perceived utility for tactical practice may partly be the result of poor modeling of the simulated companion aircraft, which had incorrect flaps and gear configurations. In addition, the restricted FOV of the Varjo headset, and narrow area of high clarity, may have required unnaturally large head movements to follow companion aircraft in tactical formation flights. Additionally, when the SNA was attempting to use peripheral scan, the SNA's eyes were outside the high-resolution inset of the Varjo, resulting in deliberate movement of the head and change in posture to read the information. An eye movement that usually requires milliseconds was extended to accommodate this scan. To reduce this delay in eye scan, the high-resolution inset in the Varjo should include eye-tracking so that the SNA scan pattern will always be in the high-resolution inset. The T-45C VR-PTTs, which did not use the Varjo HMD, also had a restricted FOV compared to natural vision. Although researchers observed similar head and posture changes during VR-PTT sessions, these SNAs did not report as much movement as those in the MRVS. This may be attributed to the distinct resolution difference between the inset and background in the Varjo HMD. Finally, although the MRVS was intended to be networkable with the T-45C BISim VR-PTT, the connection between the MRVS and VR-PTTs was too delayed to be usable. MRVS users therefore cannot take advantage of a multiplayer mode to fly off of a live lead aircraft of those SNAs in the T-45C BISim VR-PTTs, as initially intended; instead, any tactical formation flying must be done with an AI lead aircraft rather than a real SNA flying another simulator.

However, one advantage of the MRVS over the T-45C VR-PTTs is that it provides the ability to interact with a real T-45C cockpit integrated with an existing OFT. This feature alleviates a complaint frequently mentioned in the VR-PTTs, that the HOTAS and certain cockpit features were not analogous in form and function to the real aircraft. Conversely, the three VR-PTTs may allow for productive practice sessions without the need for a dedicated, system knowledgeable instructor as is required in the OFT. Thus, a consideration of a low-cost replica cockpit (similar to the UTD) that provides the ability to actuate its contents within a mixed reality environment should be considered for future development. If the system provides guided training content (e.g., emergency checklist scenario) that can be updated by Instructors and Engineers to reflect the most updated policy, then the necessity of instructor presence for operation would not be required for SNA use.

Finally, the T-6B VR-PTT scored significantly lower than the T-45C 4E18 VR-PTT on the training utility subscale of the comprehensive questionnaire. Other comparisons were not significant. The general trend showed that participants were uncertain about the training utility of the T-6B VR-PTT, remaining neutral about its ability to improve training outcomes. By contrast, the T-45C systems all received above-neutral scores on training utility, suggesting that T-45C system users, and especially T-45C 4E18 VR-PTT users, were more confident that the systems could improve training outcomes. These results are further supported by non-users’ reasons for not using the systems. All non-users were most likely to cite a lack of usefulness as their reason for avoiding the systems; however, this tendency was especially pronounced for non-users at the Primary training sites.

Overall, user perceptions indicate that the T-6B VR-PTT has lower perceived training utility and more limited perceived applicability, being most applicable to single-user practice in the Contacts phase of training. By contrast, the T-45C systems are seen as applicable to both earlier and later phases of training, including multi-user practice for formation flight skills and for tactical flight skills in the T-45C VR-PTTs. The T-45C systems also had higher perceived utility. Further research may be warranted to investigate whether these differences reflect a difference in XR system effectiveness for novice vs advanced pilots, or only a difference in the ability of novice vs advanced pilots to judge the potential utility of XR systems for different flight skills.

6.2. Training Evaluation Level 2: Learning

Although the VR/MR systems did not change study and instruction behavior, there were some significant positive associations between use and aircraft performance, providing some support for Hypothesis 2a. First, TIMS data were not available for the full set of participants in the evaluation; for the T-6B VR-PTT evaluation, the research team was unable to access sufficient data to evaluate event raw scores, and only scores that fell within the relevant date ranges were used for other analyses. Second, it was not known exactly when any single participant first used the XR systems due to low compliance with the flight log questionnaire. As a result, many training events from after 1 December 2018 may have occurred before the participant used any XR system. Third, use of the systems overall was low, with the highest number of uses being six times used. Low usage rates may prevent users from experiencing the full benefits of an XR system. Fourth, use of the XR systems was voluntary; participants who chose to use the systems may have done so because they wished to address their own performance deficiencies. Finally, the significant findings represented a small subset of all tests of interest; most tests were not significant, and some relations were not testable because the dataset was insufficient or did not have enough variation. All of the above reasons suggest that more controlled research with a larger dataset collected over a longer period may be necessary to obtain more conclusive performance results and to be able to make conclusions about whether or not the XR systems affect performance. Moreover, these TIMS analyses relied on instructor ratings, which are not true objective data, and in fact, are subjective in nature because they are often susceptible to rater error (e.g., leniency). To increase confidence in the performance metrics to which we would compare, a more objective measure of performance should be explored. For example, data collected from the aircraft during the training scenarios would be a more reliable dependent variable and provide more meaningful results as to the training utility and impact of the devices.

Overall, participants thought that their use of the XR systems did not change their behavior during training sessions. A large majority of users thought that the XR systems did not change their overall approach to studying or change the focus of their training time with instructors. Additionally, a majority of users reported that the systems did not change the head movements they used in their visual scan, although T-45C system users were more likely than T-6B VR-PTT users to report that the systems did change their head movements. This difference between T-6B and T-45C systems may reflect the difference in skills being learned; formation and tactical flying rely heavily on scanning outside the cockpit, creating a need for a wider scan. Thus, the FOV limitation of the headset would create more pronounced increases in head movements for students practicing multi-aircraft flying skills.

XR system usage was low overall, with the vast majority of participants using them once per week or less, and the majority of those participants never using the systems at all. When the systems were used, their sessions tended to last less than an hour, and users of the T-6B VR-PTT spent less time per session than users of the T-45C 4E18 VR-PTT. Across roughly 8 months of availability per system, total time spent in XR systems was between approximately 3.5 and 6.5 hours for SNAs who chose to use the devices. Thus, usage of the systems was limited to a minority of potential users, and it was infrequent and brief.

In accordance with the usage numbers, most participants expressed a preference for using no XR system at all, indicating low acceptance of the XR systems. Those who did not use the systems most often cited a lack of perceived usefulness as their reason for avoiding the XR systems; this was especially true for the T-6B VR-PTT. Thus, low perceived usefulness may be the major reason for low usage of the systems. This issue could be mitigated by efforts to educate SNAs about the potential uses of the systems, and by implementing recommended upgrades to increase utility.

When asked about their reasons for using the VR-PTTs, the T-6B participants most often responded that they were engaging in free play and least often responded that they were working on feedback they had received from instructors. The T-45C VR-PTTs had no significant differences between answers, possibly due to a relatively low sample size. For the T-6B VR-PTT, the responses provide further evidence that they may not have known what could be practiced in the system and instead opted to explore the possibilities of the device. This could suggest that giving SNAs a dedicated familiarization period with the VR-PTTs could help them understand their capabilities and give them an opportunity later on to engage in more focused usage of the systems.

6.3. Training Evaluation Level 3: Behavior

Although the research team could not directly test behavior, understanding if any XR devices influence SNA behavior in the operational environment is a critical consideration before deciding if the devices are appropriate and beneficial for SNA performance. Researchers, in the future, should be able to track exposure to the devices long-term and compare it to performance in operational aircraft after graduation from the training pipeline. If there is a statistically significant increase in performance, it can be reasonably assumed that the XR practice had an effect on behavior. Without this step, it would be premature to make a final decision regarding XR acquisition.

6.4. Training Evaluation Level 4: Results

The timeline and scope of the current evaluation did not allow for analysis of training cost and efficiency data. Given the need for low-cost solutions to pilot shortages, decreasing training costs while increasing training efficiency should be a primary consideration in XR acquisition decisions. Therefore, future research should examine changes in overall training costs and training pipeline durations as a function of introducing XR devices into the training pipeline. If overall training cost and the average time to train a pilot decrease after introduction of XR training devices, it would be a clear indication that XR can contribute to addressing the existing pilot shortages.

6.5. Simulator Sickness

Finally, the DCE included an evaluation of practice session outcome: simulator sickness.

Simulator sickness across time was evaluated to examine the possibility that there should be a delay between XR system usage and live flights. Currently, SNAs who use one of the XR systems are required to wait until the next day before they complete a live flight. The results suggested that the simulator sickness report were slight and did not last beyond one hour. The only device that was considered “troublesome” based on the total SSQ score (above 20) was the MRVS. This may be due to the high-resolution inset conflicting with the lower-resolution peripheral display in the Varjo headset. The consistent refocusing of the eyes when scanning and the exaggerated head movement primarily caused by the headset are key supporters to the simulation sickness reports. However, the MRVS, being a mixed reality device is most closely aligned with what was considered a simulation when the SSQ was developed. Thus, the ratings may also be reflective on criterion deficiency of the SSQ to tap true cybersickness—symptoms after exposure to VR (Stanney, Kennedy, & Drexler, 1997). Further, empirical criticisms of the SSQ regarding its dimensionality (i.e., the factors are not exclusive of the symptoms; Rebenitsch & Owen, 2016), pre-exposure response bias (requesting baseline data presents a demand characteristic to increase ratings after training; Young, Adelstein, & Ellis, 2006), and overall psychometric properties in capturing cybersickness (e.g., Stone, 2017) provides pause in utilizing this measure in the future. With the criticisms presented, the data that we collected still suggest that the next-day delay may be unnecessarily long, as simulator sickness returned to baseline levels within an hour for the T-45C BISim systems, and within half an hour for the T-6B and T-45C 4E18 VR-PTTs. Additionally, no participants reported delayed or relapsed simulator sickness after they finished their participation sessions.

These results are an encouraging initial indication that a shorter delay might be sufficient to ensure that SNAs are not flying while suffering from simulator sickness. However, there is no sufficient evidence for recommending a change in policy, considering that results stem from self-report data from a small proportion of their training cohorts. Further research using physiological measures of cybersickness for longer XR scenario exposure (e.g., greater than 1 hour practice scenario) is critical to support decisions regarding the appropriate delay between XR flight exposure and live flights.

7. Focus Group Recommendations

A team of Research Psychologists, Aerospace Experimental Psychologist, Visual Engineer, and Physiologist conducted a series of focus group sessions with instructor pilots and stakeholders (e.g., engineers and leadership) from all CNATRA locations participating in the evaluation. Insights from these focus group discussions were used to compile a series of prioritized recommendations for hardware/software upgrades, device implementation strategies, as well as integration into the existing training syllabus.

7.1. Hardware/Software Upgrades

7.1.1. T-6B Upgrades

The highest prioritized upgrade mentioned by instructor pilots was an improved flight model. Students commonly cited inaccuracies in aircraft behavior and control responses (e.g., throttle, flaps, trim, pitch, G response). Additionally, there were issues with aircraft stalls occurring in situations that would not normally produce a stall and vice versa (i.e., warning alarms above 17 units). The next recommended upgrade is improvements to the visual clarity within the cockpit as well as an increased field of view (i.e., more peripheral vision). The visual clarity in the current HMDs limits SNAs’ ability to use cockpit instruments and displays, requiring them to posture and strain to read necessary information. Additionally, the lack of peripheral vision inhibits SNAs from using their normal scan pattern, especially when conducting formation training missions. Visual clarity and FOV upgrades are dependent on advances in emerging HMD technology, which is primarily driven by the gaming industry. For example, the pilot horizontal field of view within the helmet was measured to be approximately 200 degrees; however, the HMDs assessed ranged from 90-105 degrees, which indicate a need for continuing research and development for improved display technology for HMDs to support a different market: aviation training. The third recommended upgrade is an improvement of cockpit functionality as a whole. Currently, not all switches in the cockpit are actionable. Ideally, the SNA would be able to interact with and manipulate all switches and gauges in the same manner they would in the aircraft. Furthermore, SNAs also need working multi-function displays (MFDs) to include a tactical situation display and flight management system (FMS). Instrumentation and indicator accuracy should also be improved. Presently, the angle of attack (AoA) indexer as well as the fuel gauge do not display accurate information. Lastly, the stick and throttle in the current T-6B device is not representative of an actual T-6B stick and throttle. Development of a realistic T-6B stick and throttle should be explored to fully optimize training utility and reduce the potential of negative training. The last recommended upgrade is improvements to the environmental mapping of common working areas and air fields, specifically landmarks for course rules (e.g., Goliad).

Communication was another noted area for attention. The networked capability is most beneficial when the SNAs have the ability to communicate via headset. The T-6B PTN devices did not have this capability, requiring them to speak in a manner that was distracting from the practice scenario. Thus, a need to improve communication across these devices is paramount. Further, simulated communication with air traffic control (e.g., Pilot Edge) could be integrated to enhance the fidelity of aviation communication during practice.

Market research should be conducted to address other upgrades that were discussed for consideration. This includes: a) an artificial intelligence companion aircraft (including communication with ATC), b) calculate jitter reduction of companion aircraft when conducting networked flight (i.e., dead reckoning), and c) incorporate a virtual kneeboard to support checklists, approach plates, and Flight Bible.

