2023 TEST REPORT

TEXAS A&M ENGINEERING TEEX EXTENSION SERVICE

TEEX-Tested Report for

FLAIM™

TEXAS A&M ENGINEERING TEEX EXTENSION SERVICE TESTED

teex.org Toll-Free 800.541.7149 Tel.979.458.6727

April 21, 2023

TEEX-Tested® Report: FLAIM Trainer™

Submitted to FLAIM Trainer™ on behalf of the Texas A&M Engineering Extension Service (TEEX) Testing and Innovation Center (TT&IC):

Date: 28 Apr 2023

Signature: Raymond C. Ivie

Printed Name: Raymond C. Ivie

Title: Technology Evaluation Manager

Accepted on behalf of FLAIM Trainer™

Date: 29 April 23

By: J. D

Printed Name: J. Miller

Title: C.E.O

Summary of TEEX-Tested Results for FLAIM Trainer

Immersive environment	The FLAIM system provides 24 distinct virtual environments that host 75 individual scenarios. The system includes a combination of tactile, video, and audio tools to create high fidelity experiences. The confluence of the system components creates a realistic, immersive environment. - a video frame rate (120 frames per second) results in an uninterrupted high-definition video display. - accompanying sound effects create an immersive environment for the user. - Tools are simulated through a blending of the virtual and physical environments for realistic effects.
Equipment realism	Physical devices are simulated by combining virtual and physical environments to create what experienced firefighters described as a realistic experience. - A physical nozzle and hose reel are used to simulate the heft and responses of operational fire hoses. - An air purifying respirator mask is used to simulate the feel of an SCBA mask. - A vest with an embedded heat element is used to simulate heat in proximity to fire. - The HTC VIVE hand controller is used within virtual environments to simulate a thermal imaging camera.
System operation	The system is set up by two people in about 15 minutes. Scenarios typically last 15-20 minutes for one participant. The system can be operated by one person; however, safe operation requires 2-3 personnel.
Reliability	All components operated without failures during the four-month test period.
Ease of use	Operator/instructor controls were intuitive. Participants adapted quickly to use with only teleporting taking a session to become proficient.
Scenario realism	24 environments, 75 scenarios and injects in operationally realistic conditions in municipal, industrial, wildland, aviation, maritime, and transportation categories.
Learning objectives	Exposure and training to infrequent, but realistic scenarios. Able to practice decision making and some Tactics, Techniques, and Procedures (TTP) with equipment and environment provided.
Safety	Trip and fall hazard. Safety observer recommended to prevent entanglement in hose or impacting room walls.
Cost/ Return on investment	Estimated $50,000. Easily relocated between facilities for training. Cost avoidance of unique training facilities, water, equipment and health issues.

Texas A&M Engineering Extension Service (TEEX) Testing & Innovation Center (TT&IC) conducts performance assessments in operational environments by experienced professionals using representative facilities and environments the product is expected to perform in. Operators perform functions that are expected in operational service and assess the products and solutions using the manufacturer's guidelines and instructions to assess performance. TEEX tests follow a process including standards reviews, metrics development, expert panel reviews, test plan and scenario development, and quantitative and qualitative measurements and surveys. This report is a summation of the functionality, reliability, and performance results.

FLAIM Trainer™ has been TEEX-Tested® based on the specific testing methodology presented in this report. This report does not constitute an endorsement by TEEX. The TT&IC developed this report for the FLAIM Trainer™. TEEX hereby disclaims and any recipient of this report waives any warranties, whether express or implied, including without limitation any implied warranties of merchantability, fitness for a particular purpose, or non-infringement. Any recipient of this report accepts the report 'as is' and acknowledges that TEEX has no responsibility or liability to the recipient. TEEX does not in any way endorse the product.

TEEX-Tested® Report for FLAIM Trainer╬

Conducted by:

TEEX Testing and Evaluation Center (TT&IC)

Texas A&M Engineering Extension Service (TEEX)

Distribution: Open

Executive Summary

The Texas A&M Engineering Extension Service's Testing and Innovation Center (TT&IC) conducted a TEEX-Tested® assessment of the FLAIM Trainer™ to provide training and acquisition decision makers with information regarding the product's operational performance. TEEX-Tested assessments follow a similar process to Military Utility Assessments (MUA) to assess the technology's performance in an operational setting. Professionals representing the targeted user base participated in the assessment.

FLAIM Trainer is a Virtual Reality (VR) training system that combines virtual visual and sound environments and hands-on equipment/gear to provide an immersive experience. FLAIM designed the system as a safe and cost-effective way to train and refresh firefighters of various skill levels and disciplines. The TT&IC received the 2022 system to conduct an operational assessment using reviewers and firefighters ranging from academy students to experienced volunteer and career departments from municipal, industrial, wildland, Aircraft Rescue and Fire Fighting (ARFF), and military disciplines.

Participants and instructors found the system easy to set up and operate reliably. The system is transportable in three cases and only requires an unobstructed, indoor 10 ft × 10 ft area with electrical power. The system is comprehensive and provides all equipment necessary for operation. Our assessment outcomes resulted in a recommendation for users to include an optional TV/monitor with an HDMI female port. Beyond the expected VR headset, computer, and software control devices (iPad and wireless keyboard) included, the system has a hose reel, nozzle, heat vest, Self-Contained Breathing Apparatus (SCBA) simulator, and a thermal imaging simulation device that operate within the VR environment for a fully immersive experience. The FLAIM system includes twenty-four environments with seventy-five scenarios in municipal, industrial, wildland, aviation, maritime, and transportation categories. FLAIM provides a one-year warranty, including software. There are new software releases every six months that include improvements, additional scenarios, and increased/enhanced capabilities to current subscribers.

Participants reported that the scenarios were realistic, and the water/foam flow and effects were normal. Additionally, the simulated hose back pressure, heat vest, and SCBA mask enhanced the immersive effect and reacted in a realistic manner. Instructors and students believed the system provided learning opportunities in decision-making; exposure to infrequent, but needed, hazardous environments; and practice of tactics, techniques, and procedures. It was noted that it would be a useful recruiting tool. No system failures occurred during testing.

As a result of reviewer and participant feedback and overall testing, we conclude that the FLAIM Trainer performs as designed and can provide training and ongoing education to the firefighter community. Although not a substitute for live-fire training, the FLAIM system provides a valid medium for conducting training while allowing safe conditions where:

- live training is otherwise too hazardous or costly;
- access to facilities is not available;
- inclement weather or environmental conditions does not permit live training; or
- the student is not conditioned to participate in live training due to temporary health issues.

