# Military Equipment Framework

***Synthetic Training Environment***

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# Executive Summary

The Synthetic Training Environment (STE) is the Army's next generation collective training system. The Military Equipment (ME) Framework defines a lexicon and establishes relationships that will allow STE capability developers, materiel developers and stakeholders to describe, understand, and communicate the STE Vision, concept of operations, capabilities, design, system requirements, and potential technologies that can provide a solution. The framework and lexicon will remove barriers to communication by converging stakeholders on a common viewpoint and eliminating jargon.

The Milgram Virtuality Continuum was adapted for application to the ME Framework. This adaptation replaces the phrase Real Environment with the phrase Live Environment and the phrase Virtual Environment with the phrase Synthetic Environment. The ME Framework includes environment, equipment, and immersion components. The framework extends the discussion to identify potential STE user interfaces for fully immersed, immersed, and semi-immersed experiences.

The report concludes with vignettes that describe a vision for how a Soldier could interact with the STE and describe what the Solider could experience during a collective training event.

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# Synthetic Training Environment Overview

The Synthetic Training Environment (STE) is the Army's next generation, collective training capability. Soldiers and Leaders will access the STE to plan, prepare, execute, and assess collective training events. The STE will stream training to the Point of Need (PoN) using Department of Defense (DoD)-provided infrastructure. The PoN includes Home Station, Combat Training Centers, Armories, Regional Training Centers, Reserve Centers, deployed locations, and Training and Doctrine Command (TRADOC) Institutions. The STE will provide training design and management, training simulation, mission command collective training, and synthetic collective trainer capabilities.

The STE is a new capability that provides a single synthetic environment that will converge elements of the existing Integrated Training Environment (ITE). The STE will use commercial off the shelf (COTS), government off the shelf (GOTS), and newly developed hardware. The approach anticipates maintaining concurrency with current and emerging operational capability sets in software. This approach will be less expensive and more responsive than maintaining concurrency in hardware.[1] This will impact how the Soldier trains in the STE.

Prior to describing the Military Equipment (ME) Framework, it is essential to understand live and synthetic training. The definitions for these terms are below:

- **Live Training:** "Training executed in field conditions using tactical equipment (involves real people operating real systems)." [1, p. 40]
- **Synthetic Training:** Training executed in the synthetic environment using computer generated, simulated military equipment (SME) (involves real people operating SME) and/or virtual military equipment (VME) (involves real people and virtual humans operating VME).[2]

Collective training in the live environment includes training events that occur at Combat Training Centers (CTC), at Home Station (e.g., ranges, training areas, etc.), and at deployed locations. In the context of the STE, the synthetic training environment will bi-directionally communicate with the live training environment. Bi-directional communications allow instrumented soldiers and platforms, mission command information systems (MCIS), and the STE to stimulate each other. The ME Framework can also apply to individual training however, the focus of this paper is on collective training.

# Why is the Military Equipment Framework Needed?

The ME Framework defines a lexicon and establishes relationships that will allow STE capability developers, materiel developers and stakeholders to describe, understand, and communicate the STE vision, concept of operations (CONOPS), capabilities, design, system requirements, and potential technologies that can provide a solution. The framework and lexicon will remove barriers to communication by converging stakeholders on a common viewpoint and

[1] Concurrency is a proponent defined change to upgrade/modify a fielded TADSS for the purpose of ensuring it accurately reflects the performance and/or physical appearance of the Army equipment it simulates, or to support a new training requirement. This is typically in response to an upgrade/modification to the base Army equipment or a doctrinal change. The proponent funds TADSS concurrency modifications and upgrades with RDA funding. The proponent may be either the tactical platform Project Manager for system specific TADSS upgrades to non-system TADSS driven by changes to the tactical platform, or DCS, G–3/5/7 (DAMO–TRS) for upgrades/modifications to non-system TADSS driven by changes in Army tactics, techniques, or procedures. [27]

[2] Derived from the AR 350-38 definitions for gaming, constructive and virtual training.

eliminating jargon. This is critical to clearly articulating capabilities, concepts, and requirements. Effective communications using a common framework can broaden understanding, reduce cycle time, and enable development of solutions that meet the Warfighter's needs and expectations. Ultimately, this can help reduce the cost of the system acquisition.