7.1.2. T-45C Upgrades

Priority one upgrades mentioned for the T-45C devices collectively are improved visual clarity inside the cockpit, as well as improved field of view. Like that of the T-6B, the visual clarity inside the cockpit is too poor to allow SNAs to read cockpit instruments and displays without significant eyestrain. Additionally, the current HMDs do not allow for clear peripheral vision, requiring the students to deviate from their normal scan pattern. Specifically, when SNAs were using the Varjo headset in the MRVS, they had to exaggerate horizontal head movements to compensate for limited peripheral view, which may have caused damage to the HMD prototype and increased simulator sickness symptoms. Included in the need for improved visuals, instructors also recommended improvements specifically for both BISim devices to include accurate Improved Fresnel Lens Optical Landing System (IFLOLS) to support Field Carrier Landing Practice (FCLPs) and a moving carrier for Carrier Qualification (CQ). The T-45C BISim VR-PTT featured a virtual representation of the user’s arm and hand to interact with the virtual cockpit (i.e., Leap Motion). However, the SNAs reported much frustration relying on the virtual limb for TACAN data input. Thus, an alternative should be explored (e.g., VR gloves, computer mouse).

The second recommended upgrade is an improvement to the T-45C flight model used in the devices. Currently, aircraft responses to certain user inputs are not accurate compared to the aircraft (e.g., throttle response, flaps, trim, pitch, stall warnings, and response to G’s). The T-45C 4E18 device, specifically, was reported to be overpowered, behaving more like an F/A-18 than a T-45C. A final flight model criticism was the perceived distance of the companion aircraft. The perceived distance did not reflect what was reported in the VR device (e.g., companion aircraft at 0.5 mile looks like 1 mile in the jet). Further, the detail was not visible beyond one mile in the T-45C BISim VR-PTT and 0.5 mile in the MRVS. A recommendation is to provide an artificial cue around the aircraft (e.g., green circle) to increase visibility beyond 0.5 mile.

The third priority upgrade is an improvement of all cockpit functionality. SNAs who evaluated the T-45C BISim VR-PTT and T-45C 4E18 VR-PTT expressed the need for the ability to manipulate all switches in the cockpit in a manner consistent with what would be expected in the aircraft. This is specifically in reference to the absence of a functioning tactical air navigation system (TACAN) and speed brakes. This also includes improving the accuracy of indicators in the cockpit (e.g., AoA gauge and fuel consumption gauge). The T-45C 4E18 and T-45C BISim VR-PTTs lack a stick and throttle setup that is comparable to the aircraft. Upgrades should be made to include improved fidelity between the stick and throttle in the VR-PTTs and what a student would find in the aircraft. The last recommended upgrade is an improvement in the quality and mapping of course rule landmarks in the common working areas and air fields. Additionally, the only cockpit concern for MRVS was that the MFDs should follow the same color scheme as would be found in the current aircraft, which is a consideration when developing mixed reality devices in outdated OFTs. Further, to facilitate the instructors' ability to interact with the SNA during mixed reality scenarios, they proposed providing an instructor station that displays a live-video feed of the cockpit and virtual environment. They also stated that having a mouse curser available to guide student attention to visual cues or other relevant information would be advantageous. To support the instructor's ability to understand the SNA gaze pattern, eye-tracking within the headset should be explored.

7.2. Implementation

With the demonstrable utility of improved XR systems, it is expected that more devices will be acquired in support of CNATRA's training curriculum. To ensure successful integration and ease in this organizational transition, it is imperative to establish a permanent billet to oversee the curriculum integration, standardization, operations, and maintenance for the XR devices. This position would be at the wing-level, requiring coordination across various departments and squadrons to ensure that the specific training needs unique to the wing are communicated and satisfied. For example, the T-45C 4E18 VR-PTTs at NAS Kingsville are in the simulation building, while NAS Meridian's are located near the ready rooms. The implementation of the trainers is different, although potential training benefits are being realized in each wing. However, the oversight of these devices is currently a lower-priority collateral duty, which has high turnover and lack of leadership consistency that could restrict the communication of the potential benefits and reduce SNA usage over time.

To support acceptance and long-term use of XR devices, the research team summarized a list of recommended improvements and integration strategies. This guidance includes how these devices should be implemented into the training wings to ensure training utility optimization and allow for accurate measurement of performance outcomes.

First, Common Access Card (CAC) readers should be integrated into all devices. This would support instructors and researchers in tracking student proficiency over time. Additionally, this could allow for future targeted training for specific SNAs. The CAC reader should automatically load the training start screen upon login and automatically log the student out when the CAC is removed. A menu-driven graphical user interface (GUI) that removes complex initialization procedures (e.g., no more than three clicks to begin scenario). Next, students should be provided with detailed user guides to include information on the capability of the devices, how to operate the devices, and the purpose for using the devices. This should also be complemented with a structured introductory course (i.e., XR 101 course) for both SNAs and instructors on how and why to use the devices.

To ensure buy-in from both students and instructors, it is recommended that training wings designate an official space specifically for these devices (e.g., an XR lab). This XR lab could supplement training by reinforcing classroom, computer-aided instruction, and / or training that is not supported by the OFT (e.g., Basic Flight Maneuvers; BFM). Having this lab could optimize time that was previously lost by cancelled flights and deploying devices on detachments to prevent out-of-order training. In addition to a designated training space, it is also recommended that training wings assign instructors or mentors (e.g., to include recently winged pilots) to maintain a presence in the virtual reality training spaces, which could serve as the SNA study hall. Pending software and hardware upgrades (e.g., adjustable chairs for height differences), instructors reported the possibility of using these devices for remediation training (e.g., having attrition-risk SNAs practice with instructor presence). This would ensure that students are utilizing their time in the virtual reality trainers in the most constructive manner possible.

When identifying this XR lab location, a concern towards the aesthetics of the layout should be respected as observed in the responses to the aesthetics and secondary questionnaires. Specifically, there should be consideration for hangar proximity, SNA access, and arrangement of devices within the space. Usage differences were attributed to those aforementioned considerations. Networked devices should be grouped together to imply this capability. For example, two of six devices in NAS Whiting Field were perpendicularly arranged (see Image 8.). SNAs assumed that these two devices could not network with the other four, and therefore, did not utilize this capability. Further, the four devices at NAS Meridian were paired in different rooms. As such, the SNAs had to be informed that they can network with their counterparts in the other squadron.

Image 8. T-6B PTN VR-PTT Arrangement at NAS Whiting FIeld

To support maintenance of these devices, it was recommended by the engineers to designate them as official training devices (i.e., formalize curriculum integration), so that the appropriate resources can be allocated during its life cycle. Further, securing the control mapping and reducing other aircraft options are necessary to reduce system failures.

Next, it is recommended that consideration be given to integrating virtual reality HMDs to existing UTDs and OFTs in a similar manner to the MRVS device included in this evaluation. This MR configuration allows students to utilize the advantages of a fully immersive virtual environment while still being able to interact with a more realistic cockpit.

Lastly, the VR-PTTs in the current evaluation were used exclusively for free play or self-guided study sessions, while the MRVS was used with traditional OFT instruction. Future research should examine different instructional strategies applied to XR, to determine how to implement XR training to the best advantage. One current effort towards integrating instructional strategies with XR training is the adaptation of the Virtual Instructor Pilot Exercise Referee (VIPER) by Discovery Machine, Incorporated (DMI). VIPER currently exists for the Air Force's PTN program, and is being adapted for the T-6B aircraft for the Navy's use, under the oversight of Research Psychologists from the STEALTh lab. VIPER is an AI tutor that provides adaptive instruction and feedback individualized to the SNA. Therefore, it serves as a method of scaffolding for pilot learning. Scaffolding is providing support for student performance, which is gradually removed as the student gains in ability (Wood, Bruner, & Ross, 1976). Scaffolding can improve the speed of skill acquisition, which could help to compress the pilot training pipeline (Sawyer, 2006).

7.3. Curriculum

The research team collected data from SNAs, instructors, and CNATRA leadership on training stages in the existing syllabus that could most benefit from XR technology. Feedback was given with respect to the devices' current form and potential utility after upgrades are implemented. Overall consensus suggests that the following T-6B stages would benefit most from the devices in their current form: Contact Flight, Contact Cockpit Procedures, Contact, Instruments, Basic Instruments, Radio Instruments, Instrument Navigation, Day Navigation, Night Navigation, and Formation. The T-45C practice that was reported across multiple devices were the Formation and Tactical Phases. Additionally, MRVS was reported to also support Contact and Instrument training. A summary of recommended scenarios and other curriculum enhancements are in the sections below.

7.3.1. T-6B Scenarios

The Instructors and students from NAS Whiting Field developed a prototype of a T-6B VR Training Syllabus that provides details on learning objectives, prerequisites, and pre-OFT practice scenarios for a 6-week period (see Appendix 10.15). Additional scenario suggestions that were collected for future iterations include:

- Emergency procedures
- Practicing scenarios on rails (e.g., 360-degree visuals)
- Providing highway in the sky (with virtual instruction)
- Voice-recorded instructions
- Checklist practice
- Landing Patterns / Course Rules (including ATC and other aircraft communications)

Discussions throughout the evaluation period centered around the revision of Naval Introductory Flight Evaluation (NIFE). "NIFE 2.0" would be a combination of NIFE, Aviation Pilot Indoctrination (API), and Primary (PRI) Ground School. The justification for this combination would be to focus instruction, reduce the training time, and expose SNAs to the T-

6B aircraft. This curriculum revision would also have morale-building implications in that the SNAs would all conduct the introductory training at a single location, reducing site-training variation and increase standardization.

7.3.2. T-45C Scenarios

In addition to the scenarios that were noted for programming in the T-6B PTN devices, the T-45C stakeholders also recommended that scenarios feature various weather conditions. Furthermore, a suggestion of leveraging the Virtual Mission Training System (VMTS) from Naval Flight Officer syllabus was also acknowledged. Finally, as observed with the T-6B PTN devices, having dual monitors allows for instrument flying sans the headset. Therefore, adding an additional monitor could greatly increase the XR training capability without significant cost increase. The recommendations for integration of the devices into existing curriculum is given in more detail in table form in Appendix 10.2 for the T-6B and Appendix 10.1 for the T-45C.

8. Conclusions

Quantitative performance data may support a link between the XR device usage and performance improvement (fewer reflys, marginals, and events to meet MIF). Further, controlled experimental research is needed to clarify the relationship between XR system usage and objective performance measures.

In addition, self-report feedback and focus groups for all four devices indicates that there are perceived benefits provided by XR flight trainers, beyond what is currently available in UTDs and OFTs. In spite of issues with clarity and FOV, the 360° field of regard was seen as a great strength of the XR systems; and their ability to provide a sight picture of flights was considered their greatest potential use. The T-45C trainers were expected to help cover existing gaps in formation and tactical phases; however, they were not seen as useful for carrier qualification landing, due to lack of functionality in the IFLOLS and aircraft carrier. In addition, without a virtual kneeboard capability, the VR-PTTs would not be appropriate for Operational Navigation (low-level flight). The T-6B VR-PTT was considered by SNAs mostly to be useful for Contact practice, but instructors and stakeholders saw additional value for instruments, navigation, and formation practice.

In spite of these positive responses, XR system usage was low, and T-6B PTN VR-PTT users were often less optimistic about its training utility than T-45C system users. Improvements in visuals, accuracy and completeness of the cockpits and external world, accuracy of the flight model, and functionality for instructors (e.g., gaze tracking, gaze guidance capability, and view repeater for the instructor) could make the systems more useful, thereby increasing perceived utility and usage of the XR systems. Low usage could also be addressed by improvements to implementation. These include a personnel support for integration, operations, and maintenance of the XR systems; a dedicated space for the XR systems with mentors or instructors present; CAC-enabled systems for SNA-specific tracking of device usage; improved start-up menus to facilitate easy system and scenario navigation; Mixed-reality systems that could integrate with UTD and OFTs to provide a realistic cockpit feel.

In conclusion, with noted upgrades, XR systems have the potential to improve performance, and can cover the gap in current training technologies for various stages in the T-6B and T-45C training pipelines. Moreover, low-cost XR devices can augment the training curriculum to allow the Navy to accelerate training throughput and reduce pilot shortage.

9. References

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10. Appendices

10.1. Appendix 1: T-45C Curriculum Recommendations

STAGE	STAGES	CURRENT MEDIA	RECOMMENDATION INPUT	NOTES
Ground Training (Intermediate)	Indoctrination	N/A	N/A	N/A
	Engineering	MIL / CAI	N/A	N/A
	Aerodynamics	MIL / CAI	N/A	N/A
	Meteorology	MIL / CAI	N/A	N/A
	Instrument Navigation	Lab / MIL / CAI	N/A	N/A
Ground Training (Advanced)	Indoctrination	N/A	N/A	N/A
	Operational Navigation Ground School	Class	N/A	N/A
Contact Training	Familiarization Flight Procedures	MIL / CAI	Yes	N/A
	Out-of-Control Flight	MIL / CAI	No	-Flight Model does not support accurate OCF / Stall Characteristics.
	Night Familiarization Flight Procedures	MIL / CAI	Maybe	N/A
	Field Carrier Landing Procedures (FCLP)	MIL / CAI	No	-IFLOS is inoperable.
	Familiarization Simulators	OFT	Yes	N/A
	Familiarization Emergency Procedures	OFT	No	N/A
	Familiarization	T-45C	Yes	N/A
	Familiarization Landing Pattern	T-45C	Maybe	-Pattern can be done up until final, where a working IFLOS is needed.
	Out-of-Control Flight Simulator	OFT	No	-Flight Model does not support accurate OCF / Stall Characteristics.