The system's packaging, ease of setup, and intuitive operation enables the system to be highly mobile and allow it to be transported from station to station to benefit volunteer and career departments. The attached TEEX-Tested report provides detailed testing and system information.

Contents

Introduction

The following TEEX-Tested report represents findings of operational test results to meet the needs of volunteers and professionals in the fire service. The Texas A&M Engineering Extension Service Testing & Innovation Center (TT&IC) leverages TEEX facilities; national and organization standards; TEEX instructors; TEEX students; and municipal, volunteer, Aircraft Rescue and Fire Fighting (ARFF), and wildland firefighters during testing. The TEEX-Tested mark is TEEX's premier offering for designing and executing testing for disruptive and innovative technologies and is a sign that a technology performs as intended under acceptable, repeatable, and real-world conditions.

This report provides an impartial third-party product evaluation of the Virtual Reality (VR) FLAIM Trainer system. This assessment was performed according to our seven step TEEX-Tested methodology from September 2022 through February 2023 at TT&IC located at 101 Gateway Blvd, College Station, Texas, 77845, and includes testing and evaluation of the FLAIM Trainer system under operational conditions by users of various experience levels including Subject Matter Experts (SME).

FLAIM Trainer is a VR immersive training system that is currently being used for firefighting training and recruiting in the United States and abroad. FLAIM developed this immersive multi-sensory VR training system as a safe and cost-effective solution that attempts to replicate the stress and uncertainty of real-world firefighting emergencies and provide training and exposure in various environments and scenarios that firefighters are likely to encounter. The hazards of emergency response scenarios are difficult and expensive to replicate in live burn training, and not all fire departments have the time or resources to attend such training. Therefore, immersive training technologies, such as VR, have recently become more popular. The FLAIM Trainer is one such training option currently available for public safety professionals. FLAIM describes their product as:

> *Designed for trainers with minimal understanding of virtual reality. The FLAIM Trainer™ system is not designed to replace live fire training, but instead allows for experiential learning through several practical scenarios developed to improve dynamic thinking, risk assessment, radio messaging, muscle memory, hose handling techniques, and nozzle control. Our system is designed so you can train people at all levels in your organization from novice through to experienced firefighters. Giving you the ability to train and develop their skillset in a safe environment with immersive, repeatable, and realistic scenarios.*

Our testing involved single participants in the VR environment. FLAIM recently provided options for a second participant to observe and interact with the VR environment.

As no operational field test can include all applications and scenarios that could be encountered, a representative set of testing criteria, conditions, and VR environments were selected and used to collect data, observations, and end user feedback. The sections that follow outline the methodology and test plan utilized during the FLAIM Trainer product evaluation, as well as observations, results, and takeaways.

System Components and Setup

The FLAIM Trainer is comprised of various hardware and software components designed to deliver an interactive VR learning environment. Some of the system components are proprietary while other

components are commonly available. The FLAIM Trainer system is contained in three impact-resistant wheeled Pelican™ cases containing the following components:

Hardware

- A main computer housed in a Self-Contained Breathing Apparatus (SCBA) backpack functions as the system's foundation.
- The VR headset immerses the user into the training scenarios through sight and sound.
- A heat vest with reactive heating element simulates the sensation of temperature changes when in proximity to simulated heat sources.
- A haptic hose reel simulates the sensation of back pressure when the nozzle bale is opened. The hose reel also houses the ad hoc system wireless router. Note: Recommend placing hose reel housing on a non-slip surface and securing using a strap or > 50 lbs of weight.
- A nozzle and VR hose tracking puck ensemble aims the simulated hose stream and is used to teleport the user in scenarios.
- A half-face mask simulates wearing SCBA and provides approximation of air consumption rates while in the simulation.
- A hand controller is used to simulate Thermal Imaging Camera (TIC) in VR environment and teleports user in select scenarios.
- An instructor iPad control and wireless keyboard are used for setup, scenario selection, and simulation control.
- Two infrared VR base stations are used for tracking movement and position in the simulated environment.
- Commercial Off-The-Shelf (COTS) rechargeable batteries are used to power the main computer and base stations.
- A COTS battery charging system is provided for recharging the main computer battery and base station batteries.
- The system comes with two lightweight tripods and mounting brackets for the base stations and rechargeable batteries.
- A hot swap cable enables changing the main computer battery during operations without requiring a complete system shutdown/restart.
- A wireless HDMI receiver is provided to send video and audio outputs to an optional television/monitor for instructor and audience viewing of the participant's activities in the environment.
- An optional television with HDMI connection is recommended for instructors, evaluators, and observers to see and control the simulated environment.

Refer to Figure 1 for an example of the hardware components.

Figure 1: FLAIM System Hardware Components

Software

Purchase of an individual FLAIM Trainer system includes a perpetual software license that includes access to FLAIM's basic scenario library. Also included is a one-year system warranty along with access to software updates, new additions to the scenario library, and technical support. The system must be registered on FLAIM's company portal to begin the initial one-year term of service.

The additional purchase of an annual FLAIM upgrade and support subscription extends the warranty beyond the first year of coverage and ensures continued access to new scenarios, software updates, and technical support. Software upgrades and the addition of new scenarios and upgrades occur continuously every six months.

During the testing period, we updated the system to the most current software version, FLAIM Trainer R2 2022. This update included new scenarios, visual enhancements, improved fire dynamics, and new multi-user scenarios. The new FLAIM Trainer R2 2022 update includes a total of twenty-four environments and seventy-five scenarios as listed in Table 1 and Figure 2.

Categories	Environment	Scenarios
Municipal	Highrise Highway Residential	14 scenarios

Categories	Environment	Scenarios
Industrial	Corrections Facility Mining Petrol Station Refinery Refinery Brazil Warehouse	16 scenarios
Wildland	Brushfires Excavation National Parks Rural	16 scenarios
Aviation	Airbase Airbase Night Airport Airport Night Airport International	15 scenarios
Maritime	Docks Naval Navy Destroyer Navy Frigate	12 scenarios
Vehicle	Electric Vehicle Fire	1 scenario
Game	Fire Station Lobby	1 scenario

Table 1: Scenario Organized by Environment and Type

Figure 2: Representative Depictions of the Six Virtual Environments

Instructors/Operators can inject events in some scenarios during the action. These include flashovers and explosions requiring immediate actions by the participant.