# Milgram's Virtuality Continuum

Figure 1 is Milgram's simplified representation of the Virtuality Continuum. Milgram's Virtuality Continuum is a scale of the levels of mixed-reality a Soldier can experience. The continuum is defined as,

> *"… a continuous scale ranging between the completely virtual, a virtuality, and the completely real, reality … the area between the two extremes, where both the real and the virtual are mixed, is the so-called mixed reality."* [2]

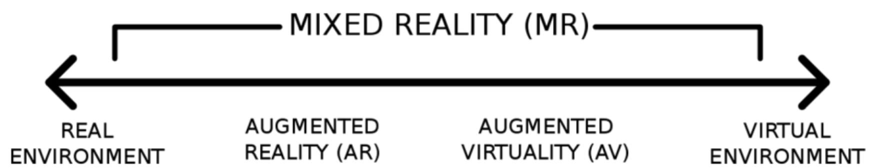


**Figure 1. Milgram's Simplified Representation of the Virtuality Continuum.**

The Milgram Virtuality Continuum was adapted for application to the ME Framework. This adaptation replaces the phrase, "Real Environment," with the phrase, "Live Environment," and the phrase, "Virtual Environment," with the phrase, "Synthetic Environment."

# Military Equipment Framework

Figure 2 depicts the ME Framework that includes environment, equipment, and the immersion components.

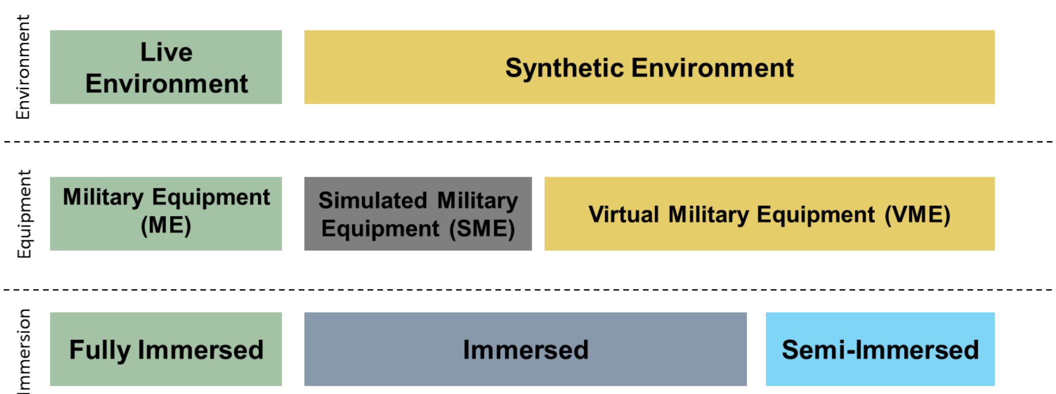


**Figure 2. STE Military Equipment Framework.**

## Environment Component

The environment component of the ME Framework consists of the Live Environment and the Synthetic Environment (see Figure 3). Augmented Reality (AR) and Augmented Virtuality (AV) technologies can bridge the Live and Synthetic Environments enabling Soldiers in these environments to see aspects of the other environment.

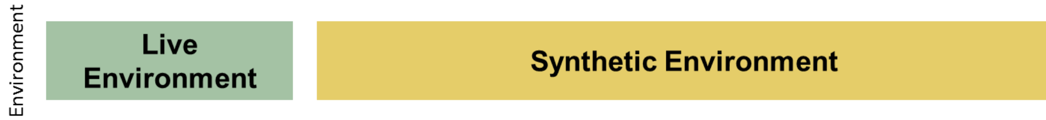


**Figure 3. Environment Component.**

AR technologies allow the Synthetic Environment to augment the Live Environment (see Figure 4). AR technologies allow a Soldier training in the Live Environment to receive output from the Synthetic Environment. This includes both synthetic objects (e.g., computer generated forces) and their effects (e.g., damage). AV technologies allow the Live Environment (instrumented live objects) to augment the Synthetic Environment (see Figure 4). AV technologies allow a Soldier training in the Synthetic Environment to experience Live Environment objects and their effects. These technologies can reduce fair fight issues since each environment can experience aspects of the other environment.