	Familiarization Safe-for-Solo Check Flight	T-45C	Maybe	-Pattern can be done up until final, where a working IFLOS is needed.
	Familiarization Solo	T-45C	Maybe	-Pattern can be done up until final, where a working IFLOS is needed.
	Day Familiarization Landing Pattern	T-45C	Maybe	-Pattern can be done up until final, where a working IFLOS is needed.
	Night Familiarization	OFT & T-45C	Maybe	N/A
	Night Familiarization Emergency Procedures	OFT	No	-CAUTION and WARNING lights are not functional.
	Night Familiarization Solo	T-45C	Maybe	N/A
	Field Carrier Landing Practice	OFT	No	-IFLOS inoperable.
	Night Landing Pattern	T-45C	Yes	N/A
	FCLP Safe-for-Solo	T-45C	No	-IFLOS inoperable during day.
	FCLP Practice Solo	T-45C	No	-IFLOS inoperable during day.
	FCLP Emergency Procedures	OFT	No	-CAUTION and WARNING lights are not functional.
	FCLP Check Flight Solo	T-45C	No	-IFLOS inoperable during day.
Instrument Training	BI /RI Course Rules	MIL	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Crew Resource Management	MIL	Maybe	-Would Require CRM Instructor to be present.
	Operational Risk Management	MIL	No	N/A
	NACES Flight Physiology	MIL / Lecture	No	N/A
	Cockpit Orientation	CAI / MIL / Lab	Yes	-But with some limitations (i.e., issues with Caution and Warning lights and cumbersome switchology associated with leap motion).
	Emergency Procedures	MIL / CAI	No	-CAUTION and WARNING lights are not functional.

	Basic Instrument Flight Procedures	MIL / CAI	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Radio Instrument Flight Procedures	CAI / MIL / Lab	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Airways Navigation Flight Procedures	MIL	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Instrument Rating Flight Procedures	CAI / MIL/ Exam	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Cockpit Orientation Simulators	IFT / OFT	Maybe	-But with some limitations (i.e., issues with Caution and Warning lights and cumbersome switchology associated with leap motion).
	Emergency Procedures	IFT / OFT	No	-CAUTION and WARNING lights are not functional.
	Basic Instrument Simulators	IFT / OFT	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Basic Instruments	T-45C	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Radio Instruments	IFT / OFT & T-45C	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Airways Navigation	OFT & T-45C	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Airways Navigation EP	OFT	No	-CAUTION and WARNING lights are not functional.
	Instrument Rating	IFT / OFT & T-45C	No	-CAUTION and WARNING lights are not functional.
	NATOPS Instrument Rating Check Flight	T-45C	No	-CAUTION and WARNING lights are not functional.

	Advanced Airways Navigation	OFT & T-45C	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
	Advanced Airways Navigation Solo	OFT & T-45C	No	-Fidelity of Radio Instruments Displays and difficulty in tuning instruments prevent effective instrument training.
Formation Training	Section Formation Flight Procedures	MIL / CAI	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Division Formation Flight Procedures	MIL / CAI	Maybe	-Requires PTT Integration or AI lead and only for light division (plane) or Multiple OFT with MRVS linked.
	Night Formation Flight Procedures	MIL / CAI	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Formation Simulators	OFT	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Formation Emergency Procedures	OFT	No	-CAUTION and WARNING lights are not functional.
	Basic Formation	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Basic Formation Solo	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Basic Formation Lead	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Cruise Formation	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.

	Cruise Formation Solo	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Division Formation	T-45C	Maybe	-Requires MRVS Integration or AI lead and only for light division (plane).
	Division Formation Solo	T-45C	Maybe	-Requires MRVS Integration or AI lead and only for light division (plane).
	Night Formation	OFT & T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Night Formation Emergency Procedures	OFT	No	-CAUTION and WARNING lights are not functional.
	Night Formation Solo	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Advanced Night Formation	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
	Advanced Night Formation Solo	T-45C	Yes	-Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hardware limits.
Tactical Training	Tactical Formation Flight Procedures	MIL / CAI	Yes	N/A
	Operational Navigation Flight Procedures	MIL / CAI	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix’s areas being built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Section Low-Level Flight Procedures	MIL / CAI	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix’s areas being built up would improve capability as well as adding "digital chart" to

				reference in the VR environment.
	Road Recce Flight Procedures	MIL / CAI	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix's areas being built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Strike Flight Procedures	MIL / CAI	Maybe	-Air to Ground mode not supported for HUD use and Weapons Employment.
	1 V 1 Basic Fighter Maneuvering Flight Procedures	MIL / CAI	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.
	2 V 1 Section Engaged Maneuvering Flight Procedures	MIL / CAI	Maybe	-Requires MRVS linked or an AI Bandit.
	Carrier Qualification Landing Flight Procedures	MIL / CAI	Maybe	-IFLOS on ship is inoperable; Catapult on ship does not work.
	Operational Navigation	OFT & T-45C	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix's areas being built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Operational Navigation (Section Low-Level)	T-45C	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix's areas being built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Road Recce	T-45C	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix's areas being built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Section Road Recce Solo	T-45C	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix's areas being

				built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Strike	OFT & T-45C	Maybe	-Air-to-Ground mode not supported for HUD use and Weapons Employment.
	Strike Emergency Procedures	OFT	No	-Air-to-Ground mode not supported for HUD use and Weapons Employment, as well as Caution and Warning lights not fully operable.
	Strike Solo	T-45C	Maybe	-Limited without being able to reference the route chart with HMD, also limited built-up route availability, El Centro and Phoenix’s areas being built up would improve capability as well as adding "digital chart" to reference in the VR environment.
	Tactical Formation	T-45C	Yes	N/A
	Tactical Formation Solo	T-45C	Yes	N/A
	Advanced Tactical Formation	T-45C	Yes	
	Advanced Tactical Formation Solo	T-45C	Yes	
	Out-of-Control Simulator	OFT	No	-Flight Model does not support accurate OCF / Stall Characteristics.
	Basic Fighter Maneuvering (OCF / 1 V 0)	T-45C	No	-Flight Model does not support accurate OCF / Stall Characteristics.
	Basic Fighter Maneuvering (TACFORM Refresher)	T-45C	Yes	N/A
	Basic Fighter Maneuvering (Offensive 1 V 1)	T-45C	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.
	Basic Fighter Maneuvering Solo (Offensive 1 V 1)	T-45C	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.
	Basic Fighter Maneuvering Solo (Defensive 1 V 1)	T-45C	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.
	Basic Fighter Maneuvering Solo (Defensive 1 V 1)	T-45C	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.

	Basic Fighter Maneuvering (High-Aspect 1 V 1)	T-45C	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.
	Basic Fighter Maneuvering Solo (High Aspect 1 V 1)	T-45C	Yes	-Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution.
	Section Engaged Maneuvering (2 V 1)	T-45C	Yes	-Requires MRVS linked or an AI Bandit.
	Section Engaged Maneuvering Solo (2 V 1)	T-45C	Yes	-Requires MRVS linked or an AI Bandit.
	Night CQL Safe-for- Solo	T-45C	No	-Need accurate and operating IFLOS.
	Carrier Qualification Landing Solo	T-45C	No	-Need accurate and operating IFLOS.
	Carrier Qualification Landing Simulators	OFT	No	-Need accurate and operating IFLOS.
	Emergency Procedures (CQL)	OFT	No	-Need accurate and operating IFLOS / Caution and Warning lights not fully functional.
	Carrier Qualification Landing Solo Check Flight (Field)	T-45C	No	-Need accurate and operating IFLOS.
	Carrier Qualification Landing Solo Check Flight (Ship)	T-45C	No	-Need accurate and operating IFLOS.

T-45C BISim MRVS

STAGE	STAGES	CURRENT MEDIA	RECOMMENDATION INPUT	NOTES
Ground Training (Intermediate)	Indoctrination	N/A	N/A	N/A
	Engineering	MIL / CAI	N/A	N/A
	Aerodynamics	MIL / CAI	N/A	N/A
	Meteorology	MIL / CAI	N/A	N/A
	Instrument Navigation	Lab / MIL / CAI	N/A	N/A
	Indoctrination	N/A	N/A	N/A

Ground Training (Advanced)	Operational Navigation Ground School	Class	N/A	N/A
Contact Training	Familiarization Flight Procedures	MIL / CAI	Yes	N/A
	Out-of-Control Flight	MIL / CAI	Yes	N/A
	Night Familiarization Flight Procedures	MIL / CAI	Yes	N/A
	Field Carrier Landing Procedures	MIL / CAI	Yes	N/A
	Familiarization Simulators	OFT	Yes	N/A
	Familiarization Emergency Procedures	OFT	Yes	N/A
	Familiarization	T-45C	Yes	N/A
	Familiarization Landing Pattern	T-45C	Yes	N/A
	Out-of-Control Flight Simulator	OFT	Yes	N/A
	Familiarization Safe-for-Solo Check Flight	T-45C	Yes	N/A
	Familiarization Solo	T-45C	Yes	N/A
	Day Familiarization Landing Pattern	T-45C	Yes	N/A
	Night Familiarization	OFT & T-45C	Yes	N/A
	Night Familiarization Emergency Procedures	OFT	Yes	N/A
	Night Familiarization Solo	T-45C	Yes	N/A
	Field Carrier Landing Practice (FCLP)	OFT	Yes	N/A
	Night Landing Pattern	T-45C	Yes	N/A
	FCLP Safe-for-Solo	T-45C	No	-IFLOS inoperable during day.
	FCLP Practice Solo	T-45C	No	-IFLOS inoperable during day.

	FCLP Emergency Procedures	OFT	Yes	N/A
	FCLP Check Flight Solo	T-45C	No	-IFLOS inoperable during day.
Instrument Training	BI /RI Course Rules	MIL	Yes	N/A
	Crew Resource Management	MIL	Yes	N/A
	Operational Risk Management	MIL	No	N/A
	NACES Flight Physiology	MIL / Lecture	No	N/A
	Cockpit Orientation	CAI / MIL / Lab	Yes	N/A
	Emergency Procedures	MIL / CAI	Yes	N/A
	Basic Instrument Flight Procedures	MIL / CAI	Yes	N/A
	Radio Instrument Flight Procedures	CAI / MIL / Lab	Yes	N/A
	Airways Navigation Flight Procedures	MIL	Yes	N/A
	Instrument Rating Flight Procedures	CAI / MIL/ Exam	Yes	N/A
	Cockpit Orientation Simulators	IFT / OFT	Yes	N/A
	Emergency Procedures	IFT / OFT	Yes	N/A
	Basic Instrument Simulators	IFT / OFT	Yes	N/A
	Basic Instruments	T-45C	Yes	N/A
	Radio Instruments	IFT / OFT & T-45C	Yes	N/A
	Airways Navigation	OFT & T-45C	Yes	N/A
	Airways Navigation EP	OFT	Yes	N/A
	Instrument Rating	IFT / OFT & T-45C	Yes	N/A

	NATOPS Instrument Rating Check Flight	T-45C	Yes	N/A
	Advanced Airways Navigation	OFT & T-45C	Yes	N/A
	Advanced Airways Navigation Solo	OFT & T-45C	Yes	N/A
Formation Training	Section Formation Flight Procedures	MIL / CAI	Yes	N/A
	Division Formation Flight Procedures	MIL / CAI	Maybe	-Requires PTT Integration or AI lead and only for light division (plane) or Multiple OFT with MRVS linked.
	Night Formation Flight Procedures	MIL / CAI	Yes	N/A
	Formation Simulators	OFT	Yes	N/A
	Formation Emergency Procedures	OFT	Yes	N/A
	Basic Formation	T-45C	Yes	N/A
	Basic Formation Solo	T-45C	Yes	N/A
	Basic Formation Lead	T-45C	Yes	N/A
	Cruise Formation	T-45C	Yes	N/A
	Cruise Formation Solo	T-45C	Yes	N/A
	Division Formation	T-45C	Maybe	-Requires PTT Integration or AI lead and only for light division (plane), or Multiple OFT with MRVS linked.
	Division Formation Solo	T-45C	Maybe	-Requires PTT Integration or AI lead and only for light division (plane), or Multiple OFT with MRVS linked.
	Night Formation	OFT & T-45C	Yes	N/A
	Night Formation Emergency Procedures	OFT	Yes	N/A
	Night Formation Solo	T-45C	Yes	N/A

	Advanced Night Formation	T-45C	Yes	N/A
	Advanced Night Formation Solo	T-45C	Yes	N/A
Tactical Training	Tactical Formation Flight Procedures	MIL / CAI	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Operational Navigation Flight Procedures	MIL / CAI	Yes	-Additional areas built-up (i.e., El Centro and Phoenix would improve training capability).
	Section Low-Level Flight Procedures	MIL / CAI	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Road Recce Flight Procedures	MIL / CAI	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Strike Flight Procedures	MIL / CAI	Yes	-Additional areas built-up (i.e., El Centro and Phoenix would improve training capability).
	1 V 1 Basic Fighter Maneuvering Flight Procedures	MIL / CAI	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	2 V 1 Section Engaged Maneuvering Flight Procedures	MIL / CAI	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Carrier Qualification Landing Flight Procedures	MIL / CAI	N/A	N/A
	Operational Navigation	OFT & T-45C	Yes	-Additional areas built-up (i.e., El Centro and Phoenix would improve training capability).
	Operational Navigation (Section Low-Level)	T-45C	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Road Recce	T-45C	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Section Road Recce Solo	T-45C	Maybe	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Strike	OFT & T-45C	Yes	-Additional areas built-up (i.e., El Centro and Phoenix would improve training capability).
	Strike Emergency Procedures	OFT	Yes	-Additional areas built-up (i.e., El Centro and Phoenix would improve training capability).
	Strike Solo	T-45C	Yes	-Additional areas built-up (i.e., El Centro and Phoenix would improve training capability).