Room and System Setup

Setup of the FLAIM Trainer system requires a space of at least 10 ft × 10 ft (recommended 15 ft × 15 ft). The system requires four separate 120-volt electrical receptacles for operation. Standard room setup involves placing the VR trackers (on provided tripods) diagonally across from each other in the corners of the designated training floor space. To allow for proper room calibration, the SCBA and VR headset is placed in the center of the room facing the twelve o'clock position with the hose reel at the six o'clock position as shown in Figure 3. Room calibration is required when the system is installed in a new location or if the VR trackers are moved. Calibration is a simple nine-step guided procedure requiring the wireless keyboard and television screen to follow the step-by-step instructions.

Figure 3: Photo of the TT&IC Room Setup

Methodology

Scope: The purpose of this evaluation is to conduct an impartial third-party assessment of the FLAIM Trainer system in a realistic and safe training environment with multiple users of various skill and experience levels. The overall objective is to assess the quantitative and qualitative aspects of the product and its potential training value and purposes. This evaluation is based on the knowledge, experience, and feedback of SMEs and quantitative and qualitative data collected during testing.

The TEEX-Tested methodology is based on a seven-step protocol designed to assess technology in the appropriate testing environment that ensures the product functions as intended and will function in the appropriate contexts. Figure 4 is a diagram of the TEEX-Tested journey and an explanation of the seven-step process as applied to the FLAIM Trainer system.

Step 1 – Review the Technology: The TT&IC team received and unpacked the technology, examined all the user manuals, and ensured the system components were in working order. The team then assembled

the system with the assistance of the FLAIM helpdesk team and a brief introduction to the operation of the system. These are standard procedures for any new purchase.

Step 2 – Determine Standards: The TT&IC team determined the standards by which the product would be evaluated and identified applicable evaluation metrics that would allow proper analysis of the technology to be tested. No National Fire Protection Association (NFPA) standards have been developed for VR pending the U.S. Department of Homeland Security/Federal Emergency Management Agency's (DHS/FEMA) Fire Protection Research Foundation project currently underway. A review of Healthcare Simulation Standards of Best Practice (INACSL Standards Committee et al., 2021) was conducted to understand possible similar standards for VR training.

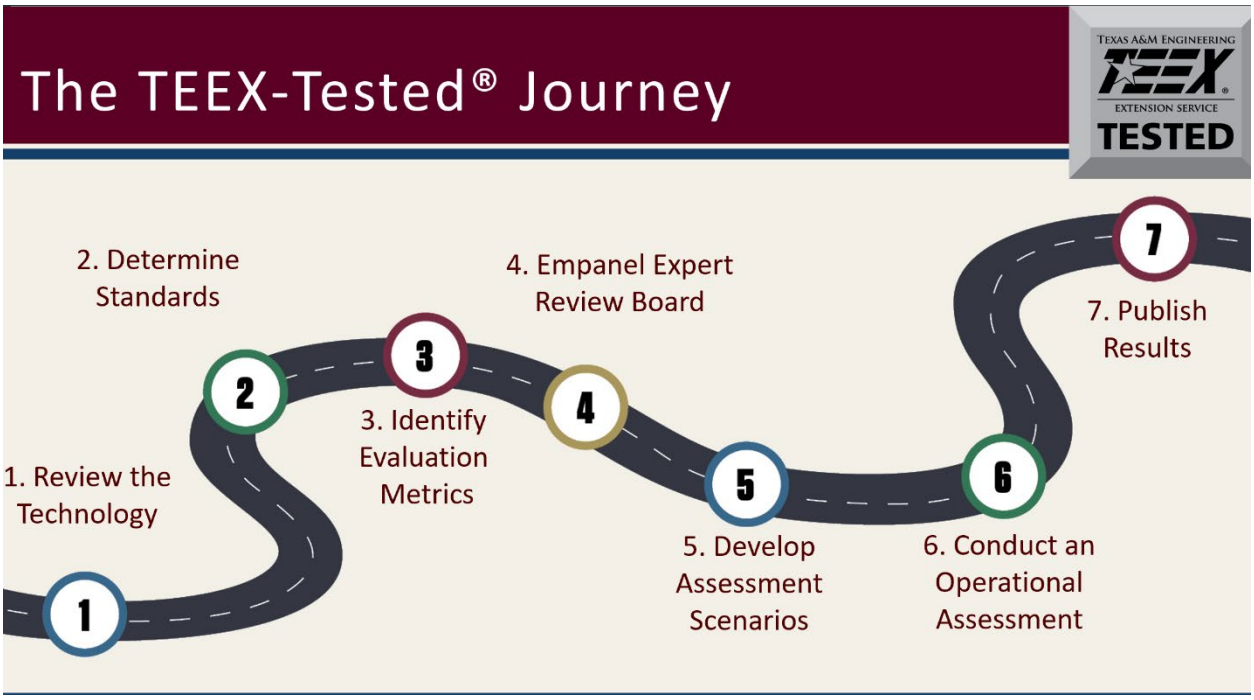

Figure 4: A Graphic Representation of the TEEX-Tested Protocol

Step 3 – Identify Evaluation Metrics: The TT&IC team selected applicable quantitative, qualitative, and technology-specific metrics upon which to evaluate the product and developed a customized test plan suited for operational testing of VR training technology.

Step 4 – Empanel Expert Review Board: The panel for FLAIM consisted of representatives from the following stakeholder communities: ARFF, municipal firefighting, industrial firefighting, fire training, military, and wildland fire fighting. Discussion, comments, and questions were captured to refine the test plan and select the best scenarios for evaluation.

Step 5 – Develop Assessment Scenarios: The TT&IC team created realistic, fair, and impartial testing scenarios leveraging state-of-the art TEEX facilities and appropriate standards and evaluation metrics.

Step 6 – Conduct an Operational Assessment: The TT&IC team conducted operational testing on the product in a realistic and safe training environment with multiple users of various skill and experience levels and collected the resulting data, observations, and end user feedback for analysis.

Step 7 – Publish Results: This comprehensive TEEX-Tested report captures, interprets, and communicates all the relevant data and completes the final step of the protocol.

Location

The evaluation of the FLAIM Trainer system was conducted at the TEEX Testing and Innovation Center, 101 Gateway Blvd, College Station, Texas 77845, in a 15 ft × 15 ft climate-controlled open room with access to at least two 120/240 power outlets, low ambient noise, and no tripping hazards.

Test Plan

The detailed test plan describing the test strategy, objectives, schedule, and metrics used can be found in Appendix A. The test plan used to evaluate the FLAIM Trainer system was developed similarly to those used in industry and the military, but was tailored to the unique characteristics of a VR training system evaluated in realistic conditions by users of all ability, skill, and experience levels. It was determined that this evaluation would not focus on the specific technical aspects of the hardware and software, but on its performance as an overall system and its purpose and utility as a training option.

