Virtual Reality (VR) Training Systems for First Responders

Market Survey Report

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The “Virtual Reality (VR) Training Systems for First Responders” was prepared by the National Urban Security Technology Laboratory (NUSTL) in conjunction with DAGER Technology, LLC, for the U.S. Department of Homeland Security, Science and Technology Directorate pursuant to 70RSAT18CB0000049/P00006.

Photos included were provided by the National Urban Security Technology Laboratory, unless otherwise noted. The report’s cover photo was captured by NUSTL employees while testing a virtual reality training system for law enforcement.

FOREWORD

The National Urban Security Technology Laboratory (NUSTL) is a federal laboratory within the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T). Located in New York City, NUSTL is the only national laboratory focused exclusively on supporting the capabilities of federal, state, local, tribal, and territorial responders to address the homeland security mission. The laboratory assists responders with the use of technology to prevent, protect against, mitigate, respond to, and recover from homeland security threats and incidents. NUSTL provides expertise on a wide range of subject areas, including chemical, biological, radiological, nuclear, and explosive detection, personal protective equipment, and tools for emergency response and recovery.

NUSTL manages the System Assessment and Validation for Emergency Responders (SAVER) program, which provides information on commercially available equipment to assist response organizations in equipment selection and procurement. SAVER knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" The SAVER program works with responders to conduct objective, practitioner-relevant, operationally-oriented assessments and validations of commercially available emergency response equipment. Having the right tools provides a safer work environment for responders and a safer community for those they serve.

NUSTL is responsible for all SAVER activities, including selecting and prioritizing program topics, developing SAVER knowledge products, and coordinating with other organizations to leverage appropriate subject matter expertise. In conjunction with DAGER Technology, LLC, NUSTL conducted a market survey of commercially available virtual reality (VR) training systems for first responders. This equipment falls under the AEL reference number 04AP-08-SIMS entitled Simulators.

SAVER reports are available at www.dhs.gov/science-and-technology/saver.

Visit the NUSTL website at www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory or contact the lab at NUSTL@hq.dhs.gov.

U.S. Department of Homeland Security

SAVER

System Assessment and Validation for Emergency Responders

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EXECUTIVE SUMMARY

Emergency response agencies use virtual reality (VR) training systems to train responders in routine, dangerous, or uncommon situations in a realistic, safe, and cost-effective manner. VR training systems for first responders require both hardware and software. The hardware includes VR head-mounted displays, and possibly a separate computer system, controllers, beacons, and accessories. VR software integrates the hardware and accessories with training scenarios to produce virtual training content. VR training systems for first responders can be commercial-off-the-shelf (COTS) training products or custom-build training products. Most companies that produce COTS training products also customize their training products. This report features both COTS training systems and customizable COTS products.

Between January 2023 and May 2023, the System Assessment and Validation for Emergency Responders (SAVER) program conducted a market survey of commercially available VR training systems for first responders. This market survey report is based on information gathered from manufacturer and vendor websites, internet research, industry publications, and a government-issued request for information that was posted on the System of Award Management website. The survey identified 21 products from 20 developers. For the purpose of this market survey report, additional criteria for inclusion were added to narrow the scope of the report to COTS and customizable COTS products. Prices vary widely based upon quantity and type of hardware included, software licensing, number of users, number of scenarios included, and customization.

While some of the COTS products can also be customized to meet an agency's training needs, specialized or agency-specific training may need to be custom-built. COTS training products may allow an agency to evaluate how VR training fits into their training plan in terms of effectiveness, acceptance, cost, and deployment at a lower cost than custom applications. Regardless of the product type selected, VR training software can provide first responders with the ability to learn and practice skills in a controlled environment. The training experience should also be immersive and interactive, cost and time effective, scalable, easily accessible, varied, customizable, and used to improve and record performance.

The products described in this report provide a wide variety of training scenarios for fire, police, and emergency medical services. The most advanced systems have features like gaze tracking, user heartrate monitoring, artificial intelligence control of interactive characters within scenarios, or the use of advanced feedback like heat suits or electrostatic shock to simulate physical sensations. The choice of a particular training product may depend on many factors, including the training needs of the agency, budget, available training space, and the level of the agency's in-house technical expertise.

The purpose of this report is to provide emergency response agencies with information that will guide them in making operational and procurement decisions. Each agency should consider the overall capabilities, technical specifications, and limitations of VR training systems in relation to their agency's needs when making equipment selections. Agencies should also consider the impacts associated with integrating VR training systems into their information technology, policy, concept of operations, and maintenance plans.

The performance of the products and information included in this report has not been independently verified by the SAVER program.

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1.0 INTRODUCTION

Public safety agencies use virtual reality (VR) training systems to train law enforcement, fire, and emergency medical responders in routine, dangerous, or uncommon situations in a realistic, safe, and cost-effective manner. Trainees can exercise response procedures in a low-risk environment and receive immediate feedback on their performance from instructors who monitor and/or control the scenarios. VR training software can be adapted to agency needs, scenarios can be freely repeated, multiple students can simultaneously interact, and sessions can be conducted remotely. VR training systems for first responders can be commercial-off-the-shelf (COTS) or custom-built training products. Most companies that produce COTS training products can also customize those training products.

Between January 2023 and May 2023, the System Assessment and Validation for Emergency Responders (SAVER) program conducted a market survey of Virtual Reality (VR) and Augmented Reality (AR) Training Systems for First Responders. This market survey report focuses solely on VR training systems. A separate market survey report titled "Augmented Reality (AR) Training Systems for First Responders" is available on the SAVER website. This VR Training Systems for First Responders Market Survey Report covers 21 different commercially available products. This market survey report is based on information gathered from manufacturer and vendor websites, internet research, industry publications, and a government-issued request for information (RFI) that was posted on the System of Award Management website. Due diligence was performed to develop a report that is representative of products in the marketplace.

Products included in this report are COTS and customizable training solutions that provide multiple and varied immersive scenarios. Many can integrate with first responder agency learning management systems (LMS) to track training and record progress. Some provide "see-what-I-see" functionality to allow for trainee assessment and review of the training scenario. The commercially available VR training products included in this report are:

- Complete pre-packaged and scenario-based VR training systems validated for first responders, and/or
- Customizable COTS VR training solutions made by companies with documented experience producing first responder VR training systems

Products that did not fall into at least one of these two categories were not included in the market survey.

2.0 VR TRAINING SYSTEMS FOR FIRST RESPONDERS

Virtual reality (VR), augmented reality (AR), and mixed reality (MR) – a combination of VR and AR elements – are subsets of a continuum commonly referred to as "extended reality" (XR). XR spans from basic tools like computer-based digital maps to 3D digital representations, AR glasses, MR glasses, VR goggles, and sensory controllers. As the complexity of XR grows, these tools may further integrate a user's senses using various devices – headsets, gloves, body suits, or even neural inputs – leading to a fully immersive experience.

VR systems are designed to completely replace the visual and often the auditory experience of the user with artificial content. There are numerous advantages to VR training systems for first responders, including an immersive and interactive experience, a safe and risk-free environment, cost and time efficiencies, scalability and accessibility, customization and personalization, and data-driven insights to training outcomes. Head-mounted displays (HMDs) for VR block out the user's physical surroundings and present a virtual environment. This is an advantage over AR systems in which the real-world is visible through the (HMDs) lenses, limiting the scope of content that can be delivered. This gives training developers full control over scenarios, allowing them to present users with unusual or dangerous situations that can't be simulated otherwise.

Using VR systems, trainees can learn and practice skills in a controlled environment without real-world risks associated with emergency response. The virtual environment can also isolate the trainee so that they can have a focused and uninterrupted training experience. Trainees can interact with the virtual world using hand controllers or other input devices that allow them to manipulate virtual objects, perform actions, and navigate through the simulated environment. Many systems allow interaction and collaboration amongst trainees and/or instructors as avatars in the virtual world. Many VR training systems also give instructors the ability to see what the trainee sees. This allows instructors to give trainees real-time feedback while conducting scenarios or record trainee actions for later review.

Concerns with VR training and simulated movement include motion sickness, which can be mitigated with the proper combination of hardware and software. Placing trainees in a virtual environment can also result in their inadvertently interacting with the physical world, so real and/or virtual boundaries must be established for safety. A VR HMD may also restrict the wearer's movement and require a minimum size area to be cleared for safe training.

VR training is best suited for scenarios that require a fully immersive environment where the trainee needs to experience a realistic situation, but where it is impractical, expensive, or too dangerous to perform the exercise in real life. VR training can reduce costs associated with travel, equipment, and training materials. It can be scaled up to accommodate large numbers of trainees or customized to meet specific training needs or individual learning requirements.

Virtual reality training systems for first responders require both hardware and software. Hardware includes VR HMDs, and possibly a separate computer system, controllers, beacons, and accessories. VR software integrates the hardware and accessories with training scenarios to produce virtual training content.

2.1 VR Head-Mounted Displays

While all suppliers detailed in this market survey report use third-party COTS headsets, some require or supply specific HMDs to use with their training simulations, while others attempt to make their system as hardware agnostic as possible.

Due to VR HMD screens being worn close to a user's eyes, they typically have high-resolution LED or organic LED screens with high refresh rates to minimize pixelation and reduce motion blur. While these attributes are important, several additional factors also affect the overall VR experience. The sense of reality, or "presence" users experience is affected by the quality of the HMD's tracking system, visual latency, image persistence, video resolution, and optical quality of the headset lenses. [1]

2.1.1 Stand-alone HMDs

Stand-alone HMDs, also known as all-in-one VR HMDs, are wearable devices featuring a processor and a battery that allow users to experience VR content without a separate computer or console (see Figure 2-1). Some stand-alone HMDs have built-in speakers and inside-out positional tracking (further described in Section 2.1.5.1). Stand-alone VR HMDs typically use Wi-Fi and/or Bluetooth to transmit data and communicate with handheld controllers.

Figure 2-1 Standalone VR HMD with handheld controllers

Image Credit: SimX

The biggest advantage of stand-alone HMDs over computer-connected HMDs is their portability: since they do not require a computer, they can be used anywhere. They also offer greater mobility for the wearer. However, stand-alone VR HMDs have limited graphics and processing power and deliver less visually complex graphics than computer-connected HMDs. Because they rely upon a built-in processor and batteries, they are typically heavier than computer-connected VR HMDs. They also have limited run-times, typically 2-3 hours, before they must be recharged, connected to power, or have the battery replaced. [2]

2.1.2 Computer-connected HMDs

Computer-connected VR, also known as personal computer VR, typically use HMDs tethered to a computer or gaming console by cable(s) that provide power and data connectivity. The power and data cable(s) allow the computer-connected VR HMD to display high-quality, immersive VR content while maintaining a stable, reliable connection to the computer. The separate computer allows greater processing power, faster refresh rates, and more powerful graphics processing units (GPUs) than stand-alone VR HMDs. Some computer-connected HMDs use high speed wireless connections such as WiGig (IEEE 802.11ad) to provide similar data transmission speeds to wired connections. These wirelessly tethered HMDs still require a power supply, which may be a battery pack (or packs) worn by the user.

Figure 2-2 Computer-connected VR HMD with nozzle controller and haptic feedback

Image Credit: RE-liON

Whether wired or wireless, computer-connected HMDs usually have more advanced features and capabilities than stand-alone HMDs. Due to their advanced graphics and processing power, computer-connected HMDs can provide a more seamless and immersive VR experience than stand-alone HMDs for some training applications. [3] Computer-connected HMDs often include features such as positional tracking (further described in 2.1.5.1), which allows users to move around the virtual environment and have their movements accurately reflected in the VR experience. A shortcoming of tethered HMDs, however, is that they limit how much the user can move around because of their physical connection to the computer. Some manufacturers mitigate this disadvantage by integrating body-worn computers in their systems, often as a backpack or belt-worn device (see Figure 2-2).

2.1.3 HMD Display Attributes

There are several important display attributes to consider when choosing a VR HMD, including resolution, field of view, refresh rate, latency, and comfort.