	Tactical Formation	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Tactical Formation Solo	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Advanced Tactical Formation	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Advanced Tactical Formation Solo	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Out-of-Control Simulator	OFT	Yes	N/A
	Basic Fighter Maneuvering (OCF / 1 V 0)	T-45C	Yes	N/A
	Basic Fighter Maneuvering (TACFORM Refresher)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Basic Fighter Maneuvering (Offensive 1 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Basic Fighter Maneuvering Solo (Offensive 1 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Basic Fighter Maneuvering Solo (Defensive 1 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Basic Fighter Maneuvering Solo (Defensive 1 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Basic Fighter Maneuvering (High-Aspect 1 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Basic Fighter Maneuvering Solo (High Aspect 1 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Section Engaged Maneuvering (2 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Section Engaged Maneuvering Solo (2 V 1)	T-45C	Yes	-Requires VR-PTT networked or another OFT with MRVS networked, or an AI lead scripted.
	Night CQL Safe-for- Solo	T-45C	Yes	N/A
	Carrier Qualification Landing Solo	T-45C	Yes	N/A
	Carrier Qualification Landing Simulators	OFT	Yes	N/A

	Emergency Procedures (CQL)	OFT	Yes	N/A
	Carrier Qualification Landing Solo Check Flight (Field)	T-45C	Yes	N/A
	Carrier Qualification Landing Solo Check Flight (Ship)	T-45C	Yes	N/A

CNATRA T-45C 4E18 VR-PTTs

STAGE	STAGES	CURRENT MEDIA	RECOMMENDATION INPUT	NOTES
Ground Training (Intermediate)	Indoctrination	N/A	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Engineering	MIL / CAI	Yes	-A VR trainer could help visualize how the engine/aircraft/systems are constructed and how the internal parts operate.
	Aerodynamics	MIL / CAI	Yes	-A VR trainer could help SNAs visualize different aerodynamic principles.
	Meteorology	MIL / CAI	Yes	-A VR trainer could help SNAs visualize different meteorological principles.
	Instrument Navigation	Lab / MIL / CAI	Yes	-VR trainers could help the SNA practice and get accustomed to the Navigation equipment. How to operate it.
Ground Training (Advanced)	Indoctrination	N/A	Yes	-Help an SNA fill out a virtual pink sheet.
	Operational Navigation Ground School	Class	Yes	-A VR trainer could help the ONAV ground school SNAs with the visual techniques of chart study, terrain crossing/following, obstruction avoidance, as well as weather contingencies.
Contact Training	Familiarization Flight Procedures	MIL / CAI	Yes	-A VR trainer could help to supplement the memorization of on deck procedures as well as the various maneuvers we do every FAM flight.
	Out-of-Control Flight	MIL / CAI	Maybe	-A VR trainer could help the SNAs visualize the different modes of the T-45C spin, upright, and inverted. Also, how to recover from them.

				-Flight Model does not support accurate OCF / Stall Characteristics.
	Night Familiarization Flight Procedures	MIL / CAI	Maybe	-Night is night, but a VR trainer might be able to help SNAs see recognizable GEO features such as city cultural lighting. -Local terrain features inaccurate for use with night FAM route.
	Field Carrier Landing Procedures	MIL / CAI	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	Familiarization Simulators	OFT	Yes	-A VR trainer could help to supplement the memorization of on deck procedures as well as the various maneuvers we do every FAM flight.
	Familiarization Emergency Procedures	OFT	Maybe	-A VR trainer could help to supplement the memorization of EP procedures.
	Familiarization	T-45C	Yes	-A VR trainer could help to supplement the memorization of on deck procedures/check list items as well as the various maneuvers we do every FAM flight.
	Familiarization Landing Pattern	T-45C	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	Out-of-Control Flight Simulator	OFT	Maybe	-A VR trainer could help the SNAs visualize the different modes of the T-45C spin, upright and inverted. -Flight Model does not support accurate OCF / Stall Characteristics.
	Familiarization Safe-for-Solo Check Flight	T-45C	Maybe	--A VR trainer could potentially help a solo fam student prep for the actual flight by flying the entire profile on the VR trainer.
	Familiarization Solo	T-45C	Maybe	-A VR trainer could potentially help a solo fam student prep for the actual flight by flying the entire profile on the VR trainer.
	Day Familiarization Landing Pattern	T-45C	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	Night Familiarization	OFT & T-45C	Maybe	-Night is night, but a VR trainer might be able to help SNAs see recognizable GEO features such as city cultural lighting.

	Night Familiarization Emergency Procedures	OFT	Maybe	-A VR trainer could help to supplement the memorization of EP procedures.
	Night Familiarization Solo	T-45C	Maybe	-A VR trainer could potentially help a solo fam student prep for the actual flight by flying the entire profile on the VR trainer.
	Field Carrier Landing Practice (FCLP)	OFT	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	Night Landing Pattern	T-45C	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	FCLP Safe-for-Solo	T-45C	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	FCLP Practice Solo	T-45C	Maybe	-VR trainers could help SNAs with the procedures while in the landing pattern but probably will not help with "Ball" flying techniques.
	FCLP Emergency Procedures	OFT	Maybe	-A VR trainer could help to supplement the memorization of EP procedures.
	FCLP Check Flight Solo	T-45C	Maybe	-A VR trainer could potentially help a solo fam student prep for the actual flight by flying the entire profile on the VR trainer.
Instrument Training	BI /RI Course Rules	MIL	Maybe	-VR trainers could help an SNA fly and practice the instrument course rules.
	Crew Resource Management	MIL	No	N/A
	Operational Risk Management	MIL	No	N/A
	NACES Flight Physiology	MIL / Lecture	No	N/A
	Cockpit Orientation	CAI / MIL / Lab	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Emergency Procedures	MIL / CAI	Yes	-A VR trainer could help to supplement the memorization of EP procedures.
	Basic Instrument Flight Procedures	MIL / CAI	Yes	-A VR trainer could help to supplement the memorization of EP procedures.

	Radio Instrument Flight Procedures	CAI / MIL / Lab	Yes	-A VR trainer could help to supplement the memorization of EP procedures.
	Airways Navigation Flight Procedures	MIL	Yes	-A VR trainer could help to supplement the memorization of EP procedures.
	Instrument Rating Flight Procedures	CAI / MIL/ Exam	Yes	-A VR trainer could help to supplement the memorization of EP procedures.
	Cockpit Orientation Simulators	IFT / OFT	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Emergency Procedures	IFT / OFT	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Basic Instrument Simulators	IFT / OFT	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Basic Instruments	T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Radio Instruments	IFT / OFT & T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Airways Navigation	OFT & T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Airways Navigation EP	OFT	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Instrument Rating	IFT / OFT & T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch

				positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	NATOPS Instrument Rating Check Flight	T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Advanced Airways Navigation	OFT & T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
	Advanced Airways Navigation Solo	OFT & T-45C	Yes	-We have static trainers that allow SNAs to get accustomed to the switch positions and cockpit layout. A VR trainer could supplement this as we only have a single static trainer.
Formation Training	Section Formation Flight Procedures	MIL / CAI	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Division Formation Flight Procedures	MIL / CAI	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Night Formation Flight Procedures	MIL / CAI	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Formation Simulators	OFT	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice

				parade position due to hard ware limits.
	Formation Emergency Procedures	OFT	Yes	A VR trainer could help an SNA visualize the proper formation positions and procedures.
	Basic Formation	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Basic Formation Solo	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Basic Formation Lead	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Cruise Formation	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Cruise Formation Solo	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Division Formation	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs

				required to fly / practice parade position due to hard ware limits.
	Division Formation Solo	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures. -Procedures can be practiced, however the "feel" of the controls does represent control inputs required to fly / practice parade position due to hard ware limits.
	Night Formation	OFT & T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures.
	Night Formation Emergency Procedures	OFT	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures.
	Night Formation Solo	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures.
	Advanced Night Formation	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures.
	Advanced Night Formation Solo	T-45C	Yes	-A VR trainer could help an SNA visualize the proper formation positions and procedures.
Tactical Training	Tactical Formation Flight Procedures	MIL / CAI	Yes	-A VR trainer could help an SNA visualize the proper Tactical formation positions and procedures. -Good for sight pictures, poor aircraft model does not reflect aircraft performance.
	Operational Navigation Flight Procedures	MIL / CAI	Yes	-A VR trainer could help the ONAV SNAs with the visual techniques of chart study, terrain crossing/following, obstruction avoidance, as well as weather contingencies. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Section Low-Level Flight Procedures	MIL / CAI	Yes	-A VR trainer could help the ONAV SNAs with the visual techniques of chart study, terrain crossing/following, obstruction avoidance, as well as weather contingencies. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Road Recce Flight Procedures	MIL / CAI	Yes	-A VR trainer could help the ONAV SNAs with the visual techniques of chart study, terrain

				crossing/following, obstruction avoidance, as well as weather contingencies. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Strike Flight Procedures	MIL / CAI	Yes	-A VR trainer could help a strike SNA with the visualization of the weapons pattern, fixing a steep or shallow dive as well as the TACADMIN throughout the flight
	1 V 1 Basic Fighter Maneuvering Flight Procedures	MIL / CAI	Yes	-A VR trainer could help with various BFM "sight" pictures as well as P-A-D-S setup
	2 V 1 Section Engaged Maneuvering Flight Procedures	MIL / CAI	Yes	-A VR trainer could help with various BFM "sight" pictures as well as P-A-D-S setup.
	Carrier Qualification Landing Flight Procedures	MIL / CAI	Yes	-Could help a SNA visualize flight deck operations.
	Operational Navigation	OFT & T-45C	Yes	-Could help a SNA visualize flight deck operations. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Operational Navigation (Section Low-Level)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Road Recce	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Section Road Recce Solo	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Limited without being able to reference the route chart with HMD, terrain not accurately rendered.
	Strike	OFT & T-45C	Yes	-Could help a SNA visualize flight deck operations.
	Strike Emergency Procedures	OFT	Yes	-Could help a SNA visualize flight deck operations.
	Strike Solo	T-45C	Yes	-Could help a SNA visualize flight deck operations.
	Tactical Formation	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, poor aircraft model does not reflect aircraft performance.

	Tactical Formation Solo	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, poor aircraft model does not reflect aircraft performance.
	Advanced Tactical Formation	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, poor aircraft model does not reflect aircraft performance.
	Advanced Tactical Formation Solo	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, poor aircraft model does not reflect aircraft performance.
	Out-of-Control Simulator	OFT	Maybe	-Could help a SNA visualize flight deck operations. -Flight Model does not support accurate OCF / Stall Characteristics.
	Basic Fighter Maneuvering (OCF / 1 V 0)	T-45C	Maybe	-Could help a SNA visualize flight deck operations. -Flight Model does not support accurate OCF / Stall Characteristics.
	Basic Fighter Maneuvering (TACFORM Refresher)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Basic Fighter Maneuvering (Offensive 1 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Basic Fighter Maneuvering Solo (Offensive 1 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Basic Fighter Maneuvering Solo (Defensive 1 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Basic Fighter Maneuvering Solo (Defensive 1 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot

				resolution, poor aircraft model does not reflect aircraft performance.
	Basic Fighter Maneuvering (High-Aspect 1 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Basic Fighter Maneuvering Solo (High Aspect 1 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Section Engaged Maneuvering (2 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Section Engaged Maneuvering Solo (2 V 1)	T-45C	Yes	-Could help a SNA visualize flight deck operations. -Good for sight pictures, however Air-to-Air Mode not supported in HUD for gun sight tracking and shot resolution, poor aircraft model does not reflect aircraft performance.
	Night CQL Safe-for- Solo	T-45C	Maybe	-Could help a SNA visualize flight deck operations.
	Carrier Qualification Landing Solo	T-45C	Maybe	-Could help a SNA visualize flight deck operations.
	Carrier Qualification Landing Simulators	OFT	Maybe	-Could help a SNA visualize flight deck operations.
	Emergency Procedures (CQL)	OFT	Maybe	-Could help a SNA visualize flight deck operations.
	Carrier Qualification Landing Solo Check Flight (Field)	T-45C	Maybe	-Could help a SNA visualize flight deck operations.
	Carrier Qualification Landing Solo Check Flight (Ship)	T-45C	Maybe	-Could help a SNA visualize flight deck operations.

10.2. Appendix 2: T-6B Curriculum Recommendations

STAGE	STAGES	CURRENT MEDIA	RECOMMENDATION INPUT	NOTES
Ground Training	Administration / Indoctrination	Classroom	No	-No relevance. -Should be a class early on to introduce use/operation of the devices.
	Systems	Classroom	No	-Better options available. -VR in general could be useful for systems, but less so in current PTN devices.
	Operating Procedures	Classroom	No	-Device does not have proper cockpit controls.
	Course Rules	Classroom	Maybe	-With higher resolution, video and imagery that resembles actual visual checkpoints this could be very valuable. Not effective in current state. -Current generic scenery should be more specific. -Needs KNGT update. Currently missing / inaccurate.
Contact Training	Contact Flight Procedures I (MIL / CAI)	MIL / CAI	No	-Procedural knowledge to study. No practical application. -Possible intro by IP during the MIL class showing a typical landing pattern. -Current flight dynamics are wrong enough for minimal / no utility
	Contact Flight Procedures II (MIL / CAI)		No	-Procedural knowledge to study. No practical application. -Possible intro by IP during MIL class showing a typical Emergency landing pattern. -Current flight dynamics are wrong enough for minimal / no utility.
	Contact Flight	Lecture	Yes	-Could be effectively used as an airfield familiarization tool, for taxi and ground operations practice. -The VR device can be useful for instruction after classroom instruction. -This event is the Contact flight 0 with the on-wing. It might be useful for one on one review of basic procedures in preparation for the C4101. -Would be great to have 360 video of a flight.
	Contact Cockpit Procedures	UTD	Yes	-As a study aid for some specific aspects of contacts, the VR is very useful. It can be used for timing in the pattern, airspace management techniques, basic transitions, and some basic air work. Improved settings that more closely resemble the T-6B would be more effective. -Device does not have proper cockpit controls. -Great for ground procedures intro, taxi, T/O, land.