FLAIM System Scenarios Used during the Evaluation

There are a total of twenty-four specific environments available in the FLAIM Trainer scenario library. For the purposes of this assessment, we categorized the environments to the following six descriptive categories:

Municipal Environments tested included residential, rural, and city.

Industrial Environments tested included refineries, mines, and warehouses.

Wildland Environments tested included grass fire, hay shed fire, backhoe fire, and barn fire.

Vehicle Environments tested included petroleum and lithium-ion battery vehicle fires on highways, in tunnels, and at petrol stations.

Aviation Environments tested included daytime and night-time aircraft fires for various military and civilian aircraft.

Maritime Environments tested included interior and exterior ship fires on various military and civilian watercraft and docks.

Sequence of FLAIM TEEX Testing Events

1. FLAIM setup and operational training for TT&IC staff
2. Data collection (setup, average scenarios, battery life, etc.)
3. Executive demonstrations (TEEX executives and curriculum staff, local fire chiefs)
4. Test kick off (review embedded scenarios for testing)
5. Updated FLAIM scenarios with new release
6. Fire recruit academy instructors and students review and assessment.
7. Municipal firefighter assessment
8. Forest Service firefighter assessment
9. TEEX advisory panel hands-on review, assessment, and feedback

Analysis and Results

The metrics measured in the TEEX-Tested assessment are grouped into three categories: quantitative metrics, qualitative metrics, and other value considerations. This section details the observations made and the subsequent results of the assessment.

Quantitative Metrics

The TEEX-Tested quantitative metrics are a set of defined measurements that provide an objective perspective to the evaluation. Quantitative metrics are typically reported using numerical data.

Setup Time/Ease of Setup: Two adults can set up the system in about 10 minutes in an open room.

Room Requirements: A 15 ft × 15 ft room with a 10 ft × 10 ft section at the center used as the designated play area. The room should be an open room, free of any tripping hazards. The room should not be in direct sunlight and should not contain reflective surfaces. Larger or smaller rooms could accommodate the system if the total distance between the VR sensors does not exceed 23 feet. When choosing the actual VR training floor dimensions, users should consider allowing extra space for safety and for access to all the system components without stepping onto the designated VR training area.

Number of Instructors Required: The FLAIM Trainer system can be facilitated by one instructor, but having an additional instructor or safety assistant is preferred. The additional instructor or safety spotter is recommended to ensure the user does not become entangled in the hose, trip over the hose reel, or bump into a wall or other obstacle in the designated FLAIM training area. An additional instructor or assistant would be helpful with changing the SCBA computer battery and to handle any other issues that could interfere during the training session.

Power Requirements: Access to at least four 120/240 power outlets. A hot swap cord is provided with the system to allow battery swap during VR training sessions without interrupting the training session.

Battery Life: The main computer battery allows 1 hour of continuous use. The VR tracking system batteries last for at least 16 hours of continuous use.

Battery Recharge: The main SCBA computer batteries and the VR tracker batteries take approximately 2 hours each to recharge. Two SCBA backpack batteries are provided with the system; however, one or two additional SCBA batteries would be required for continuous operations due to battery life limitations and recharging time.

Startup Time: It takes 4 minutes from the initiation to the start of the scenario. Occasionally, there were minor technical issues due to minor iPad settings errors causing the startup time to be slightly longer.

System Load Time: It takes 3 seconds to load scenarios or change settings and options within a scenario.

Average Scenario Length: The average is 15 minutes, although the scenarios involving lithium-ion battery fires and other challenging scenarios can be longer in duration.

Reliability: There were no notable reliability issues with the system and equipment during the testing period. The system and its components functioned as designed and as expected.

System Stability: The system was stable throughout the testing period with only one stability issue experienced resulting in a pause that lasted for approximately 30 seconds. Afterward, the system resumed exactly where it left off.

Frame Rate: The frame rate is 120 Frames Per Second (FPS). The minimum recommended VR system frame rate is 90 FPS to avoid any negative user effects such as disorientation and nausea. All users experienced good visual quality related to FLAIM's frame rate. The system was able to generate the optimal frame rate allowing for good visual quality and a realistic and immersive VR experience with no negative user effects such as disorientation or nausea.

Resolution/Refresh Rate: The resolution is 1440 × 1600 pixels per eye or a combined ocular resolution of 2880 × 1600 and a 110-degree field of view. The system's refresh rate is 90 Hertz (Hz). The resolution and refresh rate of FLAIM is representative of the current generation of VR systems. All users experienced good visual quality related to resolution.

Tracking Accuracy/Latency: Tracking accuracy/latency is 56.14 milliseconds (ms). Ideal latency for a VR system is between 100 and 40 ms. Any speed over 100 ms usually results in a noticeable lag or delay between action and reaction in the VR environment. Tracking accuracy or latency is the difference between action and reaction in a VR environment. Minimal issues were experienced with tracking accuracy and latency during testing. Some users perceived occasional tracking and latency issues, but most reported no issues. Measuring the latency and tracking accuracy of a VR system mostly relies on the perception of the user. Poor tracking and latency are detrimental to a user's perception of immersion. Most users reported a feeling of immersion while using the system and they reported the resolution and realism to be a good indication that tracking accuracy and latency was not an issue.

Measurables to Determine Success in Training Scenarios: The measurables to determine individual user success during training scenarios are logical and intuitive. Examples of the measurables are water used in gallons per minute (gpm), air supply used in standard MegaPascal (MPa) pressure units, and the time elapsed to successfully complete the scenario. An instructor/operator can also evaluate tactics, techniques, and procedures through observation.

Qualitative Metrics

The TEEX-Tested qualitative metrics are a set of measurements based on human judgement that subjectively evaluate a product and or its technology. Qualitative metrics result in observed categorical descriptive data:

- None = 0 percent
- Few = 1–24 percent
- Some = 25–50 percent
- Half = 50 percent
- Most = 50–99 percent
- All = 100 percent

Mix of Scenarios: All the users indicated the variety of scenarios was sufficient. FLAIM Trainer offers an impressive variety of training scenarios including a total of twenty-four environments and seventy-five scenarios. FLAIM continues to add new scenarios based on direct customer feedback and the needs of the fire-fighting industry. The additional purchase of an annual FLAIM upgrade and support subscription

ensures ongoing access to any new scenarios and continuous software updates that improve the existing scenario library.