- The **resolution** of the VR HMD, which is often referred to as resolution per eye, determines the sharpness and clarity of the virtual images displayed. Higher resolution displays provide more detail and a more immersive experience. Resolution may be expressed in common screen pixel dimensions like 2160 x 2160, or in pixels per degree (ppd) which denotes the number of pixels found per degree of field of view. Human vision can typically resolve around 60 ppd.
- **Field of view** (FOV) is the observable virtual area seen within the VR HMD. The average horizontal FOV for a person is around 200 degrees. A larger FOV for a VR HMD contributes to a more immersive experience. VR HMD can have a horizontal FOV ranging from less than 90 degrees and up to 180 degrees.
- The **refresh rate** of a VR HMD shows how frequently the display updates the virtual environment. Refresh rates are expressed in hertz (Hz), which is cycles per second. Thus, a 90 Hz HMD will refresh the screen image 90 times per second. Higher HMD refresh rates can reduce motion blur and improve the feeling of immersion.
- **Latency** is the delay between a user's movement and the corresponding change in the virtual space. Numerous factors can affect latency, including refresh rate, graphics processing power, tracking technology, software optimization, and network latency. Low latency is important for reducing motion sickness and a natural-feeling VR experience.
- **Weight, fit, and adjustability** can all affect wearability and the level of comfort. Being able to comfortably wear and use a VR HMD is an important consideration for training. A lightweight, comfortable, and well-fitted HMD will allow trainees to remain focused for longer periods and have a more immersive VR experience.

There are a wide variety of VR HMD manufacturers and models. Consumers should pay attention to the requirements of the VR software they are considering to determine which VR headsets are compatible. The website vr-compare.com lists features and attributes associated with various commercially available Virtual Reality (VR) headsets.

2.1.4 Video Pass-Through

Video pass-through uses external cameras that capture and project the real-world view inside the VR HMD. Some HMDs use video pass-through to provide mixed reality capability by blending the real and virtual worlds. Some VR HMDs have only monocular, black-and-white video pass-through, while others feature stereoscopic, high-resolution video pass-through in full color. Some VR HMDs have a distance sensor on the HMD to allow the user to better interact with real-world objects while in a mixed reality setting.

2.1.5 Degrees of Freedom

HMDs include hardware to track the user's position, typically an inertial measurement unit (IMU) and a method of correcting for "drift" (a compounding error in the IMU's estimate of the headset's position). IMUs contain gyroscopes, accelerometers, and optional magnetometers to estimate movement. In a three-axis HMD, the IMU tracks the yaw, pitch, and roll of the HMD, and the user's view changes accordingly (Figure 2-3). Three-axis systems have "three degrees of freedom" (3 DoF): the user remains stationary and can "look around" at VR features but 3 DoF does not allow the user to physically walk around within a space and have those movements reflected in the virtual or augmented world. Any position changes of the user's point of view or avatar within the virtual world must be facilitated by using external controllers to "walk" or to teleport. In teleportation, users select a location within the virtual environment and instantaneously "jump" to that spot.

Figure 2-3 Three Degrees of Freedom (3 DoF)

Image Credit: DAGER Technology, LLC

Six-axis systems track the yaw, pitch, and roll of the HMD, plus the user's X-, Y-, and Z-axis movements (also known as "sway," "heave," and "surge," respectively) within a training space (see Figure 2-4). Six-axis systems are said to have "6 DoF." Like 3 DoF systems, 6 DoF systems allow the user to navigate their virtual environment using controllers. However, unlike 3 DoF systems, 6 DoF systems allow the users to walk around in the real world and have those movements reflected in the virtual environment. To ensure users' safety with six-axis systems, many headsets employ external-facing cameras on the HMD, with displays that switch from the VR view to a "real-world" view whenever users approach a training perimeter, fixed objects, or another trainee in a multi-user scenario.

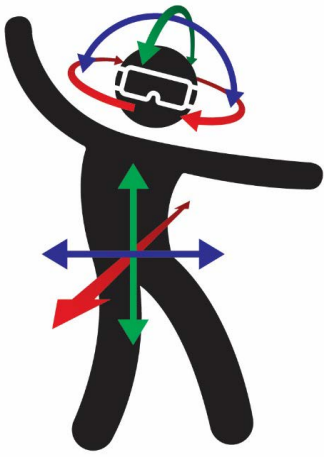

Figure 2-4 Six Degrees of Freedom (6 DoF)

Image Credit: DAGER Technology, LLC

2.1.5.1 Positional Tracking

Six-axis systems have a variety of methods to track the wearer's X-, Y-, and Z-axis, but all typically include IMUs plus cameras and/or infrared sensors. IMUs do much of the motion tracking in HMDs, but are subject to "drift," a compounding positional error. The cameras and other sensors are used to continually correct the drift and may be mounted on the HMD, in the training space, or both.

Inside-out tracking systems use cameras and/or other sensors mounted on the HMD and controllers to look at features of the external environment, monitor changes, and adjust the VR viewpoint accordingly.

Marker-based inside-out tracking systems use fixed markers like QR code stickers, reflectors, or active-infrared beacons placed around the training space as reference points. To ensure positional accuracy when using marker-based systems, careful setup, calibration, and attention to marker placement is important so that the cameras will always have a view of multiple markers.

Markerless inside-out tracking systems use existing, unique features of the training environment to track the HMD's location. Headset-mounted cameras monitor the environment and compare the viewpoint from frame to frame. Changes in relative position to existing features are then replicated in the VR environment. Markerless systems do not require external hardware; as such they are typically more portable than marker-based systems and are often found in consumer-grade HMDs. Since markerless systems rely on unique features in the environment, they can struggle with open floor areas and featureless walls and may be less accurate than marker-based systems.

Outside-in tracking systems use external cameras and other sensors to track the user's HMD. The HMD usually has infrared LEDs or other markers mounted on the headset, which are tracked by the external cameras and sensors. These systems can be more accurate than inside-out tracking HMDs; however, outside-in systems require carefully installed and calibrated hardware.

2.1.6 VR Controllers

At the core of the VR experience is the users' ability to interact with the VR environment. Typically, this involves the use of handheld controllers, usually one controller for each hand of the user. Similar to typical video game controllers, these often have buttons, joysticks, wheels, or touchpads to allow users to control their avatar's movements as well as to pick up objects, manipulate controls, open doors, and similar functions. In addition, VR controllers often have positioning hardware to sense the controller's spatial orientation and spatial relationship to their headset or to fixed beacons. This allows the user to visualize their VR "hands" as they manipulate virtual objects or perform other actions in the training environment. VR controllers typically have a haptic feature to provide tactile feedback, usually in the form of vibrations activated when the user touches something in the VR world. Controllers can also be built into props like a fire hose nozzle, a variety of training weapons (see Figure 2-5), flashlights, tools, and other first responder equipment.

Figure 2-5 Conducted Energy Device Controller

Image Credit: InVeris Training Solutions

2.1.6.1 Hand Tracking

Hand tracking allows for a more natural and immersive virtual experience than the use of handheld controllers. Several different technological approaches to VR hand tracking can capture and analyze hand movements that are translated to corresponding movements in the virtual world. Some VR systems use external facing cameras to track a user's bare hands or special VR gloves, allowing trainees to interact with virtual environments and objects using their hands rather than controllers. VR gloves have reflectors on the front, back, and fingers that allow hands and even individual fingers to be tracked. The software then digitally recreates users' hands inside the virtual world, allowing their virtual hands to manipulate virtual objects. Some VR gloves also have force-feedback mechanisms that simulate touch or resistance when users handle objects in the virtual world, which creates a more natural interaction between users and VR objects. Bare-hand tracking systems, however, cannot provide haptic feedback (see Sections 2.1.5.1 and 2.2 for additional information).

2.1.6.2 Eye-Movement Tracking

Some VR HMDs can track the user's eye gaze to determine where their attention is focused throughout a scenario or even to control user actions in the VR environment. Eye tracking (also called "gaze tracking") is typically accomplished via an internal HMD camera that monitors the movement of the wearer's eyes and may be aided by the projection of an invisible infrared point onto the user's cornea to measure the angle between this point and the center of the user's pupil. Eye tracking may be especially important for law enforcement training scenarios to determine, for example, what areas a trainee is visually scanning during a room entry or to determine if an officer is watching a subject's hands during a traffic stop. Eye tracking cameras can also automatically detect and adjust parameters for interpupillary distance, allowing for a quick and accurate calibration process when a user dons a headset. Eye-tracking may also be used for biometric identification, allowing shared headsets to instantly recognize a trainee, load their profile, adjust their optical settings, and continue their training where they left off.

2.2 Haptic Feedback

Electronic devices have traditionally provided most feedback to users via visual and auditory signals. With the ascent of video gaming, developers sought to provide more immersive experiences by providing additional signals to stimulate the human sense of touch, known as haptic feedback, often shortened to "haptics." The human somatosensory system can detect multiple types of input data including pressure, pain, temperature, hair movement, joint position, muscle stretch, and vibrations. The simplest haptics include control buttons designed to "click" when depressed or phone screens that vibrate when touched, simulating a button press.

Haptics have migrated into VR training technology. At an advanced level, some training systems for first responders use force-feedback motors to realistically simulate sensations like a charged fire hose being opened, recoil from a firearm, or steering wheel feedback. "Heat suits," which contain infrared LEDs, are available to give wearers the sensation of entering a fire-enveloped room. Developers are also working on VR systems that stimulate the users' sense of smell. Trainees may be greeted by the smell of natural gas as if they're virtually arriving at the scene of an explosion, or the smell of smoke while virtually investigating a chimney fire.

2.3 VR First Responder Training Software

VR training software can provide first responders with the ability to learn and practice skills in a safe and controlled environment. The software should provide an immersive and interactive training experience that is varied, scalable, and somewhat customizable, and be useful to improve and record trainee performance. While some VR training isolates the trainee's senses so that they can have a focused and uninterrupted training experience, other training focuses on the collaboration of trainees working together to solve problems. Many VR training systems give instructors the ability to see what the trainee sees or even interact with them in the virtual world. This allows instructors to guide and evaluate trainee actions. Many VR systems allow interaction and collaboration amongst trainees and instructors in the virtual world as avatars.

Virtual reality training systems use logical branching (sometimes referred to as "decision trees") to create interactive and engaging training experiences that simulate real-life decision-making scenarios. Branching logic can help trainees navigate through the scenario and make decisions and allows for variation in scenario play and outcome. The types of branching used depend upon the complexity of the training and the desired functionality. The decision-tree structure allows for flexible instruction and the ability to provide personalized guidance and feedback to trainees based on their individual decisions and actions.

Trainees are immersed in the virtual world, so it is important to set up boundaries to ensure their safety. In addition to a VR system's minimum and maximum training room size requirements, this may include virtual boundaries, physical barriers, and personnel tracking. Virtual boundaries or "guardian systems" can be defined inside the VR environment. Physical barriers, such as physical walls, fences, or visual markers, can be used to mark the limits of the VR training areas. Personnel such as supervisors, facilitators, or monitors can observe trainee movements, provide guidance, and address any safety concerns.

2.3.1 Customization

VR training hardware and software for first responders varies drastically in the level of customization available. The selection of the level of customization often depends on the purpose of the training, the funding available, and the level of specificity. COTS training products may allow an agency to evaluate how VR training fits into their training plan in terms of effectiveness, acceptance, cost, and deployment at a lower cost than custom applications. COTS training products may be more suitable for training based on national standards (like basic life support), equipment, or common processes (like conflict de-escalation). Custom-designed training may be more applicable for specialized procedures, departmental policies, and virtual spaces based on local infrastructure and assets.

Some simple training setups feature basic scenarios, which use COTS HMDs and their corresponding controllers to navigate the scenes. These are often pre-packaged training systems and do not allow for customization; however, new content can be downloaded from vendor libraries or even open-source online repositories.

Alternatively, agencies may elect to create their own training content using "no-code" VR software. These feature pre-programmed content such as avatars, rooms, backgrounds, objects, and actions that can be brought together using simple menus and "drag-and-drop" functionality, eliminating the need for computer programming knowledge. However, the content that can be created this way is often limited in its complexity and realism.

At the next level of sophistication are COTS systems that allow the insertion of "digital twins" of environments or objects. Users may scan actual local venues using high-resolution 360-degree cameras to create a realistic replica of a training venue. Unique objects like improvised explosive devices (IEDs) or particular weapons may also be scanned using optical photogrammetry or laser scanners or built from scratch in computer-aided design (CAD) programs. These digital twins can be placed into the VR environment and even virtually manipulated by trainees, e.g., an IED subjected to a render-safe procedure, or a knife collected as an item of evidence at a virtual crime scene. As the complexity of the training scenario increases, the required knowledge of the scenario developer increases as well and may require vendor assistance. Most VR companies selling COTS public safety training systems offer custom development at additional cost.