	Contact Emergency Procedures Trainer	UTD / OFT	Maybe	-No, with configuration not matching the actual aircraft this could be very negative training as there is more emphasis on location of switches and circuit breakers, nor appropriate control inputs that are the muscle memory foundation for handling an EP. -Not the way the device is currently structured.
	Contact (OFT)	OFT	Yes	-Has some specific uses that could be very effective. Pattern timing and sight picture, area management, course rules, and some aspects of some maneuvers. -The device can be used as a real time procedural trainer. Training would be optimized with a proctor. -Offline (after event) practice of C3101-C3203 items -Could do OFT events in UTD with Mixed Reality (MR) upgrade
	Day Contact (T-6B)	T-6B	Maybe	-Has some specific uses that could be very effective. Pattern timing and sight picture, area management, course rules, some aspects of some maneuvers. -The device can be used as a real time procedural trainer. Training would be optimized with a proctor. -Offline (after event) practice of items introduced in the aircraft.
	Midphase Contact Check Flight (T-6B)	T-6B	Maybe	-Possible study and student prep device but otherwise nothing new from contact phase.
	Contact Solo Flight (T-6B)	T-6B	No	-No additional learning objectives to be obtained.
	Final Contact Check Flight	T-6B	No	N/A
	Night Contact	T-6B	Maybe	-Could get some sense of the night environment and night landing pattern. With improved software for visuals could be very helpful in nighttime orientation.
Instrument Training	Instruments	Classroom	Yes	-Would be an excellent tool for demonstration and practice of individual types of approaches. -Can be used to augment classroom instruction. -Could supplement the R.I.O.T device currently planned for MIL and MIL/Labs
	Basic Instruments	UTD	Yes	-Yes, the device has already proved somewhat effective for instrument training without use of VR goggles but displays allow for flying instrument profiles and preparation for sim and aircraft events. Only limitation is inability to use all functions of FMS system and inability to physically push

				the buttons on the MFDs and UFCP. -Probably the best use of the device as it stands. This once again would be a real time procedural trainer. It would also allow for situational awareness during BI maneuvers.
	Radio Instruments	OFT & T-6B	Yes	-Yes, the device has already proved somewhat effective for instrument training without use of VR goggles but displays allow for flying instrument profiles and preparation for sim and aircraft events. Only limitation is inability to use all functions of FMS system and inability to physically push the buttons on the MFDs and UFCP. -Probably the best use of the device as it stands. This once again would be a real time procedural trainer. It would also allow for situational awareness during RI maneuvers. -Could do OFT events in UTD with Mixed Reality (MR) upgrade.
	Instrument Navigation	OFT & T-6B	Yes	-Yes, the device has already proved somewhat effective for instrument training without use of VR goggles but displays allow for flying instrument profiles and preparation for sim and aircraft events. Only limitation is inability to use all functions of FMS system and inability to physically push the buttons on the MFDs and UFCP. -Probably the best use of the device as it stands. This once again would be a real time procedural trainer. It would also allow for situational awareness during RI maneuvers. -Could do OFT events in UTD with Mixed Reality (MR) upgrade.
	Instrument Check Flight	T-6B	Maybe	-In reference to the point of the check ride, it would be effective as a chair flying and prep device for students on their own time. -This would only be beneficial if proctored to ensure regulation requirements are met. -All check flights should be conducted in the aircraft. VR devices may be useful for remediation during failed events.
Navigation Training	Navigation (Visual Flight Rules)	MIL / CAI	No	N/A
	Day Navigation	OFT & T-6B	Yes	-Once again with better scenery.

				-Could do OFT events in UTD with Mixed Reality (MR) upgrade.
	Night Navigation	OFT & T-6B	Yes	-Once again with better scenery. -Could do OFT events in UTD with Mixed Reality (MR) upgrade.
Formation Training	Formation	MIL / CAI	Yes	-could be effective in demonstrating positioning, relative motion, and corrections. It could be a very effective tool especially if it was easier to set up and form up. -Very little utility. Maybe as a tool for the instructor to demonstrate proper position. This can be more affectively accomplished through other means.
	Formation	OFT	Maybe	-PCL control and flight dynamics limit the utility, but has potential.
	Formation	T-6B	No	N/A
	Formation Solo Flight	T-6B	No	N/A
	Cruise Formation	T-6B	No	N/A

10.3. Appendix 3: Simulator Sickness Questionnaire

NOTE: Your DODID is only being collected to track your survey data and device usage with performance in the jet. Your DODID will not be included on any information or analysis sent outside of the research team.

DOD ID: ____________________________

Date: ______________________________

Which system will/did you use? (circle one): MRVS VR-PTT

Time slot (circle one):

Pre-Test Post-Test 30-minute 60- minute 90-minute 120-minute

Instructions: Select how each symptom below is affecting you right now.

	NONE	SLIGHT	MODERATE	SEVERE
1) **GENERAL DISCOMFORT**	☐	☐	☐	☐
2) **FATIGUE**	☐	☐	☐	☐
3) **HEADACHE**	☐	☐	☐	☐
4) **EYE STRAIN**	☐	☐	☐	☐
5) **DIFFICULTY FOCUSING**	☐	☐	☐	☐
6) **SALIVATION**	☐	☐	☐	☐
7) **SWEATING**	☐	☐	☐	☐
8) **NAUSEA**	☐	☐	☐	☐
9) **DIFFICULTY CONCENTRATING**	☐	☐	☐	☐
10) **FULLNESS OF THE HEAD**	☐	☐	☐	☐
11) **BLURRED VISION**	☐	☐	☐	☐
12) **DIZZINESS WITH EYES OPEN**	☐	☐	☐	☐
13) **DIZZINESS WITH EYES CLOSED**	☐	☐	☐	☐
14) **VERTIGO (FEELING OFF BALANCE)**	☐	☐	☐	☐

15) **STOMACH AWARENESS** **(DISCOMFORT THAT IS JUST SHORT OF NAUSEA)**	☐	☐	☐	☐
16) **BURPING**	☐	☐	☐	☐

10.4. Appendix 4: Virtual Limb Ownership

NOTE: Your DODID is only being collected to track your survey data and device usage with performance in the jet. Your DODID will not be included on any information or analysis sent outside of the research team.

DODID: ________________________________

Date: __________________________________

Instructions: Please respond to the following questions about your experience with using the VR-PTT training device. The following questions pertain to your perception of any sensations, movements, and/or characteristics of the hands you see displayed in the HMD versus your real hands.

1. I felt as if the virtual hands were my hands.

   ☐ Strongly disagree

   ☐ Disagree

   ☐ Neither disagree nor agree

   ☐ Agree

   ☐ Strongly agree

2. It seemed as if I had more than one hand on each arm.

   ☐ Strongly disagree

- ☐ Disagree
- ☐ Neither disagree nor agree
- ☐ Agree
- ☐ Strongly agree

3. It felt as if my virtual hands belonged to someone else.
   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

4. It felt as if I could control my virtual hands as if they were my own hands.
   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

5. The movements of my virtual hands were caused by my movements.
   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree

- ☐ Agree
- ☐ Strongly agree

6. It seemed as if I felt the touch of the stick or cockpit on my actual hand in the same location as I saw it touch my virtual hand.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

7. It seemed as if the touch I felt was located somewhere between my physical hand and the virtual hand.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

8. It felt as if my actual hands were located in the same location as my virtual hands.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree

- ☐ Strongly agree

9. I felt out of body.
   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

10. The movements of the limb in my field of view did not correlate with the movements of my actual limb (i.e. movements were delayed, not in the same location in space, different length, etc...)
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neither disagree nor agree
    - ☐ Agree
    - ☐ Strongly agree

10.5. Appendix 5: Automation Use in Everyday Life

DOD ID: ______________________________

Date: ________________________________

Instructions: Please respond to the following questions about your experience with automated devices. For your reference, automation is defined as the use of machines and technology to make processes run on their own without manpower. Examples of automation include using an app on your phone for driving directions (e.g., GPS), and wearing an arm device to monitor health data (e.g., Fitbit).

1. I use an app on my phone when driving to a new location (e.g., GPS, Maps, Mapquest).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

2. I use a fitness device to automatically collect my activity level (e.g., Fitbit, Apple Watch).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

3. I use online banking tools for financial management (e.g., billpay Quicken, Mint).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

4. I use subscription services for shopping (e.g., Amazon, Birch Box).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

5. I use voice command for my phone to make calls, send text messages, or search for information (e.g. Siri, Cortana, HeyGoogle).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

6. I use a home automation device (e.g., Amazon Echo, the nest, security system).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

7. I use an automatic cleaning device (e.g., Roomba).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

8. I use an entertainment subscription service (e.g., Netflix, Hulu, Gamefly).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

9. I use driving assistance features (e.g., rearview camera, OnStar, automatic personalized seat adjustment).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

10. I use personalized lifestyle apps (e.g., Weight Watchers, Spotify, Pandora, Apple News).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

11. I use a personal simulator for flight practice outside of formal training (e.g., desktop flight simulator).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

12. I play interactive video games (e.g., First Person Shooter (FPS), Real Time Strategies (RTS), Role-Playing (RPG)).

- ☐ Never: I never use this.
- ☐ Rarely: I use this only around once a year.
- ☐ Sometimes: I use this every other month.
- ☐ Often: I use this at least once a month.
- ☐ Always: I use this at least once a week.

10.6. Appendix 6: Trust in Automation

DOD ID: ______________________________

Date: ________________________________

Instructions: Please respond to the following questions about your experience with automated devices. For your reference, automation is defined as the use of machines and technology to make processes run on their own without manpower. Examples of automation include using an app on your phone for driving directions (e.g., GPS), and wearing an arm device to monitor health data (e.g., Fitbit).

1. I usually trust automation until there is a reason not to.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

2. For the most part, I distrust automation.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither disagree nor agree
   - ☐ Agree
   - ☐ Strongly agree

3. In general, I would rely on automation to assist me.

   - ☐ Strongly disagree

- ☐ Disagree
- ☐ Neither disagree nor agree
- ☐ Agree
- ☐ Strongly agree

4. My tendency to trust automated devices is high.
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neither disagree nor agree
    - ☐ Agree
    - ☐ Strongly agree

5. It is easy for me to trust automated devices to do their job.
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neither disagree nor agree
    - ☐ Agree
    - ☐ Strongly agree

6. I am likely to trust automation even when I have little knowledge about it.
    - ☐ Strongly disagree

☐ Disagree

☐ Neither disagree nor agree

☐ Agree

☐ Strongly agree

Trust in the VR-PTT

7. To what extent are you confident in the visuals that the VR-PTTs project (e.g., cockpit features, OTW environment)?

   ☐ Not at all

   ☐ A little

   ☐ Sometimes

   ☐ Frequently

   ☐ All the time

8. To what extent are the VR-PTTs consistent with the visual outputs it provides (e.g., OTW visuals vs Cockpit read outs)?

   ☐ Not at all

   ☐ A little

   ☐ Sometimes

   ☐ Frequently

   ☐ All the time

9. To what extent can you rely on the VR-PTTs to deliver accurate visuals while flying?

   ☐ Not at all

   ☐ A little

- ☐ Sometimes
- ☐ Frequently
- ☐ All the time

10. To what extent do you feel that you can make accurate maneuver decisions based on the visual outputs from the MRVS (e.g., OTW visuals, Cockpit read outs)?

    - ☐ Not at all
    - ☐ A little
    - ☐ Sometimes
    - ☐ Frequently
    - ☐ All the time

10.7. Appendix 7: Aesthetics Questionnaire

[Questions 4 – 23 are adapted from the Aesthetic Pleasure in Design Scale developed by Blijlevens et al., 2017.]