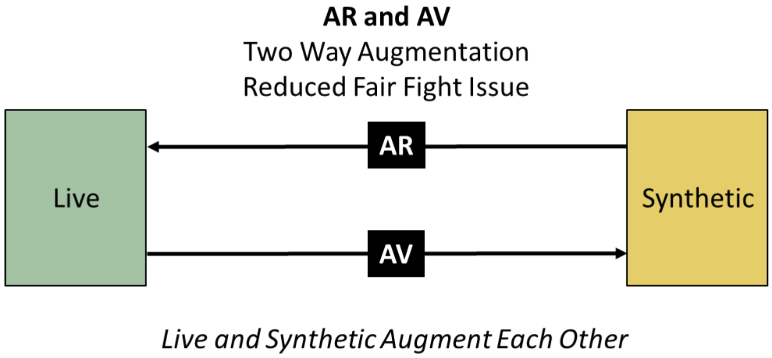


**Figure 4. Live and Synthetic Environment Augmentation.**

## Equipment Component

The equipment component of the ME framework includes military equipment (ME), simulated military equipment (SME), and virtual military equipment (VME) (see Figure 5).


**Figure 5. Equipment Component.**

### Military Equipment

In the context of the ME Framework, ME is any equipment assigned to a unit. This includes equipment assigned to the unit in the Table of Organization and Equipment (TOE), Modified Table of Organization and Equipment (MTOE), Table of Distribution and Allowances (TDA), equipment assigned to the unit from the installation, and equipment assigned to the installation that the unit can access. This includes, but is not limited to, platforms (e.g., M1A1 Tank), MCIS (e.g., Command Post of the Future [CPoF], Common Operating Environment Warfighting Function Widgets, and unit computers). ME provides full form, fit, and function (FFF) and typically has custom developed hardware.

**Figure 6. Military Equipment. [3]**

## Simulated Military Equipment

In the context of the ME framework, SME are System and Non-System Training Aids, Devices, Simulators and Simulations (TADSS) (see Figure 7).[3] Soldiers use non-system TADSS (e.g., existing ITE manned module such as Close Combat Tactical Trainer [CCTT]) as SME in the synthetic environment for collective training and system TADSS for individual training. SME provides a high-fidelity representation of ME and typically provides full form and fit, and partial function. The layout, size, weight, and resistance of items in a vehicle manned module replicate the piece of military equipment, however, not all of the items provide a functional capability. For example, a SME vehicle throttle does not increase or decrease the flow of fuel to the engine since there is no fuel or engine in the SME. SME requires custom-developed hardware and may provide a confined space. Using SME to provide a STE capability would be an evolutionary approach that builds on the capabilities provided by today's virtual manned modules.

SME provides the look and feel of ME. It provides Soldiers physical controls (e.g., sticks, grips, steering wheels, pedals) that match those in the ME. This allows Soldiers to train in a traditional manner that exercises motor skills and some cognitive learning during the training experience. Maintaining concurrency in SME includes updates to both software (SW) and hardware (HW).[4] Maintaining concurrency with mission command systems and platforms is an expensive and time-consuming endeavor, especially for the HW components of SME. These components typically lag behind the updates made in ME. SME requires the Soldier to travel to a facility to conduct training and requires special skill sets to operate and maintain the SME.

SME processing power has a greater requirement for local processing capability that is integrated or tethered to the end device. This makes SME less dependent on the network. However, because of the integrated processing capability and the HW replication of the ME, SME is expensive.

[3] The UH-60 simulator (system TADSS) and the virtual trainer manned modules (non-system TADSS) that exist today provide a visualization of the environment to the live crew operating the TADSS.
[4] Motor skills or neuro-muscular facilitation.


**UH-60 Simulator (System TADSS)** **AVCATT (Non-system TADSS)**

**Figure 7. Simulated Military Equipment. [4], [5], [6], [7]**

## Virtual Military Equipment

VME is defined as,

> *"… the replication of military equipment on a computer screen using a graphic interface and views as a cost-effective method for operational training."* [8]

VME is a new, revolutionary approach to deliver collective training.

In the context of the ME Framework, VME can range from a purely software representation of unit ME (no sticks and grips) to a combination of software and COTS/GOTS physical controls (sticks and grips) that approximate the form, fit, and function of ME physical controls. This framework considers virtual humans as weapon platforms part of VME. VME is anticipated to be less expensive than the high-fidelity virtual manned modules that exist today because the capability is delivered primarily in software. Concurrency changes; difficult and expensive to make in high-fidelity, SME-manned modules; will be less expensive and timelier in VME because most changes will be made in the software. COTS and GOTS hardware (see Table 3) will provide a physical interface for the Soldier to receive stimulus from synthetic environment and provide input back into the synthetic environment. This will allow the Soldier to control his avatar (virtual representation of the Soldier in the STE) or the VME.