VR training can also be developed entirely from the ground up, allowing agencies to have full control over training content. This typically requires hiring programmers skilled in the use of the leading VR creation software suites, usually Unity or Unreal Engine. Top-quality simulations may also require script writers, video editors, and graphic artists. Most agencies that take this approach elect to outsource this work to vendors who then work with an agency's training experts to achieve the desired results.

At the forefront of VR training design are systems that feature adaptive, realistic scenarios that can also be customized easily by trainers using agency-provided content, such as building scans, or that can be adapted to use real agency weapons in the VR world. VR training developers are also beginning to leverage artificial intelligence (AI) technology for content programming and to control non-player characters (NPCs), enabling trainees to develop flexible skillsets. AI NPCs can react to trainee actions and change their behavior on-the-fly, allowing trainees to repeat training without experiencing the exact same timeline or character behavior.

2.3.2 Interactions

VR training systems can have many different types of interactions available to trainees in the virtual world, including interactions with controllers and digital twins of tools and objects, NPCs, and other trainees, role players, and instructors.

Controllers in VR training systems are handheld devices that allow trainees to move through and interact with the virtual world. As described above, controllers enable users to pick up, move, rotate, and manipulate objects in the virtual world. Controllers can also be used to emulate specific tools or equipment in the virtual scenario. First responder VR training systems sometimes replace these handheld controllers with specialized first responder controllers, such as fire hose nozzles and weapons. For even more customized interactions with objects in a virtual environment, agencies may use digital twins. As discussed above in section 2.3.1, digital twins are accurate virtual representations of tools, equipment, and objects, which can be used in the training simulation. Interacting with and using digital twins of equipment in virtual training sessions allows trainees to learn how to maintain and operate the equipment.

VR training also allows for interactions with characters who play a role in the scenario, collaborations with fellow trainees, and engagement with instructors. NPCs are computer-controlled characters programmed to interact with the trainees and the virtual world. NPCs help with scenario storytelling, populate the virtual world to contribute to realism, and interact with trainees in the training simulation. NPCs may use pre-scripted behaviors, branching logic, AI algorithms, or a combination of these methods. Advances in AI have enhanced VR experiences by enabling more natural and realistic interactions with virtual characters. AI-powered NPCs respond to user actions in more intelligent and nuanced ways, making the virtual environment more lifelike.

Some VR training systems allow trainees to interact with other trainees, role players, and instructors within the simulation as avatars. Interaction with other trainees adds realism to the scenario and builds teamwork, collaboration, and problem-solving and conflict-resolution skills. The use of role players in training scenarios can add human-to-human interaction between trainees and characters in the scenario, such as victims, hostages, and subjects. Depending upon the sophistication of the simulation, instructors can modify the role-playing avatar actions, change environmental conditions, and vary the scenario outcome based on trainee actions.

2.3.3 Instructor Observation and Evaluation

Despite technical advancements in VR, skilled instructors remain vital for enhancing trainees' abilities. While basic VR training content is available, advanced training relies on instructors understanding trainees' VR experiences. Most VR first responder training systems feature "see-what-I-see" functionality. This allows instructors to display trainees' views on screens or to the instructor's HMD, allowing them to provide trainees with post-training feedback or real-time guidance (see Figure 2-6). Voice-over-Internet-Protocol lets instructors communicate via trainees' HMD earphones, which is also useful for remote training. Performance data available to instructors includes shot accuracy, vital signs, scene views, gaze tracking, and past performance. Recording sessions for review is common; some systems can auto-evaluate and offer feedback. Certain systems even automatically customize scenarios based on past performance. VR systems' integration capabilities with third-party LMSs vary; basic VR systems often support LMS integration while more complex ones usually use proprietary software due to data complexity.

Figure 2-6 Control Facilitator Application

Image Credit: Real Response Pty Ltd

2.4 Emerging Technologies

Technological advances in VR hardware and training systems are happening quickly. Potential developments in VR include improved hardware, more realistic environments, better integration with other technologies, and expanded applications in training. Beyond training advancements being fostered by industry and defense, the National Institute of Standards and Technology (NIST) Public Safety Communications Research (PSCR) division is focused on developing and testing modern technologies to improve public safety communications and operations. PSCR is developing realistic VR simulations for first responders, developing new VR technologies, and collaborating with partners to improve the accuracy and realism of VR simulations. NIST opened the Public Safety Immersive Test Center (PSITC) in Boulder, Colorado in the spring of 2022 to develop immersive public safety standards and measurements training. The PSITC is designed to help answer key research questions around the future of user interfaces and location-based services for public safety training operations.

Virtual-reality HMDs are likely to continue to advance towards MR headsets that blend AR and VR functionality. A new MR HMD due to be released early in 2024, for example, is reported to be a wireless, full-wraparound HMD that is able to toggle between virtual and augmented reality, effectively enabling the user to reduce or increase visual exposure to the actual world. [4]

Advances in headset technology may also include integrations with advances in how users interface with training programs. A system that can translate human brain activity into actions without any physical movement is being developed by a neurotechnology firm. [5] Wearing a prototype headset, users can perform basic actions in virtual reality by thinking about their desired movement(s). For example, in a game simulating a personal watercraft that is controlled by handles in the virtual world, users manipulate the controls by thinking about the motions, rather than squeezing their hands. The explicit goal of the technology is treating stroke and other neuro-muscular ailments, but in the process, these advancements may lead to "full-dive" VR training. The concept of "full-dive VR" is that the user's perceptions and actions could be disconnected from physical reality and, instead, fully immersed in the virtual world.

2.5 Relevant Standards

Since the majority of AR/VR headsets have much of the technology in close contact with the user's head, the VR/AR Association (VRARA) created, adopted, and published American National Standards Institute/Controller Area Network/UL Standards and Engagement 8400, "Standard for Virtual Reality, Augmented Reality, and Mixed Reality Technology Equipment." This standard is for the "safety of electrical and electronic equipment within the field of virtual reality, augmented reality, and mixed reality technologies." In addition to general product safety requirements, it also includes requirements related to see-through visual functions, flicker, skin compatibility, exposure of the eyes to thermal energy, biomechanical stress, mechanical robustness, enhancing spatial perception, safety and warning instructions, and functional safety. [6] Additional virtual reality standards to consider are detailed in Appendix A.

Special consideration must be given to systems used in emergency medical response training, as these may be impacted by the Health Insurance Portability and Accountability Act of 1996. [7]

2.6 Cybersecurity Considerations

Ensuring that the software is implemented, maintained, and backed up in a secure manner is a key consideration when looking at various products. Backing up and protecting the training scenario software is vital due to the time and financial investments VR requires. When installing training software and connected devices, follow the Federal Bureau of Investigation's (FBI) Criminal Justice Information Services (CJIS) Security Policy, which is available as a free download at le.fbi.gov/cjis-division/cjis-security-policy-resource-center. [8]

Installing software on a network carries some cybersecurity risks, depending on the requirements and implementation of the software, as well as the environment on which it is installed. Specific risks include security vulnerabilities that could allow the software itself to be exploited or allow a bad actor to gain a foothold in the network. An unauthorized person gaining access to the software itself could result in the disclosure of sensitive information such as first responders' concept of operations.

HMD devices which are connected to host-based operating systems should utilize proper PC-hardening security practices. All stand-alone devices that are listed in this market survey report can install a mobile device management (MDM) solution to help secure these end-point devices.

Care should be taken with any software that requires an active internet connection to function or receive updates. Some software is also cloud-hosted, requiring an active internet connection to function. Some software requires additional network resources to function and are not meant to be installed in a stand-alone environment.

2.7 Use of Grant Funds for Certain Telecommunications and Video Surveillance Equipment or Services

The John S. McCain National Defense Authorization Act for Fiscal Year 2019 (NDAA), Pub. L. 115-232, Section 889 (NDAA) prohibits the use of federal funds, including loan and grant[1] funds, to obtain or acquire certain telecommunications technologies manufactured by certain entities or to enter into contracts with entities that use those technologies. The Office of Management and Budget (OMB) published regulations at 2 C.F.R. § 200.216 to clarify the application of the NDAA to the use of federal grant funds to procure or obtain certain telecommunications equipment or services.

Effective August 13, 2020, federal grant recipients and subrecipients (i.e., **non-federal entities**) are prohibited from obligating or expending loan or grant funds to procure or obtain[2] the following "covered telecommunications equipment or services":

- Telecommunications equipment produced by Huawei Technologies Company or ZTE Corporation (or any subsidiary or affiliate of such entities)

For the purpose of public safety, security of government facilities, physical security surveillance of critical infrastructure, and other national security purposes, video surveillance and telecommunications equipment produced by:

1 This also includes cooperative agreement funds.
2 Nor may they extend or renew a contract to procure or obtain or enter into a contract to procure or obtain the covered equipment or services.

- Hytera Communications Corporation
- Hangzhou Hikvision Digital Technology Company
- Dahua Technology Company
- or any subsidiary or affiliate of such entities
- Other entities identified by the Secretary of Defense

The restriction also applies to systems that use the covered equipment or services as a substantial or essential component, and to subsidiaries or affiliates of those listed above[3]. See www.federalregister.gov/d/2020-17468/p-877.

Costs associated with covered equipment and services are "unallowable" for grant funding. Grant recipients are responsible for ensuring funds are used only for allowable costs, and would be obligated to refund the government for unallowable costs. The Federal Emergency Management Agency (FEMA) issued FEMA Policy #405-143-1, Prohibitions on Expending FEMA Award Funds for Covered Telecommunications Equipment or Services (Interim) for further guidance on the Section 889 prohibitions. Additionally, OMB issued frequently asked questions (FAQs) on the topic.

For **federal** entities, FEMA published interim rules amending the Federal Acquisition Regulation[4].

3 As well as telecommunications or video surveillance services provided by entities or using equipment described above.
4 www.federalregister.gov/documents/2019/12/13/2019-26579/federal-acquisition-regulation-prohibition-on-contracting-for-certain-telecommunications-and-video and www.federalregister.gov/documents/2019/08/13/2019-17201/federal-acquisition-regulation-prohibition-on-contracting-for-certain-telecommunications-and-video.

3.0 PRODUCT INFORMATION

This section provides information on 21 products that offer first-responder-focused VR training. All products are either complete, pre-packaged scenario-based VR training systems for first responders, or commercially available customizable VR training solutions from companies with documented experience in producing first responder VR training systems. All training solutions provide multiple and varied immersive scenarios and/or can either integrate with first responder agency learning management systems (LMS) to track training and record progress or provide see-what-I-see functionality to allow for assessment and review of the training scenario.

Table 3-1 provides characteristics and specifications of the products, which are listed first by responder discipline (fire, law enforcement, emergency medical services) and then alphabetically by manufacturer. Dual discipline products, however, are listed between disciplines. Please note that while cost is not included in Table 3-1 due to varying pricing models, pricing is included within individual product sections, below the table, if provided by the manufacturer. The information in Section 3.0 has not been independently verified by the SAVER program.

Below are definitions of the product information in Table 3-1, listed in column order.

Developer Country refers to the nation where the corporate headquarters for the developer is located. Some responder agencies may have restrictions regarding where they can procure products. Developer country may also influence the style of vehicles, uniforms, and equipment featured in the software. Country codes are the International Organization for Standardization (ISO) Alpha-3 codes; a key to them is provided at the bottom of the table.

Training Target refers to the primary first responder discipline that the product is intended for, such as fire, law enforcement (LE), or emergency medical services (EMS).

VR HMD refers to the type of VR head-mounted display used by the product. “Agnostic” indicates that a wide variety of VR HMDs can be used with the system.

Degrees of Freedom (DoF) refers to the degrees of freedom the user has in the VR training simulation.

Portable refers to if the system can be easily transported and set up; a checkmark indicates portability.

Multi-Trainee Collaboration refers to whether more than one user can participate in the same VR training session; a checkmark indicates that multiple users can collaborate in the VR training.

Training Area indicates the space recommended to operate the VR training simulation. If the system indicated a minimum required space, that is indicated in the individual entry.