1. If a training system is attractive, then I am more motivated to use it

    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neither disagree nor agree
    - ☐ Agree
    - ☐ Strongly agree

2. If a training system is attractive, then it is easier for me to learn from it.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither disagree nor agree
- ☐ Agree
- ☐ Strongly agree

3. If a training system is attractive, then it makes me perform better on the tasks it trains.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither disagree nor agree
- ☐ Agree
- ☐ Strongly agree

4. The [DEVICE NAME] training environment is nice to see.

- ☐ Strongly disagree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

5. The design of the [DEVICE NAME] environment is rich in elements.

- ☐ Strongly disagree
- ☐
- ☐

- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

6. The [DEVICE NAME] is an attractive training environment.
    - ☐ Strongly disagree
    - ☐
    - ☐
    - ☐ Neutral
    - ☐
    - ☐
    - ☐ Strongly agree
7. The design of the [DEVICE NAME] environment is original.
    - ☐ Strongly disagree
    - ☐
    - ☐
    - ☐ Neutral
    - ☐
    - ☐
    - ☐ Strongly agree
8. The [DEVICE NAME] is characteristic of a flight training environment.
    - ☐ Strongly agree
    - ☐

- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

9. The [DEVICE NAME] environment is a unified design.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

10. The [DEVICE NAME] is a standard design for a flight training environment.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

11. The [DEVICE NAME] environment is a coherent design.

- ☐ Strongly agree

- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

12. The design of the [DEVICE NAME] environment is innovative.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

13. The [DEVICE NAME] training environment is pleasing to see.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

14. The [DEVICE NAME] is a new example of a flight training environment.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

15. The [DEVICE NAME] environment includes multiple different components.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

16. The [DEVICE NAME] environment is an orderly design.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐

- ☐ Strongly agree

17. The [DEVICE NAME] is a beautiful training environment.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

18. The design of the [DEVICE NAME] environment conveys variety.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

19. The [DEVICE NAME] is a novel flight training environment.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐

☐ Strongly agree

20. The [DEVICE NAME] is representative of a flight training environment.

☐ Strongly agree

☐

☐

☐ Neutral

☐

☐

☐ Strongly agree

21. I like to look at the [DEVICE NAME] training environment.

☐ Strongly agree

☐

☐

☐ Neutral

☐

☐

☐ Strongly agree

22. The [DEVICE NAME] is a typical flight training environment.

☐ Strongly agree

☐

☐

☐ Neutral

☐

☐

☐ Strongly agree

23. The design of the [DEVICE NAME] is common for a flight training environment.

☐ Strongly agree

☐

☐

☐ Neutral

☐

☐

☐ Strongly agree

24. For VR-PTT systems: Does the physical layout (monitor/seat/stick and throttle) and proximity of the training systems make it obvious that you can team up with other pilots for joint flights (formation, BFM, etc)?

____ Yes

____ No

a. Is there a different physical layout that would make it more obvious?

25. If a training system has an appealing color scheme, then I am more motivated to use it.

☐ Strongly agree

☐

☐

- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

a. Why?

26. If a training system has an appealing color scheme, then I am more willing to keep using it.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

a. Why?

27. If a training system has an appealing color scheme, then I learn more from it.

- ☐ Strongly agree
- ☐
- ☐
- ☐ Neutral
- ☐
- ☐
- ☐ Strongly agree

a. Why?

28. Do you have any other comments on the visual appeal of training systems?

10.8. Appendix 8: Comprehensive Questionnaire

1. What is your DODID?: ______________________________

2. Please circle your gender: Male Female Other

3. Please provide information about your current position:
   - ☐ Position title: ________________________________
   - ☐ Years in current position: ________________________________
   - ☐ Current stage of training (Syllabus and Block): ________________________________

4. Please provide information about your experience:
   - ☐ PTO (Platform and Years): ________________________________
   - ☐ Flight Instructor (Platform and Years): ________________________________
   - ☐ Flight Experience (Platform and Years): ________________________________

5. How many hours have you spent using VR systems in the past?: ____

6. What device did you use today (what is the name of the device)? ________________________

7. Which stages did you focus on during your VR session, in order of highest focus to lowest focus? (i.e., “1” = your primary focus, “2” = your secondary focus, “X” = not a focus at all)
   - ☐ Contacts: FAM
   - ☐ Contacts: OCF
   - ☐ Contacts: NFM
   - ☐ Contacts: FCL
   - ☐ Contacts: CO
   - ☐ Instruments: BI
   - ☐ Instruments: RI
   - ☐ Instruments: AN
   - ☐ Instruments: IR
   - ☐ Formation: FRM
   - ☐ Formation: DIV
   - ☐ Formation: NFR
   - ☐ Tactical: ON
   - ☐ Tactical: RR
   - ☐ Tactical: STK
   - ☐ Tactical: TAC
   - ☐ Tactical: BFM
   - ☐ Tactical: SEM
   - ☐ Tactical: CQ

8. Which events did you focus on during your VR session?
   - ☐ Primary focus: ________
   - ☐ Secondary focus: ________
   - ☐ Other events: ________
9. [MRVS QUESTIONNAIRE ONLY] Please select which entity configuration you used during your VR session:
   - ☐ Networked with at least one other human
   - ☐ Networked with at least one other human and at least one AI entity
   - ☐ Only AI entities
   - ☐ Solo (No other human or AI entities)
10. [BISim QUESTIONNAIRE ONLY] For each scenario you completed, please complete the following items.

Snapshot Drill

i. Rate the effectiveness of the Snapshot Drill scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Flats

i. Rate the effectiveness of the Flats scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Roller

i. Rate the effectiveness of the Roller scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

6K Set

i. Rate the effectiveness of the 6K Set scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

9K Set

i. Rate the effectiveness of the 9K Set scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Butterfly

i. Rate the effectiveness of the Butterfly scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Abeam

i. Rate the effectiveness of the Abeam scenario for training BFM:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Defense Combat Spread

i. Rate the effectiveness of the Defense Combat Spread scenario for training TAC:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Offense Combat Spread

i. Rate the effectiveness of the Offense Combat Spread scenario for training TAC:

1	2	3	4	5
Not effective at all		*Somewhat effective*		*Extremely effective*

Do you have any other feedback on the scenarios you completed?

---

11. Please rank the reasons why students could use this device? (i.e., “1” = most important reason, “2” = second most important reason, etc.). If a reason below is not useful, please indicate with an “X”.
    - ☐ Preparing for their next event
    - ☐ Remediation on items for which their instructors gave feedback

- ☐ Learning new content
- ☐ Building a site picture
- ☐ Exploring what they can do on the device ("free play")
- ☐ Other:

12. Which stages could be usefully practiced with this device?
Contacts: FAM; OCF; NFM; FCL
Instruments: CO; BI; RI; AN; IR
Formation: FRM, DIV, NFR
Tactical: ON; RR; STK; TAC; BFM; SEM; CQL

13. What graded maneuvers could students practice in this device? ________

Instructions: Please indicate your level of agreement with the following statements:

14. I think students would feel motivated to use this training system.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

15. The training system was easy to set up.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

16. The training system was easy to use.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

17. I am confident that the VR training system will improve students' training outcomes.

1	2	3	4	5

Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

18. It was easy to navigate between the different scenarios within the training system.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

19. The limited width of the view in the VR-PTT compared to the OFT may not allow for training certain tasks.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

20. The view inside the cockpit was not clear enough to support scenario tasking.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

21. The view outside the cockpit was not clear enough to support scenario tasking.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

22. The auditory feedback is consistent with real-world scenarios.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

23. The communication within the VR system is consistent with real-world scenarios.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

24. Landmarks were realistic enough to adequately support scenario tasking for low level flight or CQ tasks.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

25. The behavior of OTHER aircraft in the training system is realistic enough to adequately support scenario tasking for formation or BFM tasks.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

26. The VR training system distracted me from focusing on the scenario.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-How did it distract you? ________

27. There were inconsistencies between the physical layout or appearance of the VR cockpit and the live aircraft that made it hard to complete the scenario in a natural way.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What were the inconsistencies? ________

-How did they interfere? ________

28. All of the controls and indicators in the cockpit were in the correct location.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What was in the incorrect location? ________

-For each item that was incorrectly placed, would that interfere with learning? ________

29. The cockpit was unrealistic enough to interfere with pilot learning.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What was unrealistic? ________

30. The view outside the aircraft was unrealistic enough to interfere with pilot learning.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What was unrealistic? ________

31. The cockpit was missing critical elements that I needed to complete the scenario.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What elements were missing? ________

32. The view outside the aircraft was missing critical elements that I needed to complete the scenario.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What elements were missing? ________

33. Controls that were required to complete tasking were useful analogies to controls in the live aircraft (e.g., flip switch, turn knob, push button).

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-What controls were poor analogies to the live aircraft? ________

34. The flight profile of the training system is comparable to the live aircraft.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-If not, what was wrong with the flight profile? ________

35. I had to lean in to read the indicators in the cockpit.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Which indicators did you have to lean in to read? ________

36. This training system could increase mission readiness.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-If disagree, why not? If agree, how? ________

37. This training system could improve student performance in the aircraft.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-If disagree, why not? If agree, how? ________

38. This training system could reduce cost in the training pipeline.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-If disagree, why not? If agree, how? ________

39. (MRVS only) The delay in visuals inside the cockpit made tasking difficult.

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

-Why? ________

40. (MRVS only) The OFT cockpit and the virtual outside environment worked appropriately together (e.g., transitioned seamlessly).

1	2	3	4	5
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*

Instructions: Please respond to the following questions.

39. Where in the syllabus could these virtual reality devices be used?

-Why?

40. What block(s) in the syllabus would gain the most impact of the virtual reality training?

-Why?

41. Are there any stages in the syllabus where these devices should NOT be used for training?

-Why?

10.9. Appendix 9: Flight Log Questionnaire

This is the online flight log for CNATRA students to enter data on their use of new VR and microsimulator

training devices. Please complete the log as soon as possible after your event. Data will

inform and drive future implementations of new technologies to improve training.

1. DODID:_________

2. Training Wing:

- ☐ TW-1
- ☐ TW-2
- ☐ TW-4
- ☐ TW-5

3. Squadron:

- ☐ VT-7
- ☐ VT-9
- ☐ VT-21
- ☐ VT-22

4. Please select your squadron

- ☐ VT-2
- ☐ VT-3
- ☐ VT-6

- ☐ VT-27
- ☐ VT-28

5. Which device did you use?

- ☐ One of the 4 desk devices
- ☐ CNATRA1 (left seat gaming chair)
- ☐ CNATRA2 (right seat gaming chair)

6. Date used/observed VR Device:_______

7. How many minutes were you at the controls of the VR device:_____

8. Which phase of training are you in?

- ☐ Intermediate Jet
- ☐ Advanced Strike
- ☐ E2C2

9. What stage of training are you in?

- ☐ Stashed
- ☐ Ground School
- ☐ Contacts: FAM
- ☐ Contacts: OCF
- ☐ Contacts: NFM
- ☐ Contacts: FCL
- ☐ Instruments: CO
- ☐ Instruments: BI
- ☐ Instruments: RI
- ☐ Instruments: AN

- ☐ Instruments: IR
- ☐ Formation: FRM
- ☐ Formation: DIV
- ☐ Formation: NFR
- ☐ Tactical: ON
- ☐ Tactical: RR
- ☐ Tactical: STK
- ☐ Tactical: TAC
- ☐ Tactical: BFM
- ☐ Tactical: SEM
- ☐ Tactical: CQL

10. Select the primary reason for use:

- ☐ Preparing for my next event
- ☐ Working on items I received feedback on from instructors
- ☐ Learning new content
- ☐ Building a site picture
- ☐ Exploring what I can do on the device ("free play")
- ☐ Other (please specify)

11. Did you network the device with another student using another device?

- ☐ Yes
- ☐ No

12. What was most valuable practicing with another student?

Select all that apply.

- ☐ Not Applicable/did not fly with another student.
- ☐ Building a site picture.
- ☐ Working on comms.
- ☐ Practicing FTI procedures.
- ☐ Building situational awareness.
- ☐ Understanding aircraft positions.

- ☐ Other (please specify)__________

10.10. Appendix 10: Wrap-up Questionnaire

Instructions: Please provide your feedback on the virtual reality (VR) training systems.

1. What is your DODID?

2. Which training wing are you in:
   - ☐ TW-1
   - ☐ TW-2
   - ☐ TW-4
   - ☐ TW-5

3. Which squadron are you in:
   - ☐ VT-2
   - ☐ VT-3
   - ☐ VT-6
   - ☐ VT-7
   - ☐ VT-9
   - ☐ VT-21
   - ☐ VT-22
   - ☐ VT-27
   - ☐ VT-28

4. Current stage of training (syllabus):
   - ☐ Primary
   - ☐ Intermediate
   - ☐ E2/C2
   - ☐ Advanced Strike

5. [NAS Corpus Christi, NAS Whiting Field] Current stage of training (Chapter):
   - ☐ Ground School
   - ☐ Contacts
   - ☐ Instruments
   - ☐ Navigation
   - ☐ Formation

6. [NAS Kingsville, NAS Meridian] Current stage of training (Chapter and Block):
   - ☐ Contacts Block:________________
   - ☐ Instruments Block:________________
   - ☐ Formation Block:________________
   - ☐ Tactical Block:________________

7. Do you have your own VR flight training device? Yes No
   a. How often do you use it for aviation training?
      i. Daily
      ii. Every other day
      iii. Weekly
      iv. Monthly
      v. Never
   b. Do you prefer your own device over the squadron VR devices?
      i. Why or why not?