VME without physical controls (e.g., sticks, grips, steering wheels, pedals) provides a digital representation of ME and the avatar (see Figure 8). Instead of using traditional physical controls Soldiers will control VME using an avatar that mirrors the Soldier's motions. This new approach to interacting with VME focuses on training cognitive skills and some motor skills. The term, "some" is used, because the Soldier will still move; however, feedback from the feel, weight, and resistance of objects is not provided by VME (haptic feedback can be provided).

**Figure 8. Illustrative VME [9].**

VME with sticks and grips provides a digital representation of ME and COTS/GOTS physical controls for the Soldier to control the platform. The physical controls provide a medium to high fidelity representation of the actual ME physical controls. This approach also focuses on training cognitive skills and some motor skills. Again, the term, "some" is used, because although the Soldier will have physical controls to move, the physical controls may not:

- Fully replicate the form, fit and function of the ME equipment controls.
- The physical controls may not fully replicate the feedback (feel, weight, and resistance) of the ME controls.

VME, pending availability of equipment and network support, can provide some advantages over SME. VME should allow the Soldier to train at the PoN versus traveling to a facility to conduct training. It is anticipated that a Soldier will be able to log into the STE, don equipment, and operate VME without additional people or special skill sets. VME processing power can be centralized in the cloud. This makes VME highly dependent on the network. However, because of the centralized processing capability and SW-intensive approach (a digital representation of ME with or without physical controls), VME procurement is anticipated to be less expensive.

Table 1 provides a comparison between SME and VME.

**Table 1. SME and VME Comparison.**

| | SME | VME |
|---|---|---|
| **Train at PoN** | No | Yes |
| **Concurrency** | Difficult (HW & SW, expensive, significant time lags) | Easier (primarily SW, less expensive, shorter time lags)[5] |
| **Physical Controls** | High Fidelity | Up to High Fidelity |
| **Training** | Motor Skill Centric<br>Some Cognitive Skills | Cognitive Skill Centric<br>Some Motor Skills |
| **Processing Power** | Local Processing | Cloud |
| **Network Dependent** | Less Dependent | More Dependent |
| **Cost** | Expensive | Less Expensive |
| **Approach** | Evolutionary | Revolutionary |

[5] Anticipated; SME concurrency changes impact hardware (physical change) and software. VME concurrency changes mostly impact software.

## Immersion Component

Immersion is the, "*The placing of a human in a synthetic environment through physical and/or emotional means.*" [10] The immersion component includes both physical and emotional aspects. This framework addresses emotional immersion as presence.

### Physical Immersion

The ME framework includes three levels of physical immersion: fully immersed, immersed, and semi-immersed (see Figure 9). The level of immersion achieved correlates to the number of human senses (modalities) stimulated. Human senses include sight, sound, smell, taste, touch, and proprioception.[6]


**Figure 9. Experience Component.**

The ME Framework levels of immersion are defined as:

- **Fully Immersed.** All senses are stimulated. The quality of stimulation is what the Soldier experiences in the Live Environment. In the future, technologies may mature to a level that allows a Soldier to perceive full immersion in the synthetic environment.
- **Immersed.** Sight, sound, and touch modalities are stimulated. The quality of stimulation approximates what the Soldier experiences in the Live Environment.
- **Semi-Immersed.** Sight, sound, and touch modalities are stimulated. The quality of stimulation is a low-fidelity approximation of what the Soldier experiences in the Live Environment.

Table 2 provides a summary of the modalities stimulated for each level of immersion in the ME Framework. Gray areas in the table indicate modalities that are not relevant to the level of immersion (based on this framework). High, medium, and low represent the level of fidelity, or the quality of the stimulation, provided.

**Table 2. ME Framework Levels of Immersion.**

| Level of Immersion | Modality | | | | | |
|---|---|---|---|---|---|---|
| | Sight | Sound | Smell | Taste | Touch | Proprioceptive |
| **Fully Immersed** | High | High | Medium | Medium | High | Medium |
| **Immersed** | High | High | | | Medium | |
| **Semi-Immersed** | Medium | Medium | | | Low | |

This table shows relative levels of fidelity between the levels of immersion. It does not define the level of fidelity. Sight is listed as high across all levels of immersion because each experience will use a common simulation environment to render the visualization. Differences in sight quality could be attributed to the quality of the display and the capability provided for the field of view (FoV), stereo scoping (depth perception), and head tracking. In the case of immersed and

[6] Proprioception is, "A sense or perception, usually at a subconscious level, of the movements and position of the body and especially its limbs, independent of vision; this sense is gained primarily from input from sensory nerve terminals in muscles and tendons (muscle spindles) and the fibrous capsule of joints combined with input from the vestibular apparatus. [26]

the semi-immersed levels, the increased level of immersion is attributed to the quality (fidelity) of the stimulation (not the number of modalities stimulated).