Table 3-1 Product Comparison Matrix

Manufacturer and VR Training Product	Developer Country	Training Target	VR HMD	Degrees of Freedom (DoF)	Portable	Multi-Trainee Collaboration	Training Area
FAAC, PumpOps VR Trainer	USA	Fire	Valve Index	6	✓		--
FLAIM Systems, FLAIM TRAINER	AUS	Fire	HTC VIVE Family	6	✓	✓	400 ft^2
NexGen Interactions, HazVR	USA	Fire (Hazmat)	Oculus Quest 2	6	✓	✓	--
Pixo VR, First Responder Operations (Hazmat)	USA	Fire (Hazmat)	agnostic	6	✓	✓	--
Reality in Virtual Reality Limited, RiVR Investigate	GBR	Fire	HTC VIVE Pro	3	✓	✓	--
RE-liON, RE-liON	NLD	Fire, LE	agnostic	6	✓	✓	900 ft^2
AVATAR Partners, Virtual Shooter VR Training	USA	LE	Oculus Quest 2	6	✓	✓	81 ft^2
Axon Enterprise, Inc., Axon VR	USA	LE	agnostic	3 or 6	✓	✓	100 ft^2 min
Envision, XR for Law Enforcement	USA	LE	agnostic	6	✓	✓	8 ft^2/user
GOVRED Technology, Apex Officer	USA	LE	HTC VIVE Family	6	✓	✓	25–1089 ft^2
Inveris Training Solutions, SURVIVR	USA	LE	HTC VIVE Pro	6	✓	✓	100–1225 ft^2
Street Smarts, Street Smarts VR	USA	LE	HTC VIVE Pro	6	✓	✓	81–900 ft^2
V-Armed, V-Armed	USA	LE	--	6		✓	900–40,000 ft^2

Manufacturer and VR Training Product	Developer Country	Training Target	VR HMD	Degrees of Freedom (DoF)	Portable	Multi-Trainee Collaboration	Training Area
Vizitech USA, VR Forensics, and VR Active Shooter	USA	LE	HTC Vive Pro	6	✓	✓	--
WRAP Technologies, WRAP Reality	USA	LE	HTC VIVE Pro	6	✓		400–900 ft^2
Refense AG, Refense	CHE	LE, EMS	HTC Focus 3	6		✓	1425–4975 ft^2
Augmented Training Systems, HERO Training Platform	USA	EMS	Oculus Quest 2	6	✓	✓	--
Health Scholars, Emergency Care Training Suite	USA	EMS	Oculus Quest 2 or Pico Neo 3	6	✓	✓	36 ft^2
Real Response Pty Ltd, Blue Room	AUS	EMS	Varjo XR-3 MR	6	✓	✓	32 ft^2 min
Real Response Pty Ltd, VTC3	AUS	EMS	agnostic	6	✓	✓	10 ft^2 min
SimX, SimX VR	USA	EMS	HTC or Oculus	6	✓	✓	100–625 ft^2

-- Indicates no data was available.
Country abbreviations: AUS = Australia, CHE = Switzerland, GBR = Great Britain, NLD = Netherlands, USA = United States of America

3.1 FAAC, Pump Ops VR Trainer

FAAC typically uses physical mockups of equipment integrated with video screen feedback in their simulators. This is the case in their Pump Ops Trainer, designed for training firefighters on fire engine pump operations. Now, FAAC has introduced a new VR-based version of this system (called "Pump Ops VR Trainer") that eliminates the need for a physical mockup (see Figure 3-1). Pump Ops VR Trainer is a prepackaged COTS product designed to give trainers the ability to set up fire pump operations training with minimal infrastructure.

Figure 3-1 Pump Ops VR Trainer

Image Credit: FAAC

Pump Ops VR uses the Valve Index HMD in a 6 DoF mode.* The HMD is wired to a computer using a 15-foot cable with a breakaway connector to prevent damage to the computer if the trainee moves too far away. Users wear Valve Index controllers on their hands, which allows for individual finger tracking with grip sensing. This allows users to squeeze VR items with variable force or even open their hand fully to drop or throw VR objects without dropping their controller. In Pump Ops VR, users can reach for, grasp, twist, pull, and push pump handles, buttons, knobs, and other virtual controls.

Pump Ops VR Trainer includes pre-designed training simulations and can accommodate custom-built scenarios. The software features interactive play that enables a team of users to experience the same immersive experience together, regardless of their physical locations. The simulation is operated by an instructor from an instructor operator station (IOS). The IOS has a touchscreen menu that allows the instructor to control the hose configuration, set conditions and faults, monitor trainee performance, and generate trainee assessments and reports. The VR Pump Ops Trainer also has see-what-I-see functionality that can be projected to multiple monitors.

The FAAC factory warranty covers a period of one year following delivery and acceptance of the Pump Ops VR Trainer. The basic warranty covers all parts and labor, priority service status, unlimited on-site corrective service visits, and unlimited telephone support. Routine telephone support is available Monday through Friday from 8:00 a.m. to 5:00 p.m. EST, with emergency telephone support available after-hours, 24/7. FAAC also offers an extended warranty program for an additional annual cost. The extended warranty includes one preventative maintenance visit, all parts and labor, unlimited on-site corrective service visits, priority service status, unlimited telephone support, and discounted advanced instructor training. The cost of the FAAC VR Pump Ops Trainer was not available. Information on extended warranty pricing was also requested from the company but not provided.

**Correction (June 2024): At the time of its initial publication, the Virtual Reality Training Systems for First Responders Market Survey Report incorrectly listed the Pump Ops VR Trainer as having 3 degrees of freedom (DOF) instead of 6. The section above and Table 3-1 have been edited to state the correct DOF.*

3.2 FLAIM Systems, FLAIM Trainer

The FLAIM Trainer is a multi-sensory VR training system designed for the firefighter community. The custom self-contained breathing apparatus (SCBA) simulation mask integrates with HTC Vive Pro VR goggles to simulate typical firefighter breathing apparatuses. The VR computer is contained in a mock SCBA cylinder. A fire proximity heat suit generates instantaneous heat sensations to simulate flame exposure, and a force-feedback hose reel and nozzle deliver realistic physical exertion and sensation. These models accurately simulate the interaction and variability of fire, smoke, water, and air with different combustibles to ensure realistic fire behavior.

Figure 3-2 FLAIM Trainer

Image Credit: FLAIM Systems

FLAIM Trainer uses the HTC Vive Lighthouse system to define the training area. The Lighthouse system uses portable, tripod-mounted beacons to define two corners of a cleared training area up to 20′ × 20′ (400 ft^2), allowing trainees to operate with 6 DoF.

FLAIM Trainer has a library of fire suppression scenarios. The instructor can inject variables in scenarios to vary the experience. The system has a wireless receiver with HDMI output, which provides see-what-I-see viewing on standard televisions or monitors. User performance can also be recorded for playback via the HDMI output. The SCBA mask has technology to capture respiration and fatigue data. The system also includes an armband monitor to capture heartrate.

FLAIM Trainer ships with an instructor iPad for system calibration, scenario setup, and trainee evaluations. The after-action-review feature provides data on trainee performance, monitors air consumption, and allows the instructor to provide feedback in real time, or from recordings, on the trainees' scenario execution.

The system is available in the United States from eDarley.com. The FLAIM Trainer Fully Immersive Virtual Reality Training Simulator retails for $49,500 and includes the Vive Pro VR Headset, SCBA mask, backpack computer, the "Feels Real" hose reel and nozzle, and the "Feels Hot" heat proximity vest. The system includes a one-year hardware warranty and a perpetual license, which includes over 55 training scenarios. Additional training scenarios and ongoing warranty support are available with an annual subscription currently retailing for $7,000. New scenarios are released every six months. If a customer discontinues the annual subscription, they maintain access to all scenarios available at their last semi-annual update, but without access to future scenario releases or product support. FLAIM Systems also offers custom scenario development.

3.3 NextGen Interactions, HazVR

NextGen's HazVR is a fully interactive and open-ended hazmat VR air monitoring training system developed in conjunction with subject matter experts. HazVR allows hazmat teams to train with air monitors in a VR environment that mimics dangerous chemical scenarios. HazVR training focuses on air monitoring basics, sampling procedures, and testing various gases under different conditions and locations. Scenarios can range from lab testing to large facilities with multiple gas leaks. Virtual gases are designed to behave in accordance with the specific conditions of the scenario using actual physical and chemical properties of a gas. HazVR also allows virtual gas visualization, to demonstrate flow and congregation.

Figure 3-3 HazVR

Image Credit: NextGen Interactions

HazVR uses the Oculus Quest 2 HMD, handheld controllers, and a Windows laptop. HazVR allows for 6 DoF and is completely portable. The primary virtual tools in HazVR are air monitors, with additional tools such as pH paper in development.

HazVR training allows three co-located users to collaborate in one scenario. Training is assessed through instructor participation and guidance, and after-action review of objective metrics and data. HazVR does not feature haptic feedback and does not integrate with learning management systems. NextGen can customize the HazVR training and scenarios as needed. NextGen also offers user and instructor training on the HazVR system.

NextGen warranties, customer service, and technical services are customized based upon the needs of the customer. While pricing for the HazVR was requested, the company did not provide that information.

3.4 Pixo VR, First Responder Operations (Hazmat) Tanker and Trailer

The First Responder Operations (Hazmat) Tanker and Trailer training allows trainees to learn and practice hazmat identification and response at the virtual scene of a tractor trailer accident. First Responder Operations (Hazmat) is hardware agnostic and works with most HMDs. The training meets Occupational Safety and Health Administration training requirements for Hazardous Waste Operations and Emergency Response (HAZWOPER) and allows responders to practice emergency response procedures. [9]

Figure 3-4 First Responder Operations (Hazmat)

Image Credit: Pixo VR

The First Responder Operations (Hazmat) Tanker and Trailer training focuses on team communication and collaboration techniques, proper application of the Emergency Response Guidebook, identification of hazardous materials (labels, containers, shipping manifest, transport vessels), and appropriate application of response actions and hazard management. The training can be used by a single user or used simultaneously by a team. The software allows dozens of users to learn, interact, and collaborate in the same virtual space—even if the users are not co-located. Pixo allows an unlimited number of users to be trained on the system, subject to the number of VR HMD systems the agency has available. First Responder Operations (Hazmat) randomizes the scenarios and uses real-time data and analytics. The content from any VR headset can be cast onto a monitor for the instructor to see. First Responder Operations (Hazmat) can integrate with any LMS platform to track and consolidate agency training data.

The Pixo platform and its library of content has tier pricing based on the number of users. Each tier includes a certain number of off-the-shelf training courses. Purchasing access to the platform and library of content includes access to a designated customer service representative, technical support via phone or email, and access to Pixo's online Support Center.

3.5 Reality in Virtual Reality (RiVR), RiVR Investigate

RiVR Investigate immerses users in a photorealistic environment for fire and arson investigation training. Users search for and collect virtual evidence within a fire scene. It equips the user with realistic, interactive VR tools, such as a camera, evidence markers, flashlight, and a gas detector. The software includes a "VR sniffer dog" called to each scene to search for accelerant evidence. Trainees can fully examine a scene, take photographs, record information on a VR Dictaphone, and examine evidence prior to making professional conclusions. The system requires an HTC Vive or Oculus Quest wireless headset with link cable and a gaming laptop. The system has 3 DoF and can be used with or without controllers.

Figure 3-5 RiVR Investigate

Image Credit: RiVR

To ensure training accuracy, RiVR Investigate scenes are based on real-world fires and designed in accordance with current International Association of Arson Investigators certified training standards. In preparation for every VR scenario, a realistic setup of a room or office is built, burnt, and modelled. Using 3D modelling techniques, RiVR's photogrammetry team recreates the post-burn scene by capturing the environment with thousands of photos and laser scans. 360-degree models of both the pre- and post-incident scene are recorded to assist the investigator in assessing forensic evidence.

The VR training can be used as a multiplayer interactive session with the ability to communicate and pass objects between multiple users, even if they are in different geographical locations. Users can record investigations using RiVR's Virtual Reality Monitor (VRM), which allows them to revisit and review a training or assessment. Alternatively, instructors can train a single trainee independently from a class and guide them through the investigation process. Individual training sessions can be extended into a classroom environment by streaming the individual's HMD view onto a VRM, a large TV, or projector screen. By offering instructors and other students a see-what-I-see view, the RiVR Investigate enables them to watch, discuss, and evaluate the training scenario as a class.