____
____
____

8. How often do you use the squadron VR devices?
   a. Daily
   b. Every other day
   c. Weekly
   d. Monthly
   e. Never

If Never:

i. Why have you not used the squadron VR devices?
   1. Did not know about them
   2. Did not know how to use them
   3. Do not feel they will be useful.
   4. Was told not to use them by peers
   5. Was told not to use them by instructors
   6. Just checked in to the Wing/Squadron
   7. Other: ___________________________________

Additional comments on why you did not use the VR devices:

____
____
____

9. On average, how long do you spend in a VR training session? ___________ minutes

10. On average, how long do you spend using VR to aid training per week? ____________ hours

11. How many total hours would you estimate you have spent using a VR device to aid your training: ___________ hours

12. [NAS Kingsville] How much total time have you spent using each of the VR devices?
    a. 4E18 VR-PTT: __________ hours
    b. Bohemia Interactive Simulations VR-PTT: _______ hours
    c. MRVS: ___________ hours

13. [NAS Kingsville] Which VR device do you prefer?
- ☐ 4E18 VR-PTT
- ☐ Bohemia Interactive Simulations VR-PTT
- ☐ MRVS
- ☐ Prefer not to use the squadron VR devices

14. Rank order the most valuable experience in the *squadron* VR training systems:
- ☐ Building a sight picture
- ☐ Working on comms
- ☐ Practicing FTI procedures
- ☐ Building situational awareness
- ☐ Understanding aircraft positions
- ☐ Flying with another student (e.g., formation)
- ☐ Other: ____

15. [NAS Kingsville, NAS Meridian] The [Device Name] is most applicable to improve **knowledge** and **skill** for:

Contacts	Instruments	Formation	Tactical
___FAM	___BI	___FRM	___ON
___OCF	___RI	___DIV	___RR
___NFM	___AN	___NFR	___STK
___FCL	___IR		___TAC
___CO			___BFM
			___SEM
			___CQL

a. Never used the [Device Name] device
b. Not useful

16. [NAS Corpus Christi, NAS Whiting Field] The VR device is most applicable to <u>improve</u> **knowledge** and **skill** for:
   - ☐ Not useful
   - ☐ Contacts
   - ☐ Instruments
   - ☐ Navigation
   - ☐ Formation

a. Never used the PTN T-6B device

17. Have the VR devices changed the way you approach studying or training outside of scheduled events (CAI's classroom work, SIMS, etc.)? (i.e., spend more or less time chair flying
   - ☐ Yes
   - ☐ No

If yes, please explain: ____

18. Did using the VR devices change your eye scan or head movement patterns compared to the OFT and aircraft?
   - ☐ Yes
   - ☐ No

If yes, please explain: ____

19. During events with an instructor, were you able to focus on fling the aircraft more or go more in-depth on topics/maneuvers/procedures because you had used the VR devices and were better prepared?
   - ☐ Yes
   - ☐ No

Please describe why or why not:

____

____

____

20. Training in the VR devices <u>improved</u> your **performance** in training.
   - ☐ Strongly Disagree
   - ☐ Disagree
   - ☐ Neutral
   - ☐ Agree

- ☐ Strongly Agree
- ☐ Never used the VR devices

Please describe how it has or has not improved your performance:

____

21. Please provide any additional comments on how CNATRA might improve VR training to better prepare students for SIMS and flights:

10.11. Appendix 11: BISim T-45C MRVS Feedback

Positive Feedback

Aspect or Application of the Device	**Pros**	**# of Participants**	**CNATRA Location**
Usability	Easy setup when knowledgeable instructor is present	16	NAS Kingsville
	Does not require articulation of virtual controls	14	NAS Kingsville
Avionics	Utilizes real T-45C cockpit	*MRVS incorporates all avionics and displays in standard OFT cockpit	NAS Kingsville
Environmental Appearance	360° field of regard is better than the traditional OFT display	6	NAS Kingsville

	Outside view better than the OFT	9	NAS Kingsville
Flight Model	Similar to OFT flight model	7	NAS Kingsville
Networking Capabilities	Can network with the BIS VR-PTTs	*Capability was not available to students during feedback testing.	NAS Kingsville
Stage of Training	Most useful for Formation, Tactical, and/or Contacts stages	34	NAS Kingsville
Training Utility	May also be useful for preparing for the next event, remediation, and learning new content	26	NAS Kingsville
	Most useful for building a sight picture	21	NAS Kingsville

Negative Feedback

Aspect or Application of the Device	Cons	# of Participants	CNATRA Location	Research Team Recommendations
Usability	Easy setup assumes instructor knows how to operate system	9	NAS Kingsville	Simplify system setup or provide step-by-step setup guide
	Calibration of the mask (that separates the virtual environment and video pass through of the cockpit) needs to be reset periodically; does not always calibrate correctly	7	NAS Kingsville	Update software to maintain calibration of pilot positioning within cockpit across multiple sessions
Avionics	Gauges and indicators requires some visual focus to read	17	NAS Kingsville	Explore future integration of new, higher-acuity AR headsets
Environmental Appearance	Complaints of eyestrain due to limitations in visual acuity and MFDs flickering	31	NAS Kingsville	Explore the possibility of changing refresh rates in video feed to reduce MFD flicker

	in video feed			
	Higher incidence of simulator sickness symptoms compared to VR-PTTs	34	NAS Kingsville	Explore future integration of new, higher-acuity AR headsets Explore future integration of AR headsets with smaller lag in pass-through video or see-through displays
Flight Model	Unrealisitc aircraft behavior	13	NAS Kingsville	Integrate with accurate OFT flight model or reprogram to adjust aircraft behavior
Networking Capabilities	Significant jitter in companion aircraft	4	NAS Kingsville	Provide the OFT data to make capability usable
Stage of Training	Not useful for CQ or FCLP stages due to lack of a functioning IFLOLS	7	NAS Kingsville	Reprogram to include functional IFLOLS for FCLP and CQ training

	Not useful for Instruments stages due to low visual acuity	30	NAS Kingsville	Explore future integration of new, higher-acuity AR headsets to improve readability of cockpit instruments
Training Utility	Reduced peripheral vision and limited visual acuity may reduce utility due to increased need to turn head	18	NAS Kingsville	Explore future integration of wider-FOV and higher-acuity AR headsets if they become available
				Encourage use before new events to build sight picture

10.12. Appendix 12: BISim T-45C VR-PTT Feedback

Positive Feedback

Aspect or Application of the Device	Pros	# of Participants	CNATRA Location
Usability	Easy, simple setup for experienced users.	18	NAS Kingsville

	Helpful quick start guide and how- to video.	11	NAS Kingsville
Avionics	Accurate, complete, and realistic cockpit layout.	17	NAS Kingsville
Environmental Appearance	360° field of regard is better than the OFT.	15	NAS Kingsville
	Clear, complete, and realistic landscape view outside aircraft.	23	NAS Kingsville
Flight Model	Relatively few inconsistencies and may be easy to adapt to inconsistencies.	5	NAS Kingsville
Networking Capabilities	Able to rendevous and fly formation with other aircraft.	10	NAS Kingsville
Stage of Training	Most useful for Formation, Tactical, and/or some Contacts stages.	45	NAS Kingsville
Training Utility	Extremely useful for building a sight picture.	41	NAS Kingsville
	Useful for preparing for upcoming events and free play.	32	NAS Kingsville
	May increase mission readiness and performance.	12	NAS Kingsville
	Could replace chair flying.	3	NAS Kingsville

Negative Feedback

Aspect or Application of the Device	Cons	# of Participants	CNATRA Location	Research Team Recommendations
Usability	Setup can be difficult and complex for novice users.	15	NAS Kingsville	Develop unified and simplified interface for startup and configuration.
	Software failures increase setup time.	11	NAS Kingsville	
	Hand tracking controls difficult to use, causing user distraction while flying.	12	NAS Kingsville	Provide mouse as an alternative to hand tracking for controls.
Avionics	Virtual controls difficult and unrealistic to use.	27	NAS Kingsville	Explore future integration with simulated cockpit (e.g., 3D printed cockpit). Provide mouse as an alternative to hand

				tracking for controls
Environmental Appearance	Blurry cockpit	34	NAS Kingsville	Explore integration of new, higher-acuity VR headsets as they become available.
	Visual clarity limits ability to see other aircraft at long distances.	8	NAS Kingsville	
Flight Model	Aircraft behavior not realisitc.	22	NAS Kingsville	BISim has continued to consult SMEs and reprogram flight model to address inaccuracies; recommend further iterations.
Networking Capabilities	Jitter or lag in the position of the other aircraft may inhibit close formation.	14	NAS Kingsville	Change update rate or calculations for displayed image when networked.
Stage of Training	Not suitable for Instruments stages.	38	NAS Kingsville	Explore future integration of new, higher-acuity VR headsets to improve readability

				of cockpit instruments.
	Some users may not find the system useful in any stage of training.	4	NAS Kingsville	
Training Utility	May not be useful for learning new content or remediation.	14	NAS Kingsville	Encourage use before new events to build sight picture.
	Difficult virtual controls, inaccurate control feel, and flight model inaccuracies may decrease motivation to use.	47	NAS Kingsville	Continue to reprogram flight model to address remaining inaccuracies.

10.13. Appendix 13: T-45C 4E18 VR-PTT Feedback

Positive Feedback

Aspect or Application of the Device	**Pros**	**# of Participants**	**CNATRA Location**

Usability	Easy, simple setup and use	14	Meridian (7) Kingsville (7)
	Helpful usage guide	6	Meridian (6) Kingsville (0)
Avionics	Representative, realistic, and nearly complete cockpit layout	7	Meridian (4) Kingsville (3)
Environmental Appearance	360° field of regard is better than the OFT	40	Meridian (23) Kingsville (17)
	Clear, realistic, and complete view outside the aircraft	36	Meridian (21) Kingsville (15)
Flight Model	Pitch buck is programmed in	6	Meridian (2) Kingsville (4)
	Accurate flight appearance	8	Meridian (5) Kingsville (3)
Networking Capabilities	Useful for formation flying	11	Meridian (8) Kingsville (3)
	Other aircraft behave realistically	17	Meridian (12) Kingsville (5)
Stage of Training	Best for advanced students	9	Meridian (8)

			Kingsville (1)
	Most useful for Formation and Tactical stages	50	Meridian (24) Kingsville (26)
	Useful for some Contacts stages and Cockpit Orientation	14	Meridian (5) Kingsville (9)
Training Utility	Extremely useful for building a sight picture	27	Meridian (14) Kingsville (13)
	Suitable for preparing for next event and free play	14	Meridian (11) Kingsville (3)
	Increased mission readiness and performance	21	Meridian (11) Kingsville (10)
	Motivating	34	Meridian (21) Kingsville (13)
	Greater availability than OFT; provides additional training and preparation time	5	Meridian (3) Kingsville (2)

Negative Feedback

Aspect or Application	**Cons**	**# of Participants**	**CNATRA Location**	**Research Team Recommendations**

of the Device				
Usability	Mapping of functions to physical controls does not match the T-45C	13	Meridian (7) Kingsville (6)	Explore future integration with simulated cockpit (e.g., 3D printed cockpit) or consult SMEs for best mapping to the Warthog HOTAS or virtual cockpit.
Avionics	Inconsistent responsiveness in stick, throttle, and trim	30	Meridian (11) Kingsville (19	Reprogram aircraft responses to stick, throttle, and trim to improve consistency. Reprogram cockpit to include TACAN. Reprogram AoA indexer and gauge to correct inaccurate displays.
	TACAN absent or incorrect	22	Meridian (8) Kingsville (14)	
	AoA indexer and gauge inconsistent with each other and with aircraft AoA	23	Meridian (9) Kingsville (12)	
Environmental Appearance	Blurry cockpit	53	Meridian (25) Kingsville (28)	Explore future integration of new, higher-acuity VR headsets as they
	Unclear view of other aircraft	13	Meridian (7)	

			Kingsville (6)	become available.
Flight Model	Takeoff speed is high	11	Meridian (7) Kingsville (4)	Consult SMEs and reprogram aircraft to match T-45C airspeeds for takeoff and flight maneuvers. Reprogram stall warnings to occur under correct circumstances. Reprogram aircraft to match T-45C AoA.
	Airspeeds are high	16	Meridian (6) Kingsville (10)	
	G forces is not similar to fighter aircraft	4	Meridian (3) Kingsville (1)	
	Stall warning inappropriately goes off above 17 units AoA	13	Meridian (5) Kingsville (8)	
	AoA does not match T-45C AoA	15	Meridian (4) Kingsville (9)	
Networking Capabilities	Close configuration causes jitter or lag, which may inhibit close formation	16	Meridian (8) Kingsville (8)	Explore changes to networking to reduce lag, reduce own-aircraft adjustments, and increase reliability of headset communications.
	Exaggerated own-aircraft adjustments relative to other aircraft	11	Meridian (6) Kingsville (5)	
	Frequent failures in	14	Meridian (7)	

	communication via headsets		Kingsville (7)	
Stage of Training	Not best for initial- or intermediate-stage students	5	Meridian (2) Kingsville (3)	Explore future integration of new, higher-acuity VR headsets to improve readability of cockpit instruments. Reprogram cockpit to include TACAN and accurate AoA indexer and gauge.
	Not suitable for Instruments stages	39	Meridian (17) Kingsville (22)	
	May not be useful for remediation	6	Meridian (4) Kingsville (2)	Encourage use before new events to build sight picture. Other recommended actions could improve usefulness for remediation and suitability for replacing or supplementing syllabus events.
Training Utility	Reduction in training cost may be small or nonexistent due to insufficiency	16	Meridian (7) Kingsville (9)	Other recommended actions could improve usefulness for remediation

	to replace current syllabus events			and suitability for replacing or supplementing syllabus events.