Physical immersion can be measured by counting the number of modalities stimulated and assessing the quality of the stimulation. The number of senses stimulated and the quality of the stimulation helps a Soldier establish presence in the training event.

### Presence

Emotional immersion, or presence, is a state of involvement or engagement in an activity. A person reading a book can become emotionally immersed in the story by reading and using their imagination to project themselves as part of the story. Establishing presence is a function of many factors to include:

- Human aspect (e.g., character, life experiences, imagination, embracement of Army values)
- How a Soldier interacts with the STE (e.g., how the STE stimulates modalities).
- The quality of the stimulation the Soldier experiences (e.g., representation of real-world objects in the STE; the look, sound, smell, feel, taste, and motion of synthetic objects the Soldier experiences).

The intent of establishing a high level of presence in a STE training event is for the Soldier to act in the STE as if he or she were conducting live training or a real-world combat mission. Establishing a high level of presence in the training event enables a Soldier to train as they would fight. The TRADOC Capability Manager (TCM) Virtual/Gaming (V/G) hypothesis is that an engaged Soldier will achieve higher skill retention resulting in increased training effectiveness. Further analysis is required to validate the hypothesis.

Measuring presence is difficult because of the human aspect. Devices and stimuli that provide a high level of presence for one individual may provide a lower level of presence for a different person. Different techniques allow one to measure presence. An observer can watch a Soldier train and can subjectively assess the level of presence achieved during the training event. A post training event interview can provide the level of presence established from the Soldier's perspective.

## User Interfaces

Soldiers will interact with the STE using COTS and GOTS user interfaces that allow human to computer interaction (HCI) and human to machine interaction (HMI).[7] HCI is a,

> *"Discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."* [11]

HCI is a general user interface for computer users. HMI is an interface people use to interact with tools, objects, or robots. For example, a steering wheel (e.g., sticks and grips) in a vehicle simulator is an HMI while a keyboard is an HCI for a computer.

Table 3 contains examples of potential STE user interfaces for fully immersed, immersed, and semi-immersed experiences. Table 3 provides an initial understanding based on the best information available at this time. See Appendix B, Peripheral Vision, for rationale on selection

[7] Previously known as Man Machine Interaction (MMI).

of FoV ranges. Frame rates were inferred from the Combined Arms Command Training Innovation Facility VBS3 & Oculus Rift Report published 2 November 2015 by Ryan Manning.

**Table 3. ME Framework User Interfaces.** [8&9]

| Modality | Fully Immersed | Immersed | Semi-Immersed |
|---|---|---|---|
| **Sight** | Head mounted display. Motion Tracker, Camera.[10] Natural field of view. Frame Rate: >= 90 FPS[11]. | Head mounted display, Mobile Device with VR Gear, Motion Tracker, Camera[10]. Natural field of view.[12] Frame Rate: >= 75 FPS. | LCD/LED monitor Mobile Devices. Field of view >= to 80 degrees (1st Person) Field of view Frame Rate: >= 30 FPS. |
| **Sound** | Spatialized sound that allows the Soldier to determine direction and distance and microphone. Sound is degraded by the effects of the atmosphere. | Surround sound with noise canceling headphones and microphone | Speaker/headphone and microphone |
| **Smell** | Smell generator capable of >= 5 battlefield smells (e.g., gunpowder residue, rotting flesh, etc.) | N/A | N/A |
| **Taste** | N/A | N/A | N/A |
| **Touch** | Haptic clothing covering 90% of the body with increasing levels of density and motion tracker.[10] Mixed reality with object. | Haptic clothing sensors on front and back of limbs and torso and motion tracker.[10] Mixed reality with object. | Touch screen, keyboard, mouse, joystick |
| **Proprioception** | Hydraulic chair with TBD degrees of freedom | N/A | N/A |

# STE Vignettes

The following vignettes provide insight into how a Soldier could use STE semi-immersive (vignette 1), immersive (vignette 2), and mission command collective training (vignette 3) capabilities. Each vignette starts after the unit Commander and his Staff have scheduled the exercise and exercise resources (the current Joint Exercise Life Cycle [JELC] process), and has designed the exercise and scenario that will drive the training event (creation of the warfighter training support package [WTSP]).