The RiVR Investigate package includes a VR tutorial, instructor manuals and videos, and a VR training setup guide. The purchase of RiVR Investigate includes a subscription to their global library of arson investigation scenarios consisting of different fire causes. Pricing and customer support information is available from the manufacturer upon request.

3.6 RE-liON

Figure 3-6 RE-liON

Image Credit: RE-liON

RE-liON is an immersive VR training experience for fire departments, police departments, and special operations units. The system is a pre-packaged COTS product that can be used with various COTS VR HMDs. Users can select a quick setup version that uses just an HMD and controllers or a full body "Smartvest" that allows participants' avatars to be rendered with full body and limb movement. Users can interact with items like doors, fire, and people, using their avatar's hands and feet and VR tools that replicate gas meters, weapons, and fire nozzles, among others. RE-liON includes haptic stimulus, including shock-based pain feedback and even smells. The system includes a mix of computer-generated and live role-play to create a "force-on-force" training environment. An open 30′ × 30′ training space is ideal for RE-liON, but the system can be deployed in smaller or larger areas. The portable kit can be set up in five minutes, while the full-body VR experience requires about an hour of setup.

The platform uses COTS hardware, including a Windows-based laptop, and an untethered VR HMD that has 6 DoF and built-in boundary control (perimeter warning system). The system operates on Wi-Fi; its controllers and Smartvest is designed to be used with an untethered VR HMD to allow operators to freely move around the training space. The fire physics for RE-liON's fire suppression scenarios are based on a National Institute of Standards and Technology (NIST) model. RE-liON can be customized using their Scenario Development Kit to create specific training scenarios for fire reconnaissance and suppression, law enforcement, and tactical operations, including room clearance and bomb squad operations. Users can also create interactive digital twins using 3D Studio Max from Autodesk; the company plans for the capability to add digital twins using Blender open-source software in the future.

The platform comes with two options: the Trainee Kit and the Academy Kit. The Trainee Kit includes a VR HMD, tactical belt and replica tools, full-body haptic feedback, and on-call and/or on-site support. The Academy Kit adds instructor control and review tools, including see-what-I-see functionality. All actions in the Academy Kit option of the platform, including voice, are recorded, allowing instructors and trainees to perform an after-action review immediately after a scenario is finished. The review feature includes the ability to view participant avatar actions from any angle. The RE-liON training system can support up to 12–16 simultaneous users; however, when large numbers of users participate in a scenario, trainees must wear backpack computers to overcome wireless streaming bandwidth limitations.

RE-liON offers user training, instructor training, and development training for customizing content. The company also provides stand-alone or subscription-based licensing, and can provide headsets, computers, controller hardware, software, and peripherals. The Trainee Kit costs $30,000 per kit per year, and the Academy Kit is $58,900 per kit per year. Information about the warranty and customer support hours is available upon request.

3.7 Avatar Partners, Virtual Shooter VR Training

The Avatar Partners Virtual Shooter VR Training has anti-terrorism (proactive) and counterterrorism (reactive) scenarios. The system must be used with the Oculus Quest 2 VR HMD. One to four trainees can collaborate on scenarios that are customizable and interactive. Trainees are represented as avatars, allowing them to navigate and interact with the simulated world alongside their team members and NPCs. Trainees can interact with objects, manipulate their surroundings, and employ tactical strategies. Haptic suits can also be incorporated into the training. The system is completely portable but requires a minimum space of 81 ft^2 to provide trainees with enough room for movement and interaction.

Figure 3-7 Virtual Shooter VR

Image Credit: Avatar Partners

Avatar Partners places emphasis on minimizing motion sickness through optimization of the VR experience. For example, the Virtual Shooter VR Training system's design shrinks the FOV slightly while the user is moving, which reduces the chances of VR motion sickness. Virtual Shooter VR Training uses physics-based models for weapons, ammunition, and other equipment and how these objects affect avatars (for example, wounding or killing them). Trainees also interact with NPCs, which respond to the environment and react realistically to different situations. The NPCs may take cover under desks, obstruct trainees' movements, and behave as if they were real individuals within the scenario. Instructors can modify and tailor scenarios to meet specific training needs. The system also provides see-what-I-see functionality for evaluating training outcomes.

Avatar Partner sells the software to the client, and the client is responsible for providing their own compatible hardware. Licensing for the software costs $150 per user per year. Avatar Partners is in the process of adding Virtual Shooter VR Training to their GSA pricing. Avatar Partners is currently available on the General Services Administration (GSA) Multiple Award Schedule (MAS) as GS-35F-433BA. Customer service is provided via phone and email on normal working days from 08:00 a.m. to 9:00 p.m. Eastern Time. Warranty information is available upon request.

3.8 Axon Enterprise, Inc., Axon VR

Figure 3-8 Axon VR

Image Source: Axon Enterprise, Inc.

Axon VR is a COTS VR product designed for law enforcement training in de-escalation and use of force. Officers progress through increasingly complex scenarios, requiring them to quickly make crucial decisions under evolving conditions. Scenarios menus can also use gaze tracking to facilitate user inputs. Axon VR uses stand-alone wireless HMDs with either 3 or 6 DoF. The system is compatible with several wireless HMDs, including the HTC Vive Focus 3, HTC Focus Plus, and the Oculus Go. It does not require external tracking equipment. Users can select whether to use compatible COTS wireless handheld controllers, wrist tracking sensors, and/or simulated TASER conducted energy weapons and Glock-brand pistols available for an additional cost from Axon. While Axon VR does not need to be set up in a dedicated training room, the training space should be at least 100 ft^2 and free of obstructions and obstacles.

Instructors have see-what-I-see capabilities via a tablet computer or screen-casting technology and can control avatars' interactions with the trainee. "Community Engagement" scenarios focus on developing skills in empathy and de-escalation tactics for engaging with individuals in mental health crisis, trauma situations, and peer intervention. "Simulator Training" scenarios allow trainees to practice firearm proficiency on a virtual shooting range as well as to train in use-of-force situations with Tasers or handguns. In Simulator Training scenarios only, trainers and trainees can collaborate in real time from separate locations via Wi-Fi connection. Axon uses a proprietary LMS called Axon Academy to record scenario videos, track trainee progress, and log performance metrics. Axon Academy also houses a library of supplemental e-learning content and training materials designed to strengthen the skills learned in the Community Engagement and Simulator Training scenarios.

Axon estimates that Axon VR would cost an agency wishing to train 150 officers approximately $34,000 per year. Warranty information is available upon request. Axon support representatives are available 24/7 for technical and product-related issues. After hours or on weekends, the after-hours support service can answer generic support questions. Axon's after-hours support service also has the ability to page an Axon support representative in case of emergencies.

3.9 Envision Innovative Solutions, Extended Reality (XR) for Law Enforcement

Envision's XR for Law Enforcement offers a COTS Active Shooter Response Simulator and VR Forensic Crime Scene Simulator modules. Both simulations can be customized to agency specifications if needed. Envision is compatible with Steam VR Oculus, HTC, Valve Index, and any Windows-based MR device. The product's VR controllers feature haptic feedback.

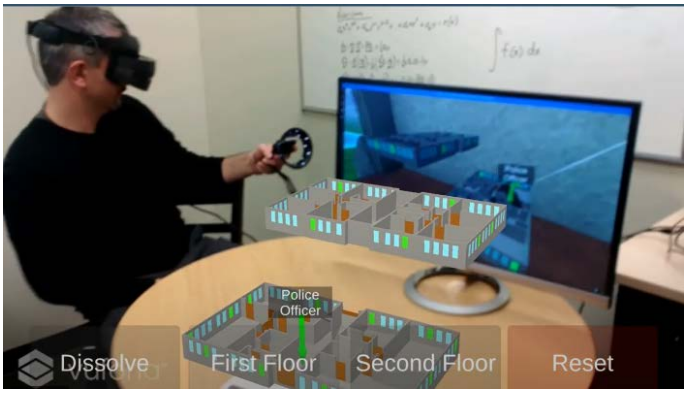

Figure 3-9 XR for Law Enforcement

Image Credit: Envision Innovative Solutions

Envision allows up to 12 trainees to collaborate in its training simulations. The Envision Active Shooter Response Simulator (see Figure 3-9) combines both AR and VR platforms into a single collaborative experience. A VR user would experience the active shooter scenario in first person while an AR user would experience it from a third-person perspective and could communicate with any VR users via audio or text. Upon encountering the active shooter, the VR user is placed in a stop, shoot, or do not shoot situation. The VR Forensic Crime Scene Simulator consists of 10 immersive crime scene environments, ranging from rural to urban, that can be processed at night or during the day. Trainees interact with crime scene tools, victims, and other evidence. Trainees must virtually take crime scene photos as well as collect evidence, place it in the correct containers, process it, and submit the evidence for additional testing. For both the active shooter and VR Crime Scene-Simulator, instructors can monitor trainee performance on a separate monitor. Instructors using the Crime Scene Simulator can produce comprehensive data reports for each trainee's performance and can view the evidence gathered and photographs taken by trainees during the simulation.

Envision comes with a gaming laptop and VR HMD hardware for $2,500. Software licensing, customer support, and technical support cost $200/month per system. Envision extends all third-party hardware warranties to one year. E-mail, phone, and remote support by chat are available Monday through Friday from 8:00 a.m. to 5:00 p.m. Eastern time.

3.10 GOVRED Technology, Apex Officer

Apex Officer is a prepackaged, customizable, COTS VR training system that provides law enforcement and corrections officers with training in conflict de-escalation, active shooter, and tactical operations (see Figure 3-10). Apex Officer is designed to enhance decision-making, critical thinking, and communication skills. Each Apex Officer training simulation starts with background information and case law, and then places the officer into a randomized scenario where those concepts will be exercised. The system uses trainer interaction and machine learning to create a customized, interactive branching logic. Following the simulation, the officer goes through a debriefing session with an instructor or subject matter expert to discuss their decision-making process and room for improvement.

Figure 3-10 Apex Officer

Image Credit: GOVRED Technology

Apex Officer requires a minimum training space of 25 ft^2 and allows a maximum area of 1089 ft^2. Four base stations are used for tracking and to set the dimensions of the scenario. Apex Officer uses the HTC Vive family of HMDs with 6 DoF. The headsets are connected to a backpack-mounted computer worn by each officer, providing freedom of movement around the training space. Trainees can use specially modified inert firearms supplied by Apex or HTC Vive handheld controllers, depending upon the agency's preference. Trainees can interact with digital twins and other tools as well as with other officers and instructor-controlled role players in the scenario. Apex Officer offers a haptic feedback suit and other sensory feedback to enhance the immersive experience for trainees.

Trainers select and can modify the scenarios based upon trainee actions. Up to four officers can collaborate on each scenario. Auxiliary laptops can be used to allow human role-players to enter the scenario as victims, hostages, and subjects. The system also includes AI NPCs, furthering the variety and realism of the scenarios to which trainees respond. The software includes a see-what-I-see feature that enables instructors to give real-time feedback and to adjust the training scenarios as needed. Also, the system includes an internal LMS that allows trainers to track trainee progress and provide feedback. Apex Officer is run from a local workstation and managed from an instructor laptop. Additional content and LMS management are cloud-based, providing organizations with secure access to their training data from any location.

Apex Officer comes in different configurations based upon agency needs, but a two-officer Apex Officer system costs $69,500 and includes a trainer laptop, two trainee backpack laptops with VR HMD, TASER, pistol, rifle, and a universal wand that can serve as a flashlight or other tool. The basic system purchase includes Apex Arsenal VR training accessories, a VR-ready workstation with Windows 10 x64-bit operating system, the Apex haptic feedback suit, Apex wireless tracking technology, Apex Vitals heart rate monitoring system, an instructor/operator laptop and workstation, 1000+ training scenarios, a train-the-trainer course, Apex Officer training and compliance reports, 24/7 customer and technical support, and Apex Officer weekly content library updates. Three software licensing packages are available: the Apex Officer X1 System designed for agencies with 1–49 sworn officers, the Apex Officer X3 System designed for agencies with 50–249 sworn officers, and the Apex Officer X9 System designed for agencies with 250+ sworn officers. Each package includes 100+ training modules, 100,000+ training scenarios, unlimited usage per officer, and 24/7 support and updates.