10.14. Appendix 14: PTN T-6 VR-PTT Feedback

Positive Feedback

Aspect or Application of the Device	Pros	# of Participants	CNATRA Location
Usability	User-friendly	1	NAS Corpus Christi
		2	NAS Whiting
	Clear and simple instruction binder makes setup easy	1	NAS Corpus Christi
		14	NAS Whiting
Avionics	Realistic and complete cockpit layout	6	NAS Corpus Christi
		16	NAS Whiting

Environmental Appearance	Realistic and complete view outside the aircraft	10	NAS Corpus Christi
		14	NAS Whiting
	View inside cockpit sufficiently clear for some users	2	NAS Corpus Christi
		8	NAS Whiting
Flight Model	Flight model accurate enough for some users	3	NAS Corpus Christi
		2	NAS Whiting
Networking Capabilities	Networking enables formation practice	4	NAS Corpus Christi
		10	NAS Whiting
Stage of Training	Most useful for Contacts stages	44	NAS Corpus Christi
		105	NAS Whiting
	Also useful for Instruments and Formation stages	22	NAS Corpus Christi
		83	NAS Whiting

Training Utility	Extremely useful for building a sight picture	46	NAS Corpus Christi
		110	NAS Whiting
	Suitable for learning new content and free play	48	NAS Corpus Christi
		109	NAS Whiting
	May be more beneficial than chair flying	6	NAS Corpus Christi
		4	NAS Whiting
	Will improve student performance in the aircraft	10	NAS Corpus Christi
		6	NAS Whiting

Negative Feedback

Aspect or Application of the Device	**Cons**	**# of Participants**	**CNATRA Location**	**Research Team Recommendations**
Usability	Mapping of functions to physical controls does not match the T-6B	12	NAS Corpus Christi	Explore future integration with simulated cockpit (e.g., 3D printed cockpit) or consult SMEs for best mapping to the
		19		

			NAS Whiting	Warthog HOTAS or virtual cockpit
Avionics	Warthog HOTAS was not a useful analogy to the PCL/throttle or landing gear	16	NAS Corpus Christi	Explore future integration with simulated cockpit (e.g., 3D printed cockpit) or consult SMEs for best mapping to the Warthog HOTAS or virtual cockpit
		43	NAS Whiting	
	Lack of control feedback makes flying more difficult	5	NAS Corpus Christi	Explore use of weighted controls to provide haptic feedback
		17	NAS Whiting	
Environmental Appearance	Instruments and indicators, especially altitude indicator, too blurry for some users	29	NAS Corpus Christi	Explore future integration of new, higher-acuity VR headsets as they become available
		67	NAS Whiting	
Flight Model	Trim is difficult	7	NAS Corpus Christi	Consult SMEs and reprogram power settings to match T-6B aircraft
		26	NAS Whiting	
	Power settings may be inaccurate	3	NAS Corpus Christi	
		8	NAS Whiting	

Networking Capabilities	Insufficient communication with partners in formation practice	3	NAS Corpus Christi	Provide realistic communication options via VR headset or other microphone
		5	NAS Whiting	
Stage of Training	Fewer users consider it useful for Navigation stages due to lack of visual detail and checkpoints	43	NAS Corpus Christi	Explore use of more detailed landmarks and accurate checkpoints to improve usefulness for Navigation training
		111	NAS Whiting	
Training Utility	Lack of visual clarity, unrealistic physical control mapping, and lack of control feedback may reduce training utility	12	NAS Corpus Christi	Encourage use before new events to build sight picture
		35	NAS Whiting	
	Divided opinions on utility for preparing for the next event and remediation	15	NAS Corpus Christi	Educate students on the primary purposes and limitations of VR-PTTs
		51	NAS Whiting	
	Students may not be open to the idea of training in VR-PTTs	20	NAS Corpus Christi	Other recommended actions could improve training utility

10.15. Appendix 16: T-6B Prototype Syllabus

VR Curriculum Instructions:							
1. This curriculum is meant to aid in procedural and checklist familiarization. *Tactile feel and cockpit memorization should first be done in the static and FMS trainers.*							
2. All flights start and end at KNSE. Alternate RWY in use each flight. Course rules are not necessary to be used for weeks 1-3. After week 3, begin using course rules and alternate working areas							
3. When scheduled, ELP/PEL should be last maneuver in the working area. Land at nearest suitable airfield and then proceed to KNSE for touch and gos and course rules.						**Weeks 1-3 are the condensed curriculum	
4. Prior to each week, flight procedures should be reviewed via information from the FTI. All information can be found on-line via the eBook Bag, CNATRA web pages,							
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Notes**	
Week 1	**Reading:** Contacts FTI (CFT) 1-3 (1) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** Familiarize yourself with VR binder and rules. Practice both VR and	**Reading:** CFTI 4-5 (1)(2) **Flash Cards:** Memory EPs, Ops Limits, IMSAFE, 4 Forces, Stalls, Yaw Forces, Trim, Attitude Flying, Flight Maneuvers, Scan Pattern, Turns, P.A.T., 3 Cs	**Reading:** CFTI 6 (1-3) **Static Trainer:** Hollywood Checklist, Non-Memory EPs **VR Trainer:** 5 Touch and Go (TG), 1Full Stop (FS), GAwareness Exercise (GX), Basic Turns, Transitions	**Reading:** CFTI 7-9 (1-3) **Flash Cards:** Memory EPs, Ops Limits, Fuel, Ejection Seat/Strap-in, Start Procedures, Taxi, Ground Procedures, ALDIS Lamp, Takeoff, Striaght and Level, Transitions, Turn Pattern, Level Speed Change, Stalls,	**Reading:** CFTI 10-C (1-3) **Static Trainer:** Hollywood Checklist, Non-Memory EPs **VR Trainer:** 5 Touch and Go (TG), 1Full Stop (FS), GAwareness Exercise (GX), Level Speed Change (LSC), Student Slow Flight (SS), Turn	(1)Chair fly LDG pattern video: www.t6bdriver.com/c3102.html (2) Watch Checklist video www.t6bdriver.com/checklist-procedures.html	
Week 2	**Reading:** SY0101-0103 (1-4) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 5TG, 1FS, LSC, Power-on Stall (PoS), ELP Stall (ES)	**Reading:** SY0104-0106 (1-5) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI Cards1-4, Systems Review Questions 0106	**Reading:** SY0107-0109 (1-5) **Static Trainer:** Hollywood Checklist, Non-Memory EPs **VR Trainer:** 5TG, 1FS, GX, SS, TP Landing Approach Turn Stall (LTS), Slip **Flash Cards:** Review CFTI 4-6	**Reading:** SY0110-0112 (1-5) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 7-9, Review Questions 0106-0112	**Reading:** SY0114-0190 (1-5) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, LSC, PoS, LAT, Landing Attitude Stall (LAS), ES, Slip on **Flash Cards:** Review CFTI 10-Systems Review Questions 0190	Helpful App: https://www.avedapps.com/t-6b-systems--html (T6B Systems & EPs in store) (4) Start Scan Pattern https://www. (5) Engine Abnormal Start Videos https://www.t6bdriver.com/c2102.html	
Week 3	**Reading:** SY0201-0203 (1-3) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, LSC, PoS, ES, Unusual Attitudes (UA), Spin	**Reading:** SY0204-0206 (4-7) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 1-5, Review Questions 0201-0206	**Reading:** SY0207-0208 (1-3) **Static Trainer:** Hollywood Checklist, Non-Memory EP's **VR Trainer:** 3TG, 1FS, GX, LTS, LAS, UA, Spin	**Reading:** SY0209-0210 (4-7) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 6-10, Review Questions 0207-0210	**Reading:** SY0212-0290 (1-7) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, LSC, ES, UA, PoS, Spin **Flash Cards:** Systems Review Questions 0212-0290	(6) Engine In-flight Emerg (7) Handling Emergencies emergencies.html	
Week 4	**Reading:** FWOP 1-4 (8 Part 1) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, LSC, SS,	**Reading:** FWOP 5-6 (8 Part 1) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 1-5	**Reading:** FWOP 7-8 (8 Part 2) **Static Trainer:** Hollywood Checklist, Non-Memory EP's **VR Trainer:** Abort on first TO,	**Reading:** FWOP 9-12 (8 Part 3) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 6-10	**Reading:** FWOP 13-E (1-8) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** Abort, 3TG, 1FS, LAS, LTS,	(8) Course Rules Familiarization https://www.t6bdriver.com/course-rules.html as the week progresses, you should be finishing this	
Week 5	**Reading:** Instrument FTI (IFTI) 1-4 (I1) (8) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, GX, LSC, SS, TP, PoS	**Reading:** IFTI 5-6 (I1-I2) (1-5) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 1-5	**Reading:** IFTI 7-813 (I1-I2) (6-7) **Static Trainer:** Hollywood Checklist, Non-Memory EP's **VR Trainer:** 3TG, 1FS, LTS, LAS,	**Reading:** IFTI 814-9 (I1-I2) (8) **Flash Cards:** Memory EPs, Ops Limits, Review CFTI 6-10	**Reading:** IFT10-L (I1-I2) (8) **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, Spin, UA, ELP to nearest field	(I1) Instrument and Airspace Flow https://www.t6bdriver.com/i3204.html (I2) Instrument Scan and transition https://www.t6bdriver.	
Week 6	**Reading:** Review Systems 1 **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 3TG, 1FS, Standard Rate Turn (SRT), Half Standard Rate Turn (HSRT), Steep Turn (ST)	**Reading:** Review Systems 2 **Flash Cards:** Memory EPs, Ops Limits	**Reading:** Review CFTI **Static Trainer:** Hollywood Checklist, Non-Memory EP's **VR Trainer:** 3TG, 1FS, S-1 Pattern, IFR Unusual Attitudes (IUA), GCA pattern, Approach Pattern	**Reading:** Review FWOP **Flash Cards:** Memory EPs, Ops Limits	**Reading:** Review IFTI **Static Trainer:** Hollywood Checklist, Memory EPs **VR Trainer:** 2TG, 1FS, S-1 Pattern, Approach Pattern, LSC, SS, LAS, LTS, Spin	**This Week you should incorporate and use course rules to/from KNSE. Attempt Instrument transition while in working area, use instrument setup and not VR headset** **Review all videos from previous weeks.**	

11. List of Symbols, Abbreviations, and Acronyms

ACM	Air Combat Maneuvering
ACT	Aircrew Coordination Training
ADF	Automatic Direction Finder
AEP	Aerospace Experimental Psychologists
AERO	Aerodynamics
AETC	Air Education and Training Command
AI	Artificial Intelligence
AN	Airways Navigation
ANOVA	Analysis of Variance
AOA	Angle of Attack
API	Aviation Pilot Indoctrination
AR	Augmented Reality
ARMS	Small Arms Qualifications
ASI	Aviation Student Indoctrination
ATC	Air Traffic Controller
AV	Augmented Virtuality
AWTD	Air Warfare Training Development
BFM	Basic Fighter Maneuvering
BI	Basic Instrument
BISim	Bohemia Interactive Simulations
C	Contact
CAC	Common Access Card
CAI	Computer-Assisted Instruction

CG	Computer Generated
CNATRA	Chief of Naval Air Training
CO	Cockpit Orientation
COTS	Commercial Off-the-Shelf
CQ	Carrier Qualification
CQL	Carrier Qualification Landing
CR	Course Rules
CRM	Crew Resource Management
CSV	Comma Separated Values
DCE	Device Capability Evaluation
DIV	Division Formation
DODID	Department of Defense Identification
DON HRPP	Department of Navy Human Research Protection Program
ENG	Engineering
EP	Emergency Procedures
F	Formation
FAM	Familiarization
FCL	Field Carrier Landing
FCLP	Field Carrier Landing Practice
FMS	Flight Management System
FOV	Field of View
FPS	First-Person Strategy
FPS	Frames Per Second
FRM	Formation

FTI	Flight Training Instruction
GUI	Guided User Interface
GEO	Geographical
HOTAS	Hands On Throttle And Stick
HMD	Head Mounted Display
HSD	Honestly Significant Difference
HUD	Head Up Display
I	Instrument
IBM	International Business Machines
IFLOS	Improved Fresnel Lens Optical Landing System (FLOLS)
IFT	Instrument Flight Trainer (2F137 – nonvisual)
IN	Instrument
INAV	Instrument Navigation
IOS	Instructor Operating Station
IP	Instructor Pilot
IR	Instrument Rating
IRB	Institutional Review Board
METRO	Meteorology
MFD	Multi-Function Display
MIF	Maneuver Item File
MIL	Mediated Interactive Lecture
MR	Mixed Reality
MRVS	Mixed Reality Visual System
N	Navigation

NA	Navigation
NACES	Navy Aircrew Common Ejection Seat
NAS	Naval Air Station
NAWCTSD	Naval Air Warfare Center Training Systems Division
NFM	Night Familiarization
NFO	Naval Flight Officer
NFR	Night Formation
NIFE	Naval Introductory Flight Evaluation
NISE	Naval Innovative Science and Engineering
NSS	Navy Standard Score
OCF	Out-of-Control Flight
OFT	Operational Flight Trainer
ON	Operational Navigation
ONAV	Operational Navigation
ONR	Office Of Naval Research
ORM	Operational Risk Management
PCL	Pocket Check List / Power Control Lever
PMA 205	Aviation Warfare Training Systems and Ranges Program Office
PRI	Primary
PTN	Pilot Training Next
PTO	Pilot Training Officer
PTT	Part Task Trainer
RECCE	Reconnaissance

RI	Radio Instruments
RIOT	Radio Instrument Orientation Trainer
RPS	Role-Playing Strategy
RR	Road Recce
RTS	Real-Time Strategy
RV	Reality Virtuality
SAIC	Science Applications International Corporation
SEM	Section Engaged Maneuvering
SIM	Simulator / Simulation
SME	Subject Matter Experts
SNA	Student Naval Aviator
SPSS	Statistical Package for Social Sciences
SSQ	Simulator Sickness Questionnaire
STK	Strike/Air-to-Ground Weapons
TAC	Tactical Formation
TACADMIN	Tactical Administration?
TACAN	Tactical Air Navigation
TACF	Tactical Formation
TIMS	Training Integration Management System
TOFT	Tactical Operational Flight Trainer
UFCP	Up Front Control Panel
USAF	United States Air Force
UTD	Unit Training Device
VBS	Virtual Battlespace

VMTS	Virtual Mission Training System
VR	Virtual Reality
VR-PTT	Virtual Reality Part-Task Trainer
WEP	Weapons
XR	Extended Reality

12. Distribution List

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