Immersion: All users indicated they experienced the feeling of immersion while using the system. User feedback from the G-force nozzle and hose reel, heat vest, SCBA face mask, and VIVE infrared hand controller all significantly contributed to the VR immersion experience. The addition of using firefighter bunker gear, employing firefighter tactics and techniques, and following established department protocols further contribute to the immersion experience.

Realism: All the scenarios tested portrayed an accurate level of realism commensurate with fire hazard emergencies that have occurred or can really occur. None of the users that participated in the testing mentioned anything that would question the realism of the scenarios. However, there were a few user comments regarding the lack of overall realism associated with training in a live-fire environment. Comments regarding scenario improvements and actions were made and provided to the manufacturer for consideration.

Instructor Control/User Interface: The instructor interface consists of an iPad and wireless keyboard. All the instructors indicated the iPad interface and screen design layout were intuitive and easy to use and teach from. All instructors were able to operate the system and control the training sessions after observing a single session.

Ease of Use: All users, and particularly all the instructors, reported the FLAIM Trainer equipment performed as expected and was easy to use.

Range of Settings: All users, including the instructors, reported the range of settings was adequate. The scenario settings are controlled in the iPad through a series of drop-down menus. All instructors and TEEX testing staff indicated the settings options were intuitive and provided a comprehensive interface of choices to control the training environment.

Audio Quality: All users had good comments regarding the audio quality, particularly regarding some of the intricate background and peripheral sound effects that enhanced the VR immersive experience and made the scenarios more realistic. The VR headsets have two high-quality earphone speakers. Users can choose to have both in the down position or can raise one of the earphones to better hear instruction and commands from instructors or teammates.

Perceived Value of Nozzle/Hose: The nozzle extinguishes VR fires and teleports the user in scenarios; the hose and reel simulate the sensation of backward hose pressure. All the users indicated the hose and nozzle functioned as expected and contributed to realism and the overall immersive experience. Most users reported actual physical fatigue from the constant pull generated by the hose reel, which is very similar to experiencing actual hose pressure when extinguishing a fire.

Perceived Value of Heat Vest: The heat vest with reactive heating element simulates the sensation of heat in proximity to the VR fire source. All users indicated the heat vest functioned as expected and contributed to realism and the overall immersive experience. All users reported the perception of being close to an actual fire and users wearing bunker gear reported a sensation of heat that was like experiencing the heat in an actual fire emergency.

Perceived Value of SCBA Mask: The SCBA mask simulates assisted breathing in a VR hazardous environment. Most users indicated the SCBA functioned as expected and contributed to realism and the overall immersive experience. A few users, who are experienced firefighters, reported the SCBA mask did not react to specialized breathing techniques used to conserve air.

Perceived Value of IR Heat Detection: FLAIM Trainer™ comes with a peripheral VIVE hand controller that functions as an infra-red (IR) heat detector. The IR detection device significantly contributes to the overall training value in terms of realism and immersion. Fire and heat sources are accurately displayed through the IR hand controller allowing a user to employ realistic firefighter tactics and techniques, especially in scenarios where visibility is limited due to smoke and darkness.

Perceived Value as a Tool to Develop Firefighter Tactics and Techniques: Some users successfully implemented firefighter tactics and techniques during the training sessions. Crouching below the smoke, getting low to see underneath objects, hose handling techniques, and other firefighter methods had a positive response and effect regarding the overall scenario outcome.

Perceived Value as a Tool to Develop Decision-Making and Risk Management Skills: Most users and all advisory board members indicated that FLAIM could be used for developing decision-making and risk management skills. VR training provides a low-risk environment where users can make decisions and take risks without dire consequences. FLAIM provides a training option where firefighters can learn from successes and failures across a broad spectrum of environments and scenarios. Such experience would take much longer to acquire from live burn training or from real world experience.

Training Value for Rare and Difficult Scenario Exposure: Some users, and most of the advisory panel members commented favorably regarding the capability of FLAIM to provide rare and difficult scenarios. FLAIM allows firefighters that are trained and equipped for a specific environment like industrial, municipal, or wildland to experience rare and difficult scenarios they rarely or may not have opportunities to train for. Enabling firefighters to experience unfamiliar, once-in-a-career fire emergency scenario training enhances their professional development and preparedness without having to coordinate expensive training for an event they may never operate in.

Perceived Value of FLAIM Learning Outcomes: All users, and specifically all instructors, indicated the post-scenario debrief metrics were sufficient. At the conclusion of each scenario, there are numerous learning outcomes listed that are related to the specific scenario. The learning outcomes focus instructors and users on what was important from the scenario. Some example FLAIM learning outcomes are hose handling techniques, water application techniques, flashover, ventilation, and risk assessment considerations. Some instructors recommended the ability to type in their own academy- or department-specific learning outcomes; however, that feature is not included.

Other Value Considerations

This category includes critical considerations that are beyond measurable metrics that explain the perceived value of the system as a training tool.

Cost of Training: The FLAIM Trainer demonstrates a potential for significant reduction of training costs over live burn firefighter training and other types of traditional firefighter training. Live burn firefighter training involves the costly consumption of flammables, water, and extinguishing agents that pose environmental issues along with health and safety risks. Other live burn training expenses are access to

specialized training sites, transportation costs, and lodging requirements. The FLAIM Trainer mitigates many of these costs with a fraction of the cost to purchase and maintain the system. The FLAIM Trainer offers the potential for cost savings but is not intended to replace live burn firefighter training or any other required firefighter training standards.

Mobility and Storage: The FLAIM Trainer consists of approximately twenty-eight system components all stored within three compact, transportable, high-impact Pelican foam-padded tactical cases, allowing for easy transport and minimal storage space.

Durability: The FLAIM Trainer system and its components proved to be durable as well as easy to store and transport. During the product testing period, nothing was found to be broken, damaged, or defective.

Target Training Audience: The FLAIM Trainer system was designed for firefighter trainers and professionals with a minimal understanding of VR. Our testing demonstrated that anyone can successfully use the system and experience a positive and challenging immersive learning experience. Our user feedback indicated the FLAIM Trainer is a valid training tool for initial, refresher, and advanced firefighter training, provided its use and application is facilitated by a professional instructor. The FLAIM Trainer system is also a viable alternative for firefighters who cannot attend live burn training due to injury or illness, provided a user's limitation allows him/her to wear the FLAIM Trainer equipment. The system is ideally suited for refresher training when weather or training field availability restricts training. Also, use of the system is not limited to firefighter training. It can also be used as a public awareness tool to increase appreciation for fire and emergency services or to recruit future public safety professionals.