3.11 InVeris Training Solutions, SURVIVR

SURVIVR is a law-enforcement VR training system, designed to improve officers' communication skills, decision-making ability, adherence to policies and procedures, and situational awareness in a variety of environments and with various virtual suspects and bystanders. The Vive system features both eye tracking and hand tracking technology. SURVIVR uses HTC Vive Pro 2 HMDs with wireless adapters that allow for 6 DoF. The system features firearms with CO_2 powered recoil simulation and less-lethal device simulators that provide realistic functions and feedback to reinforce weapons handling skills. The SURVIVR system also features a haptic vest to simulate events such as rain, collision, and other physical impacts. The SURVIVR system is portable and can be set up in 20 minutes or less.

Figure 3-11 SURVIVR

Image Credit: InVeris Training Solutions

The training area can be as small as 10′ × 10′ as large as 35′ × 35′ or any combination in between. The system only requires controllers during setup. When users set up the VR training space, they can set a standoff distance from physical objects or walls. Then in the VR realm, the user will see an outline or a grid showing the barrier that they cannot cross. Additional features include up to 12 simultaneous weapons/tools per system configuration, a scalable footprint, expanded suspect verbiage and actions, over 180 suspect and bystander avatars, over 40 environments, over 120 drag-and-drop props, shot trajectory metrics, a nuisance generator, a practice shooting range, and a heart rate monitor. Weapons supported include the Glock 17, 19, Sig Sauer P320, S&W M&P 9, 40, SIG M18, Beretta Px4, X26P, X2, AR15/M4, Remington (lethal or less lethal), MK-3 OC Spray, Stinger LED Flashlight, Expandable baton, and a 40 mm Less Lethal Launcher.

The SURVIVR software allows for infinite scenario environments with real-time location, movement, orientation, and bio-sensing. The system is interactive and allows trainees to use their hands for actions from opening doors to handcuffing suspects, with this action reflected in the VR view. Each trainee has a virtual avatar that can interact with up to three additional users with synchronized relative positions. Instructors have a see-what-I-see view of participant action. Furthermore, they can create constantly changing training scenarios and have control over suspect, bystander, and hostage actions. Instructors can dynamically escalate or de-escalate the scenario depending on the trainee's actions.

The after-action review feature also allows instructors to review decision-making skills from any angle. The system includes multiple replay options, including eye tracking and view cones to observe officers' areas of focus. The system does not integrate with LMSs.

InVeris is not on the GSA Schedule. Pricing on individual units consisting of a VR HMD, rifle, pistol, taser, OC spray, and flashlight varies from $37,000 to $50,000. A 12-month warranty is included with the purchase of the system and covers all parts, repairs, or replacements, 24/7 on-call technical support; and technician visits if on-site repairs are needed. All hardware components are COTS and can be replaced by the end-user after the warranty period is over. An extended service agreement for software and updates is $950 per year for the first simulator and $350 for each additional system. Custom extended warranties are also available.

3.12 Street Smarts VR

Street Smarts VR (SSVR) is a prepackaged, portable, and immersive VR tactical and police training system. SSVR features scenarios designed to teach appropriate use-of-force and advanced de-escalation techniques. The system uses HTC Vive Pro wireless HMDs in conjunction with HTC Vive trackers that allow users to transform any duty weapon (including impact weapons and conducted energy weapons) into a VR weapon. Scenarios include active shooter, firearms training, non-lethal weapons training, high-risk entry, active shooter, domestic violence, public disturbance, suicidal subject, mental illness, suspicious subject, traffic stop, and gate entry. New scenarios are released regularly. As a portable solution with 6 DoF, the system requires a training space free of obstacles. The training area is set-up using outside-in tracking towers. The size of the training area can be as compact as 3′ × 3′ or as large as 30′ × 30′.

Figure 3-12 Street Smarts VR

Image Credit: Street Smarts

Two users can train together in a scenario. Instructors use a VR workstation with see-what-I-see functionality and can communicate via voice with trainees in the simulation. Instructors can manipulate scenario types, weapons, and environments; intervene at decision points; and choose to escalate or de-escalate VR subjects' behavior. SSVR also has a review mode that allows scenarios to be replayed from multiple viewing angles and can be used to help assess decision-making skills and actions of trainees. The SSVR software does not integrate with external LMSs; however, the system does have an internal database tool that can track users' performance throughout the life of the system.

The system ships with a Dell Precision 5820 Tower and a folding 24″ USB-C Monitor packed inside a 33″ Pelican 1615 Air hard-sided case. Available accessories include inert M4, Glock17, Glock 19, M17, M18, OC, Taser 7, Taser X26P, Baton, or Flashlight. SSVR also offers the FlexForce Drone Buster as an additional option. SSVR provides four hours of on-site training on setup, operation, and troubleshooting for the users. This covers all aspects of operation from unboxing the system to running trainers through how to use the trainee database for tracking analytics. The system includes how-to guides (available in both print and video formats) for refresher courses.

The basic system includes the standard hardware warranties from the headset manufacturer, either HTC or Dell. Extended warranty support services are available to purchase for 3-and 5-year terms. The warranty covers all components and services and includes three software/content updates per year for the term of the agreement. The 3-year plan includes hardware and software support as well as three accessories with the option to include additional accessories if needed. No hardware refresh is included. The 5-year extended warranty plan includes hardware and software support as well as five accessories and a mid-term hardware refresh. Pricing information is available upon request.

3.13 V-Armed, V-Armed

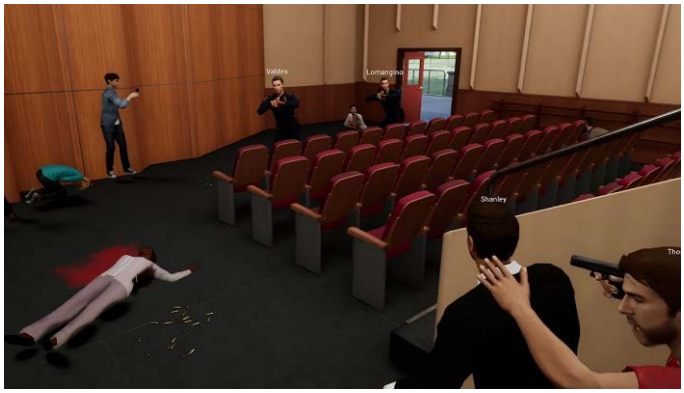

Figure 3-13 V-Armed

Image Credit: V-Armed

V-Armed is a VR tactical training system for police agencies. The system allows trainees to participate in free-roaming scenarios fully equipped with tactical gear, less-lethal weapons, and firearms. The V-Armed system allows trainees to wear VR HMDs wired to backpack-mounted computers, allowing 6 DoF. The V-Armed system was developed using both live action motion capture and animation. V-Armed uses wireless sensors strapped to the trainees' wrists and ankles to create a full-body tracking system. The system tracks the trainees' real-life movements on the floor and replicates them in the virtual world through their avatars. The scale of training environments can be altered to fit the agency's needs, from 30′ × 30′ to 200′ × 200′. The company's platform also features directional spatial audio and sound effects as well as AI NPC shooters and civilians that respond to trainee actions.

Trainees—up to 10 at a time--can see each other in the virtual world and communicate with body gestures or verbal commands. Instructors have see-what-I-see capability and can communicate via audio with trainees. Training scenarios can be modified for weather, lighting conditions, and other parameters. For example, AI NPC characters can be programmed to take various general actions, including hiding, filming with mobile phones, or being aggressive or compliant. V-Armed offers a scenario creator and editor software that allows trainers to independently create an unlimited number of scenarios. The after-action review system allows trainers to evaluate scenario performance from any visual perspective within the session. The platform tracks data such as a trainee's reaction time, shots fired with their trajectories, first aid application, muzzle discipline, and biometric measurements.

V-Armed offers a drag-and-drop shared asset library of 3D modeling and animations. The company's weapon and prop trackers can be placed on Airsoft guns or company supplied facsimile weapons. The weapon and prop tracking system offers less-lethal force options, including handguns, long guns, conducted-energy weapons, OC spray, batons, flashlights, multi-tools, beanbag launchers, and radios. The system can also track physical props like doors, windows, and furniture.

Warranty, support, and pricing information are available upon request.

3.14 Vizitech USA, VR Forensics and VR Active Shooter

The Vizitech USA VR system is a COTS training system that has two law enforcement modules. The VR Forensics learning system teaches the fundamentals of crime scene investigation (Figure 3-14) and the VR Active Shooter focuses on the response and management of active shooter incidents. Vizitech uses the computer-connected HTC Vive Pro VR HMD in both training solutions.

Figure 3-14 VR Forensics

Image Credit: Vizitech USA

VR Forensics allows trainees to process virtual crime scenes and allows an instructor to evaluate or guide their training experience. VR Forensics features nine crime scenes with 36 different scenarios and two modules: the Evidence Collection Module and the Blood Splatter Analysis Module. Trainees use controllers to interact with crime scene equipment (like cameras and swabs) and collect evidence. Trainees can process the crime scene individually or as a team.

The VR Active Shooter features four scenes – a courthouse, a large residence, a large store, and a school – where the training scenarios play out. The Vizitech active shooter scenarios focus on managing the chaos of an active shooter scene. Trainees can interact with and talk to AI NPCs that populate the scenarios. The AI NPCs have different personalities and behaviors that change based upon the level and tone of interaction with the trainees. Trainees can collaborate on entry, incident command, and communication aspects of the active shooter response. Trainees participating as incident command can view virtual body camera footage from the trainees making entry into the active shooter scene.

The VR Forensics training system comes with all necessary VR hardware and a VR laptop computer with VR Forensics software installed. The system costs $9,995 and includes software and technical support for one year. Pricing, included hardware, user training, service and warranty information about the VR Active Shooter training system must be requested from the manufacturer.

3.15 WRAP Technologies, WRAP Reality

WRAP Reality is a portable VR training system focused on rapid decision-making skills and creating the appropriate muscle memory for law enforcement officers to make appropriate tactical responses, including the use of the BolaWrap restraint. The BolaWrap is a remote restraint device for police to restrain non-complaint individuals, which is also made by the company WRAP Technologies. Life-like scenarios in WRAP Reality allow trainees to advance their skills in de-escalation, conflict resolution, process and procedure, and use of force.

Figure 3-15 WRAP Reality

Image Credit: WRAP Technologies

WRAP Reality has a library of over 40 pre-scripted training modules and an ADAPT module that allows instructors to customize the training to meet the needs of their trainees. The WRAP Reality uses an HTC VIVE Pro VR HMD which allows 6 DoF but requires a cable connecting it to a computer. WRAP Reality features customized controllers that are modeled to replicate all of the essential tools that an officer needs, including rifles, shotguns, pistols, Tasers, OC spray, and BolaWrap. WRAP Reality requires a minimum of 400 ft^2 (20' x 20') of training space.

WRAP Reality allows an instructor to guide and modify scenarios but does not support multiuser collaboration. The training system features an after-action rewind function that allows trainers and trainees to replay the audio and video from each session to review shot placement, trajectory, and accuracy from any angle or vantage point.

Pricing, training, customer service, and warranty information is available upon request.

3.16 Refense AG, Refense

Refense is a facility-installed, turnkey VR paramedic and police tactical training system that is customized to meet an agency's training needs (see Figure 3-16). Refense installs the system and provides all the equipment, hardware, and software to start training. Refense scenarios include active shooter, hostage, close quarters battle, negotiation, mass casualty, and counterterrorism. The Refense VR training system uses VR equipment on a modular training platform controlled from an instructor panel. The platform has tracking cameras mounted on a stage truss surrounding the platform. Trainees are fitted with Refense's specially designed VR equipment, which includes a VR HMD with 6 DoF (currently a wireless Wi-Fi 6E streaming HTC Focus 3) and tracking sensors for the hands and feet. Objects are tracked with high accuracy (0.03 inch), which allows trainees and objects to be precisely positioned in the VR environment. The training platform requires a dedicated space of between 1,425 ft^2 and 4,975 ft^2.

Figure 3-16 Refense

Image Credit: Refense AG

Refense allows trainees to use tactical gear, tools, stethoscopes, weapons, pepper spray, less-lethal weapons, and batons in scenarios. Up to 16 participants can participate in a training scenario simultaneously. Trainees appear as avatars within the scenario on their HMD. The instructor panel can control a wide range of training scenarios. Refense features AI NPCs that can be autonomous or controlled by instructors. The instructor panel records all training movements; Refense can also record the vital signs of the trainees during the scenarios. The instructor panel offers an after-action review feature to evaluate training that can be viewed from the perspective of the trainees, from a bird's-eye view, and from other viewing angles. Refense can customize and design new scenarios. Refense allows users to test Scenario Designer, which allows instructors/agencies to build and equip their own training scenarios.

To improve the feeling of immersion, Refense offers haptic feedback to include pain (to replicate hits or injuries from weapons or hazards), heat, and scent. Refense can also add wind feedback to better simulate outdoor environments. Weapon ballistics and fired round trajectories are part of the simulation logic. Walls, furniture, props, and other virtual objects are configured to accurately mimic bullet penetration.

Refense trains at least two instructors before delivering the finished product. Instructors are trained in using the system and how to fix the most common issues. Refense also offers refresher and certification courses. Refense offers customer service and technical support via telephone, email, and online. Refense can also provide an on-site engineer to troubleshoot and resolve any other issues. Support and service agreements are negotiated to meet agency needs. The standard warranty is one year but can be extended based on agency needs. Pricing for the Refense system is available upon request.

3.17 Augmented Training Systems, HERO Training Platform

The Augmented Training Systems (ATS) HERO Training Platform is an EMS focused VR simulator. The ATS HERO Training Platform can deliver pre-packaged COTS scenarios that can also be customized, for ambulance buses (AMBUS) and mass casualty incident (MCI) triage training using Simple Triage And Rapid Treatment (START) and Sort, Assess, Lifesaving Interventions, Treatment/Transport (SALT) triage methodologies. The system uses branching logic to guide the training and are developed using actual medical data. The HERO training platform allows for the creation of additional scenarios and updated content by the user and/or ATS. The system uses the Oculus Quest 2 VR HMD, which allows 6 DoF, and is fully portable. ATS advised that the system is designed to be used in a training area the size of a small emergency department room but did not provide exact dimensions.

Figure 3-17 HERO's MCI Triage Training

Image Credit: Augmented Training Systems

The HERO training platform can support 100 users playing simultaneously, in groups of four to five people per room. The Oculus Quest 2 device creates a room grid that allows users to move around the room safely to prevent falls and collisions. There are three movement modes for the trainee: seated mode, smooth locomotion, and teleportation. ATS recommends that controllers be used for navigation. Users can interact with staff, victims, triage kits, and medical equipment. An instructor guides the training. Trainers can access the playback feature to review user experiences. The ATS web portal provides access to training, analytics, and application management. The Microsoft Azure cloud-based ATS HERO dashboard displays trainee performance, key performance indicators (KPIs), and other user metrics. ATS HERO is compliant with information security standards. The ATS HERO application can be integrated with most LMS systems.

The Oculus Quest 2 controllers have haptic sensors that are used to simulate heartbeat, breathing, and more. Trauma graphics are embedded in realistic 3D avatars, such as bullet wounds, fractures, and bleeding. Varying weather conditions can be simulated, including storms, flooding, fires, and minimal visibility. Smells can be deployed to simulate gun smoke, diesel, or other relevant scents that can make the environment seem more realistic. Sounds can be inserted into each environment to mimic real-life situations.

The ATS HERO platform uses the Oculus Quest 2 Immersive All-In-One VR Headset, which is purchased separately at a cost of $399. The ATS HERO software requires access to the Meta Store. An annual subscription for training and access to the HERO platform is based upon the number of users; it ranges from $20,000/year for up to 200 users to $50,000/year for up to 1,000 users. The cost of customized training varies based upon the training complexity and ranges from $40,000 for low complexity to $200,000 for highly complex training development. ATS provides a 12-month warranty (when operated according to the documentation and other instructions) for their software. ATS HERO provides technical support and training setup. Customer service and support for software is provided during the contract period. Information on customer service hours was not provided.

3.18 Health Scholars, Emergency Care Training Suite

The Health Scholars VR Emergency Care Training Suite has several modules including Advanced Cardiac Life Support (ACLS), VR Pediatric Emergency Care, Pediatric Emergency Assessment, and Stroke Assessment training simulations. The ACLS and Pediatric Emergency Care applications are designed for both first responders and hospital personnel. The Health Scholars VR Emergency Care Training Suite is fully portable, requiring a minimum area of 6′ × 6′, and a stand-alone Oculus Quest 2 or Pico Neo 3 VR HMD connected to Wi-Fi. Trainees have 6 DoF to interact with virtual patients to conduct assessment and administer care. Health Scholars uses voice-directed technology to allow trainees to interact with their virtual team and patients by speaking, removing the need for haptic feedback or controllers.

Figure 3-18 ACLS VR

Image Credit: Health Scholars

From putting on the headset to debriefing, the training averages about 30 minutes per scenario. The training is focused on individual skills in directing emergency care scenarios and requires a facilitator to participate in the training. Health Scholars offers instructors a see-what-I-see review through screen casting, allowing them to monitor progress and guide trainees through the scenario if necessary. The application also provides learners with a readiness score, determined by assessing core competencies throughout the simulation and micro-debriefs to reinforce learning gains.

The ACLS VR learning objectives include identifying and managing non-cardiac arrest stable and unstable rhythms and situational awareness and management of cardiac arrest rhythms. The ACLS VR simulation provides randomized case presentations. Paramedics can use the ACLS VR training as a pre-learning application before physical simulation or to validate and refresh competencies required to identify and manage patients exhibiting the ACLS core rhythms in stable and unstable conditions. The simulation can also reinforce team dynamics, such as addressing team members by name and making eye contact, maintain situational awareness of team member fatigue and performance of tasks, and use of closed loop communications. The ACLS VR simulation was designed in accordance with the International Liaison Committee on Resuscitation's *Consensus on Science with Treatment Recommendations* (CoSTR) and nationally recognized resuscitation council guidelines.

The Pediatric Emergency Assessment VR training is designed for emergency medical technicians, paramedics, nurses, and clinicians to form impressions of pediatric patients based on the Pediatric Assessment Triangle (PAT): Appearance, Circulation to Skin, and Work of Breathing. (PAT is integral to pediatric care and has become a cornerstone for hospital pediatric pathways.) The Pediatric Emergency Care VR training provides a series of high-risk and high-pressure scenarios involving critically-ill infants and toddlers using the PAT. The training focuses on recognizing the subtle indicators of severe illness in infants and children without delay and initiating stabilization or resuscitation when indicated.

Pricing for the Health Scholars VR Emergency Care Training Suite varies. Health Scholars offers the VR Emergency Care Suite as an unlimited learner and unlimited user model based upon the hospital or agency size. Hardware warranties are through the VR HMD manufacturer. Health Scholars provides software updates and customer support via follow-up to voicemail and email. Hours of customer support were not provided.

3.19 Real Response, Blue Room

Blue Room is designed to enable aeromedical responders to conduct VR training in virtual aircraft. The Blue Room is a mixed reality (MR) simulator that features a chroma key (the use of green or blue screens to layer two video streams together), a room set (see Figure 3-19), an interactive mannequin, and a Varjo XR-3 MR HMD that has video pass-through, hand tracking, and eye tracking capabilities. Unlike VR, where controllers are required to interact with the digital world, MR allows users to enter the virtual world as themselves, and to practice their skills physically just as they would in the real world. Trainee biometrics from an integrated Garmin watch provides data on users' heart rate, stress levels, and oxygen level saturation.

Figure 3-19 Blue Room

Image Credit: Real Response

The Blue Room allows the training facilitator to use a mission control center to adjust scenarios in real-time. Blue Room MR Tactical Combat Casualty Care (TCCC) – including Direct Threat Care, Indirect Threat Care, and Evacuation Care training – enables students to follow the three stages of TCCC, make decisions, and use fine motor skills to complete the process. The Blue Room MR system requires at least 32 ft^2 of space and, though portable, requires one or two days to set up. Alternatively, Blue Room can be set up and delivered as a training suite inside of a 20-foot shipping container.

The system includes all software customization, hardware, support, training, and travel to support deployment. Pricing data is available upon request. Costs agreed upon will not vary unless the customer changes the scope of the project. Real Response provides user training, user manuals, video tutorials, and online support. Instructor training includes live training sessions for facilitators, online training sessions, manuals, videos, and online support. Real Response provides a 2-year warranty, which includes support for the 2-year term.

3.20 Real Response, VTC3

VTC3 or Virtual Tactical Combat Casualty Care (TCCC) is a COTS VR training solution that provides an immersive environment for medics to refine their combat casualty care. VTC3 supports multiple stand-alone VR HMDs with 6 DoF for freedom of movement; virtual walls in the scenarios ensure that trainees do not walk into real-world objects. The training system also uses a Garmin watch to collect trainee biometric data; including heart rate, heart rate variability, peripheral oxygen saturation, stress, and respiration. VTC3 uses this biometric data to adjust difficulty levels while avoiding overstressing trainees to provide immersive and realistic training. Real Response provides a range of virtual scenarios, from routine medical care to combat casualties to challenge medics. Real response can customize the VTC3 scenarios as needed.

Figure 3-20 VTC3

Image Credit: Real Response

The training system is completely portable: VTC3 takes approximately five minutes to set up and requires at least 10 ft^2 of space. Multiple users can collaborate in VTC3. Instructors have see-what-I-see functionality and the option to participate in scenarios. The maximum number of simultaneous participants depends upon the VR HMD used. The VTC3 system integrates with LMSs and can collect trainee's performance and their biometric data during the scenario.

VTC3 system licensing, which includes software, hardware, support, training, and travel to support deployment, typically costs $50,000 per year, plus additional fees for customization. VTC3 is NDAA Section 899 compliant but is not available on the GSA Schedule. Costs agreed upon will not vary unless the customer changes the scope of the project. Real Response provides user training, user manuals, video tutorials, and online support. Instructor training includes live training sessions for facilitators, online training sessions, manuals, videos, and online support. Real Response provides a 2-year warranty, which includes support throughout the 2-year term.

3.21 SimX, SimX VR

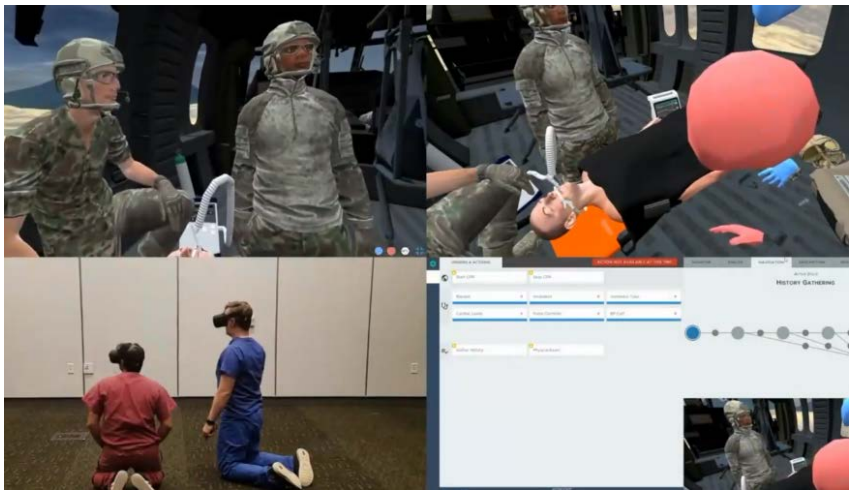

Figure 3-21 SimX VR

Image Credit: SimX

The SimX VR EMS training scenarios include anaphylaxis, middle cerebral artery stroke, advanced trauma life support, overdose on a tricyclic antidepressant, inferior ST-elevated myocardial infarction, shortness of breath, and many others. SimX VR offers over 165 patient scenarios (not including military scenarios), over 30 treatment environments (e.g., homes, hospital, woods, clinics), and over 300 tools and procedures, including fully functioning medical equipment like anesthesia machines, bronchoscopes, and transvenous pacemakers. The platform works with wirelessly tethered headsets for 6 DoF and controllers from HTC or Oculus (Pico in Europe) and may be compatible with other HMDs with manufacturer support. The SimX VR requires a minimum of 10′ × x 10′ training space and can accommodate up to a 25′ × 25′ area when using an Oculus Quest headset. The system is portable and designed to set up in around five minutes.