Safety: Safety considerations for the FLAIM Trainer system mostly concern trip and fall accidents that could occur during use because the user's vision is blocked by the VR headset. Other safety concerns are the potential for Visually Induced Motion Sickness (VIMS) and Photosensitive Seizures (PSS). Tripping hazards can be mitigated by ensuring the training space is free of all tripping hazards and designating an additional safety spotter to ensure the user does not get entangled in the hose, trip over the hose reel, or bump into a wall or other obstacle in the designated FLAIM training area. If no safety spotter is available, the designated instructor should ensure the safety of the FLAIM Trainer user. During our testing, no accidents or issues with VIMS or PSS were encountered. A safety spotter was used during testing to mitigate tripping hazards and training sessions were limited to one to two scenarios per user to mitigate any issues with VIMS or PSS.

Environmental Impact/Exposure Mitigation (Heat Stress, Carcinogens, and Hazards): Operation of the FLAIM Trainer system causes no significant environmental impact in comparison to live burn training which entails significant water consumption and toxic emissions. Also, training with FLAIM reduces the overall environmental footprint in comparison to live burn training in terms of eliminating the use of fuel for burning and operating fire trucks. Additionally, the system poses no risk to life or health since there is no exposure to the hazards encountered during live burn training.

System Updates: The additional purchase of an annual FLAIM upgrade and support subscription extends the warranty and ensures ongoing access to any new scenarios, software updates, and continued technical support. FLAIM advertises the addition of new scenarios and software upgrades approximately every six months on a continual basis. During the testing period, we updated the system software to the latest version with no issues or difficulties. However, after installing the update there were some minor issues with the iPad settings. FLAIM technical support staff easily resolved the iPad issues, and no further issues were encountered. The latest system update (FLAIM Trainer R2 2022) included new scenarios, visual enhancements, improved fire dynamics, and new multi-user scenarios.

Technical Support: The technical support received from FLAIM throughout the testing period was outstanding. All technical issues were resolved quickly and efficiently by the FLAIM customer support team. Product support and warranty begins after system registration and continues for one year; however, extended support can be negotiated, or product subscriptions are also available.

Maintenance: The FLAIM Trainer requires minimal maintenance and care. Some key maintenance steps are to decontaminate the Head-Mounted Display (HMD) between users and to clean the internal lenses with quality lens wipes only. Also, never let the HMD hang freely from its cord to prevent damage. The SCBA face mask should be decontaminated between users and thoroughly dried before re-use to prevent damage to the breath detection system. Batteries should not be left connected to the SCBA and should be regularly inspected to detect bulging or cracks. Dispose of and replace any damaged batteries. The heat vest can be hand washed as needed after removing the internal electronic parts.

System Longevity: The current FLAIM Trainer system and HTC VIVE PRO VR headset is representative of the current generation of VR technology. The next generation of 4K and 5K VR technology and the HTC VIVE PRO 2 VR headset are on the horizon but will most likely not be incorporated into the next generation of FLAIM Trainer systems. According to FLAIM, there are no current plans to incorporate 4K or 5K VR technology in the next generation of VR headsets.

Savings on Wear/Tear of Equipment: The FLAIM Trainer is a standalone system that does not require any additional equipment except for an optional television. Therefore, it eliminates the wear and tear of firefighter tools and equipment used in live burn training. Individual bunker gear can be worn while using the system, but such use entails no significant wear and tear.

Training/Education Value: Immersive technology are devices or environments that enable a user to experience multisensory stimulation, through interaction with varying degrees of fidelity. These environments enable learning to occur through tactile and cognitive engagement. Our analysis of the FLAIM Trainer clearly indicated that this system satisfies the aforementioned conditions and provides a viable mode for simulation-based learning.

Training Limitations: Although users had positive feedback regarding the realism of FLAIM, there is no substitute for live burn firefighter training or the reality of experiencing an actual fire emergency. Also, there are several firefighter skills and tasks leading up to arrival on the scene of a fire emergency and after a fire has been extinguished that are not covered. FLAIM focuses its learning objectives on actions that take place during fire emergencies, not before or after. Also, FLAIM has a mechanism to customize desired learning outcomes in the after-action review tab. This allows instructors or training designers to create additional objectives and remove existing objectives as part of the training scenario. However,

FLAIM does not provide feedback on participant body mechanics, postures, or movement and therefore, the evaluation of an individual's proper technique must be observed by a trained instructor.

User Feedback

Feedback was collected throughout the evaluation period. Additionally, surveys were administered at the conclusion of each product demonstration session to capture feedback pertaining to testing. We gathered feedback from fire academy instructors, fire academy students, full-time municipal firefighters, and professional forestry firefighters. Also, our advisory panel members were surveyed and provided feedback.

Fire Academy Instructor Review and Assessment

The fire academy instructors reported some previous experience with VR technology. Based on that previous experience, they considered the resolution to be good but detected some latency and tracking issues. However, they indicated the FLAIM Trainer system and equipment did operate and perform as they expected. All the instructors indicated they did feel immersed in the scenarios and found them to be realistic. Also, they thought there was a good variety of scenarios offered and each had sufficient sub events and valid training objectives. All indicated they did learn from the VR experience and saw a valid use for the FLAIM Trainer for initial, refresher, and advanced firefighter training. Also, they agreed upon its value for volunteer and full-time firefighters as well as for recruiting. As instructors, they all agreed the system is easy to operate and teach from and felt the post-training metric checklists were sufficient. They noted the value of the option to add additional customized learning outcomes at the conclusion of scenarios. Figure 5–Figure 8 show various stages of scenario participation.

Figure 5: Fire Academy Instructors and Recruits Observing a Scenario

Fire Academy Student Review and Assessment

The fire academy students had varying experience levels with VR applications from very experienced to no prior experience. The students participated in two FLAIM sessions, one prior to live-fire training and one after live-fire training. All students reported they found the scenarios to be realistic despite their lack

of real-world experience with firefighting. Their expectations regarding how the system and equipment operated were mixed due to experiencing the fire-fighting components for the first time and frustrations with learning how to teleport in scenarios. All considered the resolution to be good and did not detect any latency or tracking issues. All felt immersed in the scenarios and found them to be realistic. Everyone indicated they did learn from the VR experience, and many felt the instructor's facilitation was the most important part of the learning process. The students felt the variety of scenarios and training objectives were good and saw a valid use for training all levels of firefighter, but especially experienced firefighters who have real-world firefighting experience.