Training scenarios can support an unlimited number of users, but SimX typically limits them to a maximum of five practitioners to replicate the maximum number of people who can realistically attend to a patient at one time. The SimX VR customizable case system is based on the Society for Academic Emergency Medicine's open-source case model; it allows for the construction of cases with interdependent states, enabling instructors to create endless combinations of patient scenarios, environments, tools, and critical actions. SimX features haptic feedback, enabling trainees to feel pulses or receive tactile feedback when they push a button on a machine. SimX VR also incorporates the psycho-social aspects of case management, requiring trainees to calm patients or deal with distraught family members.

Training scenarios allow for multi-user interaction and instructor monitoring. Users interact naturally with simulated patients, having conversations, and picking up and using VR tools like stethoscopes, bandages, and blood pressure cuffs as they normally would. SimX uses proprietary technology to synchronize user proximity, allowing trainees to touch hands in the VR world and have that touch replicated in the real world. Moderators have see-what-I-see capability and can modify scenarios as needed. SimX has a built-in assessment and reports tool that allows for trainee performance reviews and progress tracking. SimX does not natively interact with LMSs, however, the company can build that capability for a cost.

The recommended computer system specifications for running a typical scenario include an Intel Core i7-2300 or AMD FX-4350 processor, 8 GB of RAM, Nvidia GeForce GTX 3060 graphics card, DirectX 11, and 12 GB of available storage space. SimX does not manufacture hardware, but they can supply HMDs if requested. When used with the HTC Focus headset, the system is compliant with Section 899 of the NDAA.

SimX charges companies per device rather than per user. Licensing for two headsets is approximately $8,500 per year. A common license option is 6–8 headsets per site. Each licensee gets access to 15 scenarios of their choice. Additional scenarios are available à la carte at additional cost. In addition to number of headsets and any additional scenarios, a large variety of options can affect the price. For example, SimX offers a revenue sharing model, whereby institutions who fund the development of a custom case scenario receive credits when other institutions buy the same scenario they funded. These credits can then be used to download additional training scenarios from SimX. For licensed clients, SimX includes onboarding and training, a training refresher every six months, and technical support from 9 a.m. to 5 p.m. Pacific time.

4.0 MANUFACTURER CONTACT INFORMATION

Additional information on the VR training systems for first responders included in this market survey report can be obtained from the manufacturers listed in Table 4-1.

Table 4-1 Manufacturer Contact Information

Manufacturer	Website	Address	Phone Number	Email Address/Web Form
Augmented Training System (ATS)	www.augmentedtrainingsystems.com	383 Seneca Dr. Austin, TX 78737	512-348-5999	contact@atsvr.com
Avatar Partners	www.avatarpartners.com	19700 Fairchild Road, Ste 265 Irvine, CA 92612-2520	714-959-0573	info@avatarpartners.com
Axon Enterprise, Inc.	www.axon.com/training/vr	17800 N 85th St. Scottsdale, AZ 85255	800-978-2737	customerservice@axon.com
Envision	envision-is.com/xr-law-enforcement	4814 Outlook Drive, Wall Township, NJ 07753	732-722-7435	info@envision-is.com
FAAC	www.faac.com/simulation-training/public-safety/pump-operator-training	1229 Oak Valley Dr, Ann Arbor, MI 48108	734-761-5836	www.faac.com/contact
FLAIM Systems	www.flaimsystems.com/products/trainer	ManuFutures Building NP 75, Pigdons Road, Waurn Ponds, VIC 3216 Australia	+61 3 8657 3350	flaimsystems.com/contact
GOVRED Technology	www.apexofficer.com	5006 Bond St. Las Vegas, NV 89118	702-901-5344	support@apexofficer.com
Health Scholars	www.healthscholars.com	7403 Church Ranch Blvd, Unit 110, Westminster, CO 80021	720-741-8129	info@healthscholars.com

Manufacturer	Website	Address	Phone Number	Email Address/Web Form
InVeris Training Solutions	inveristraining.com	296 Brogdon Rd. Suwanee, GA 30024	800-813-9046	its-marketing@inveristraining.com
NextGen Interactions	nextgeninteractions.com	3701 Rolston Dr. Raleigh, NC 27609	408-348-1834	hazvr@nexgeninteractions.com
Pixo VR	www.pixovr.com/vr-training-categories	2838 Coolidge Hwy, Suite 112, Berkley, MI 48072	248-996-8298	pixovr.com/contact
Real Response Pty Ltd	www.realresponse.com.au	117 Wellington Street, St Kilda, Victoria, 3182. Australia	1300 744 980	www.realresponse.com.au/contact-us
RiVR	rivrlink.co.uk	Unit 6E, Southfield Road, Kineton Road Industrial Estate, Southam, Warwickshire, CV47 0FB United Kingdom	+ 44 0 1926 800 740	info@rivr.uk
Refense AG	www.refense.com	Kantonsstrasse 25, 8807 Freienbach, Switzerland	+41 44 497 16 00	info@refense.com
RE-liON	www.re-lion.com	Vliegveldstraat 100, B517, 7524 PK Enschede The Netherlands	+31-85-7430290	re-lion.com/fireservices
SimX VR	www.simxvr.com	521 Del Medio Ave, #101, Mountain View, CA 94040	650-761-4809	www.simxvr.com/get-started/
Street Smarts VR	www.streetsmartsvr.com	44 Wall Street, Suite. 702 New York, NY 10005	413-438-7787	info@streetsmarts.com

Manufacturer	Website	Address	Phone Number	Email Address/Web Form
V-Armed	www.v-armed.com/	630 Flushing Ave, 3rd Floor, Brooklyn, NY 11206	212-595-0400	contact@v-armed.com
Vizitech USA	www.vizitechusa.com	103 East Sumter Street, Eatonton, GA 31024	706-749-8099	csr@vizitechusa.com
WRAP Technologies	www.wrap.com	1817 West 4th Street, Tempe, AZ 85281	800-583-2652	support@wrap.com

5.0 CONCLUSIONS

Emergency response agencies use VR training systems to train responders in routine, dangerous, or uncommon situations in a realistic, safe, and cost-effective manner. VR training systems for first responders require both hardware and software. The hardware includes VR head-mounted displays, and possibly a separate computer system, controllers, beacons, and accessories. VR software integrates the hardware and accessories with training scenarios to produce virtual training content. VR training systems for first responders can be COTS training products or custom-built training products. Most companies that produce COTS training products also customize their training products and produce customized training. This report features both COTS training systems and customizable COTS products.

VR training software can provide first responders with the ability to learn and practice skills in an immersive, interactive, and risk-free environment. The VR training experience should also be cost and time effective, scalable, easily accessible, varied, customizable, and used to improve and record performance. This market survey report identified 21 products from 20 developers that are COTS or, customizable COTS VR training products for first responders. While some of the COTS products can be customized to meet an agency's training needs, specialized or agency-specific training may need to be custom-built. COTS training products may allow an agency to evaluate how VR training fits into their training plan in terms of effectiveness, acceptance, cost, and deployment at a lower cost than custom applications. The prices of the VR training systems vary widely based upon quantity and type of hardware included, software licensing, number of users, number of scenarios included, and customization.

The products described in this report provide a wide variety of training scenarios for fire, police, and emergency medical services. The most advanced systems have features like gaze tracking, user heartrate monitoring, artificial intelligence control of interactive characters within scenarios, or the use of advanced feedback like heat suits or electrostatic shock to simulate physical sensations. The choice of a particular training product may depend on many factors, including the training needs of the agency, budget, available training space, and the level of the agency's in-house technical expertise.

The purpose of this market survey is to provide emergency responders with information that will guide emergency response agencies in making operational and procurement decisions. Emergency responder agencies should consider overall capabilities, technical specifications, and limitations of VR training systems in relation to their agency's operational needs when making equipment selections. Performance of these products and information included in this report has not been independently verified by the SAVER program. Agencies should also consider impacts associated with integrating equipment into their power and information technology infrastructure, data management, concept of operations, and required maintenance.

Appendix A. VIRTUAL REALITY STANDARDS

1. ISO/IEC 18038:2020, *Information Technology – Computer Graphics, Image Processing and Environmental Representation – Sensor Representation in Mixed and Augmented Reality* [10]

   This document defines the framework and information reference model for representing sensor-based 3D mixed-reality worlds. It defines concepts, an information model, architecture, system functions, and how to integrate 3D virtual worlds and physical sensors to provide mixed-reality applications with physical sensor interfaces. It defines an exchange format necessary for transferring and storing data between physical sensor-based mixed-reality applications.

   This document specifies the following functionalities:
   a) Representation of physical sensors in a 3D scene
   b) Definition of physical sensors in a 3D scene
   c) Representation of functionalities of each physical sensor in a 3D scene
   d) Representation of physical properties of each physical sensor in a 3D scene
   e) Management of physical sensors in a 3D scene
   f) Interface with physical sensor information in a 3D scene

2. ISO/IEC TR 23843:2020, *Information technology for learning, education, and training — Catalogue model for virtual, augmented, and mixed reality content* [11]

   This document describes how to search for virtual reality (VR), augmented reality (AR), and mixed reality (MR) content through a curriculum catalogue based on curriculum and achievement standards information.

3. ISO/TS 9241-430:2021, *Ergonomics of human-system interaction — Part 430: Recommendations for the design of non-touch gestural input for the reduction of biomechanical stress* [12]

   This document provides guidance on the design, selection, and optimization of non-contacting hand and arm gestures for human-computer interaction. It addresses the assessment of usability and fatigue associated with different gesture set designs and provides recommendations for approaches to evaluating the design and selection of gestures. This document also provides guidance on the documentation of the process for selecting gesture sets.

   This document applies to gestures expressed by humans. It does not consider the technology for detecting gestures or the system response when interpreting a gesture. Non-contacting hand gestures can be used for input in a variety of settings, including the workplace or in public settings and when using fixed screens, mobile, virtual reality, augmented reality, or mixed-mode reality devices.

4. ISO/IEC 23488:2022, *Information technology - Computer graphics, image processing, and environment data representation - Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)* [13]

   This document specifies an image-based representation model that represents target objects/environments using a set of images and optionally the underlying 3D model for accurate and efficient objects/environments representation at an arbitrary viewpoint. It is applicable to a wide range of graphic, virtual reality, and mixed reality applications which require the method of representing a scene with various objects and environments.

5. ISO/IEC TS 23884:2021, *Information technology — Computer graphics, image processing, and environmental data representation — Material property and parameter representation for model-based haptic simulation of objects in virtual, mixed, and augmented reality (VR/MAR)* [14]

   This document specifies physical and material parameters of virtual or real objects expressed to support comprehensive haptic rendering methods, such as stiffness, friction, and micro-textures. It supplements other standards that describe scene or content description and information models for virtual and mixed reality, such as ISO/IEC 19775 and ISO/IEC 3721-1.

   Finally, the standard supports reuse and repurposing of existing (learning) content in "mixed" experiences that combine real-world guidance with traditional media such as instructional video material or existing web applications and widgets.

6. ANSI/CA/UL UL8400, *the Standard for Virtual Reality, Augmented Reality, and Mixed Reality Technology Equipment* [15]

   This is a standard for the "safety of electrical and electronic equipment within the field of virtual reality, augmented reality, and mixed reality technologies." In addition to general product safety requirements, it also includes requirements related to see-through visual functions, flicker, skin compatibility, exposure of the eyes to thermal energy, biomechanical stress, mechanical robustness, enhancing spatial perception, safety and warning instructions, and functional safety.

7. Consumer Technology Association (CTA), CTA-2069-A, *Definitions and Characteristics of Augmented and Virtual Reality Technologies* [16]

8. *ANSI/CTA-2085, Definitions and Characteristics for VR Video and VR Images* [17]

   This document defines the definitions and characteristics for VR Video and VR Images, which are still or moving imagery captured and formatted explicitly as separate left and right eye images, usually intended for display in a VR headset.

9. ANSI/CTA-2087, Recommendations and Best Practices for Connection and Use of Accessories for XR Technologies [18]

   This document explores XR hardware accessories and their connections. The goal is to agree on common terminology and definitions for XR hardware accessories on a common connectivity standard, including device compatibility.

10. CTA-2013, *Best Practices for Diversity in XR* [19]

    This standard will establish a list of criteria that will provide considerations for the XR industry to build an ecosystem of content, hardware, and software to advance diversity and inclusion.

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