Figure 6: Cadet Firefighter Using FLAIM

Municipal Firefighter Assessment

The municipal firefighters who participated in the testing had a broad range of firefighting experience, from one year to over fifteen years of service. They reported varying levels of familiarity with VR applications from experience in training and gaming platforms to no prior experience with VR applications. All the firefighters indicated they felt immersed in the scenarios and found them to be realistic; also, they indicated the system and equipment operated and performed as they expected. Users especially liked the simulated pounds per square inch (psi) from the nozzle and hose reel and the jolt experienced when the hose was turned on. All considered the resolution to be good and did not detect any latency or tracking issues. All indicated the variety of scenarios and sub events offered was sufficient. Not everyone indicated that they learned from the training; however, these same individuals do see the FLAIM Trainer as a valid training tool for the right target training audience.

Figure 7: A Municipal Firefighter Using the Simulated TIC

Wildland/Wildland Urban Interface (WUI) Assessment

The wildland firefighters who participated have extensive firefighting experience, from six years to over fifteen years of service, but no previous experience with VR technology. All indicated they felt immersed in the scenarios and found them to be realistic; also, they indicated the system and equipment operated and performed as they expected. All indicated the variety of scenarios and sub events offered was sufficient. All indicated the visuals to be realistic and reported no issues with latency or tracking issues. Not everyone indicated that they learned from the training; however, these same individuals did see the FLAIM Trainer as a valid training tool for volunteer and full-time firefighters as well as for recruiting.

Figure 8: Wildland Firefighter in an Active Scenario

Advisory Panel Hands-On Review, Assessment, and Feedback

One member of the advisory panel reported that FLAIM is best suited for experienced firefighters who are fully trained, otherwise it could cause false perceptions and bad habits. The member stated that he felt FLAIM training is not recommended for new recruits and students who have not yet received basic foundational fire training. *Editor's note: This is an issue with respect to the curriculum and instructor skill.*

One member of the advisory panel recommended incorporating the use of mayday procedures into the various FLAIM scenarios. The mayday procedures could either be programmed into FLAIM or users could implement their own department's mayday procedures with a department radio if they fail in a scenario or if a catastrophic event occurs. The mayday response should be included in the system's After-Action Reports (AAR).

One member recommended incorporating civil unrest scenarios (e.g., riots, looting, criminal acts, etc.) in FLAIM or into the existing scenarios as an instructor toggle option. Civil unrest incidents are becoming a commonplace occurrence that firefighters and first responders will experience.

Conclusions

This report documents the testing and evaluation of the FLAIM Trainer system. Our product assessment placed the system and its components in realistic conditions and tested its functioning with appropriate methods in the proper environment. The TT&IC staff provided operational and technical oversight throughout the testing process assisting with execution and documentation of this product evaluation and capturing the results.

Our test plan was tailored to the unique characteristics of a VR training system and focused on capturing relevant quantitative and qualitative data obtained from the experiences and feedback of multiple users of all experience levels and SMEs. It was determined that this evaluation would not focus on the specific technical aspects of the hardware and software, but on its performance as an overall system, the quantitative and qualitative aspects of the product, and its potential training value, utility, and purpose as a training option.

Based on our test results and user comments, the FLAIM Trainer system functioned and performed as intended. The VR environments and scenarios tested portrayed an accurate level of realism commensurate with real-world fire hazard emergencies. All users indicated they experienced the feeling of immersion while using the system. User feedback from the G-force nozzle and hose reel, heat vest, SCBA face mask, and VIVE infrared hand controller all significantly contributed to the VR immersion experience. The addition of using firefighter bunker gear, employing firefighter tactics and techniques, and following established department protocols further contributed to the immersion experience.

Our testing showed that most personnel can successfully use the system and experience a positive and challenging immersive learning environment. User feedback indicated the FLAIM Trainer is a valid training tool for initial, refresher, and advanced firefighter training, provided its use and application is facilitated by a professional instructor. Also, use of the system is not limited to firefighter training. It can also be used as a public awareness tool to increase appreciation for fire and emergency services or to recruit future public safety professionals.

The FLAIM Trainer system is not intended to replace live burn firefighter training. Rather, it is a viable additional training option that can be used to augment required live burn training. In this capacity, it allows additional time for firefighters to develop skills, exercise decision-making, and experience rare scenarios in a safe and environmentally friendly training environment.

The findings and observations presented in this report are subject to limitations based on assigned workers, evaluation location, and the time allotted to perform the assessment. Every effort was made to replicate the actual training environment for the purpose of this evaluation. It should also be noted that even the best test plan and expert testing personnel cannot account for every possible real-world situation encountered or intentional act to circumvent the system; therefore, an evaluation of this type cannot capture every scenario.

References

Craig, A. B., Bock, D., McGinty, B., Kendig, K., Ledford, N., & Joop, P. (2023). *Firefighter Immersive Learning Environment (FILE): Literature Review*. Quincy, MA:

Defelice, R. (2019). *Microlearning: Short and Sweet* [Electronic](1st ed.).

Farra, S. L., Miller, E. T., & Hodgson, E. (2015). Virtual reality disaster training: Translation to practice. *Nurse Education in Practice, 15*(1), 53-57. https://doi:10.1016/j.nepr.2013.08.017

Gerwitz, R. J. (2016). Modern strategy for operational excellence: building agile and adaptive organizations. *Journal of healthcare protection management : publication of the International Association for Hospital Security, 32*(2), 121-124.

Guinan, P. J., Parise, S., & Langowitz, N. (2019). Creating an innovative digital project team: Levers to enable digital transformation. *Business Horizons, 62*(6), 717-727. Doi https://doi.org/10.1016/j.bushor.2019.07.005

Hale, L., Eigel, J., & Trosclair, C. (2022). *Immersive Technologies in Public Safety Training* Internal report. TEEX Testing & Innovation Center. Texas A&M Engineering Extension Service.

Huang, J. L., Ran, S., & Blume, B. D. (2017). Understanding Training Transfer from the Adaptive Performance Perspective. In K. G. Brown (Ed.), *The Cambridge Handbook of Workplace Training and Employee Development* (pp. 75-97). Cambridge: Cambridge University Press.

INACSL Standards Committee, Watts, P. I, McDermott, D. S., Alinier, G., Charnetski, M., Ludlow, J., Horsley, E., Meakim, C., & Nawathe, P. (2021). Healthcare Simulation Standards of Best Practice™ Simulation Design. *Clinical Simulation in Nursing, 58*, 14–21. https://doi.org/10.1016/j.ecns.2021.08.009

Johnston, S., Coyer, F. M., & Nash, R. (2018). Kirkpatrick's Evaluation of Simulation and Debriefing in Health Care Education: A Systematic Review. *Journal of Nursing Education, 57*(7), 393-398. doi: https://doi-org.srv-proxy1.library.tamu.edu/10.3928/01484834-20180618-03

Kolb, D. A. (2015). *Experiential learning : Experience as the source of learning and development.* (Second edition ed.): Upper Saddle River, New Jersey : Pearson Education Ltd,.

Marlow, S. L., Lacerenza, C. N., Reyes, D., & Salas, E. (2017). The Science and Practice of Simulation-Based Training in Organizations. In K. G. Brown (Ed.), *The Cambridge Handbook of Workplace Training and Employee Development* (pp. 256-277). Cambridge: Cambridge University Press.

Messmann, G., Segers, M., & Dochy, F. J. R. C. (2018). *Informal Learning at Work : Triggers, Antecedents, and Consequences*. Abingdon, Oxon: Routledge.

Moats, J. B. (2015). Influences on the Acceptance of Innovative Technologies Used in Learning Opportunities: A Theoretical Perspetive. In F. M. Nafukho & B. J. Irby (Eds.), *Innovative Technology in Higher Education* (1 ed., Vol. 1, pp. 20). Hershey, PA: IGI Global.

Trentini, B. (2015). Immersion as an embodied cognition shift: aesthetic experience and spatial situated cognition. *Cognitive processing, 16 Suppl 1*, 413-416. doi: https://10.1007/s10339-015-0684-y

Sasangohar, F., Moats, J., Mehta, R., & Peres, S. C. (2020). Disaster Ergonomics: Human Factors in COVID-19 Pandemic Emergency Management. *Human Factors, 62*(7), 1061-1068. doi: Https://10.1177/0018720820939428

Willette, K., Grant, C., & Rangathan, S. (2023). *Firefighter Immersive Learning Environment (FILE): Focus Group Summary*. Quincy, MA:

Verzoni, A. (2022). Full Immersion. *NFPA Journal: The Magazine of the National Fire Protection Association,* (Winter 2021).

Appendix A: TEEX-Tested Test Plan for FLAIM Trainer

Test Plan: Product: FLAIM Trainer VR system consisting of Apple iPad for setup and instructor use. VIVE Pro VR Headset incorporated in SCBA visor, current FLAIM software (Feb 2023 release). External gear: Heat vest, fire nozzle/hose, simulated TIC.

Test Strategy: Primary testing is for the software and external supplied gear/hardware as other computer and VR headset options are useable. Testing to be conducted by fire academy instructors and students during currently scheduled classroom time, as well as additional free engagement time. Testing will be observed and controlled by TT&IC staff.

Test Objectives: Assess the training value (information, decision-making and mechanical learning, time to learn and understand, knowledge retention, time, and level of learning versus cost of system and time/cost of traditional classroom training)

Resources Needed:

- FLAIM Trainer consisting of approximately twenty-eight hardware and software system components
- Access to standard U.S. 120/240 voltage power outlets
- Television with HDMI connection and long HDMI cable (not provided with system)

Staff:

- TT&IC staff
- Firefighter academy instructors
- Certified firefighters
- Panel members
- Analyst/Writer

Test Environment: 15 ft x 15 ft climate-controlled open room with access to several 120/240 power outlets, low ambient noise, and no tripping hazards

Schedule:
FLAIM setup and operations training for TT&IC

Data collection (setup, average scenarios, battery life)

Executive demonstrations (TEEX executives and curriculum staff, local fire chiefs)

Test kick off (review embedded scenarios for testing)

Update FLAIM scenarios with new release

Fire recruit academy instructors and students review and assessment

TEEX advisory panel hands-on review, assessment, and feedback

Forest Service firefighter assessment

Municipal firefighter assessment

T1: Recruit review panel

T2: < 4 hr. Review technology
Representatives from: TEEX BFTF chief/director, asst chief/director, TEEX fire academy director, TX-TF1 director, TEEX training director, Texas A&M Forest Service

T3: Instruction to TEEX curriculum and academy instructors for setup and operations; run instructors through scenarios; collect survey data/feedback for operating, instructing, and use of system

T4: Academy instructors use with academy student class, collect survey data/feedback for operating, instructing, and use of system

T5: Report. Analyze data, draft report, publish
System Setup, Registration, and Familiarization
TEEX-Wide Demonstration
Initial Demonstration and Testing with Fire Academy Students
College Station Fire Department Demonstration
Follow-Up Demonstration and Testing with Fire Academy Students
FLAIM Trainer System Advisory Panel

Quantitative Metrics:

System Setup Time	
Battery Life	
Battery Recharge	
Startup Time	

System Load Time	
Average Scenario Length	
Tracking Accuracy/Latency	
Resolution/Display Quality	
Frame Rate	
Reliability	
Functionality of Equipment	
System Stability	
Durability	
Cost of Training	

Qualitative Metrics:

Ease of Setup	
Ease of Use	
Mix of Scenarios	
Realism of Scenarios	
Immersion	
Instructor Control, User Interface	
Range of Settings	
Training Value of Hose/Nozzle	
Number of Instructors Required	
Training Value of SCBA Mask	
Training Value of IR Heat Detection	
Training Value of FF Techniques and Use on Fires	
Audio Quality	
Assessed Value for Initial Academy Training	
Assessed Value for Refresher Training	
Assessed Value for New/Difficult to Set Up in Real-World Scenario Exposure	

Pre-Scenario Teleport Time Training	
Post-Scenarios Debrief	

Metrics Other:

Safety of Training Environment	
Assessed Savings in Fuel	
Assessed Value of Scenarios vs Available Facilities	
Assessment of Exposure (heat stress, carcinogens prevention)	
Assessed Savings in Labor, Travel, etc.	
Assessed Limitations in Training	
Skills, Decision-Making, Exposure	
Savings on Wear/Tear of Equipment	

Expert Review Panel

- Fire Academy Chief: Paul Siebert
- Municipal Fire Department: Captain Ben Miller
- Texas A&M Forest Service: William Hood
- Volunteer Fire Department: Chief Harvey Cheshire
- U.S. Department of Defense: 1LT Casey Wood

Scenarios Tested

Municipal, Industrial, Wildland, Aviation, Vehicle, Maritime

Cost: $50,000 includes the core system with one year of the software/support/subscription package. Customers may buy additional annual or three-year subscription packages.

Test deliverables: TEEX-Tested report, photos during testing.

TEXAS A&M ENGINEERING

EXTENSION SERVICE