[8] This table does not define STE requirements. This table provides items that could allow a soldier to achieve a level of immersion.
[9] This table includes potential user interfaces for the STE, not the Live Environment which includes embedded and appended training.
[10] Cameras and motion trackers provide ways to interact with the STE. A camera provides stimulus to AI driven virtual humans in the STE. This stimulus enables virtual humans to react to the Soldier's position, motion, and facial expression. The motion tracker enables the Soldier's avatar to mirror the Soldier's motions and enables the STE visualization provided to the Soldier to mirror the Soldier's head and eye movements.
[11] 90 FPS in each eye was an observation from demonstrations during the Game Developer Conference (GDC).
[12] See Appendix B Peripheral Vision.

## Vignette 1 Semi-Immersive

The STE semi-immersive capability will replace the existing ITE Games for Training (GFT) Flagship capability. Assumed Department of Defense Information Network (DoDIN) constraints (e.g., bandwidth available, latency) will require a local processing capability (node) to process and stream the training content from the cloud to the user or a thick client solution. This is because the semi-immersive capability has a low latency tolerance (~50 milliseconds) to provide a user acceptable experience. An approach is to implement a local processing capability (node) and semi-immersive equipment sets at facilities that host existing GFT suites. The semi-immersive equipment set will provide user interfaces for sight, sound, and touch (e.g., thin/zero client display, speaker, microphone, mouse, and keyboard). The semi-immersed experience does not track the Soldier's motion. It does provide a fixed point of view that the Soldier can manually change (there is potential to have multiple screens displaying different views or the ability to have multiple views open on the same display).

As per the training event schedule, the vehicle commander arrives at the MTC (or other designated facility housing the STE capability or other PoN), checks in, and goes to his assigned semi-immersive station. Enroute to his station, the vehicle commander sees other members of his company moving to their semi-immersive stations. The vehicle commander dons his headset and microphone, logs into the STE, and joins the exercise based on his user role (e.g., vehicle commander, driver, and gunner). Figure 10 is an example of the vehicle semi-immersive station.

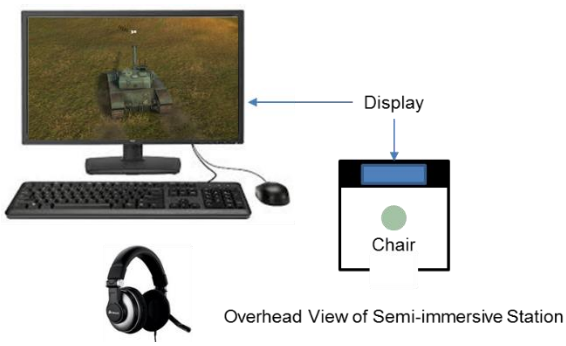


**Figure 10. Illustrative Semi-Immersive Station. [12], [13], [14]**

The display enables the vehicle commander to see the synthetic environment and the VME. The vehicle commander controls the view he sees and the VME using the semi-immersive input devices (e.g., mouse, keyboard). The vehicle commander must physically toggle his point of view if a single display is provided or manage multiple open views on the single display.

Figure 11 is an illustrative view of a single display screen that the vehicle commander uses to toggle between a view of the synthetic environment and a view of the VME main console via keyboard or mouse inputs.


**Figure 11. Semi-immersive Fixed Point of View. [15], [16]**

After starting the VME vehicle (the vehicle commander will hear the vehicle running), the vehicle commander uses the VME intercom system to establish communications with other crew members (e.g., driver, gunner). He then uses the VME radio (controlled by the VME main console and his inputs) to contact his platoon leader to provide a slant report (e.g., fuel and ammunition status report) and notify the platoon leader that his vehicle is ready to join the platoon formation. The platoon leader provides the vehicle commander final instructions to line up in the formation. The vehicle commander provides a movement order to the driver and watches the synthetic environment move by as the vehicle lines up in the formation in preparation for the platoon's tactical maneuver in support of the company operation.

## Vignette 2 Immersive

This section describes STE immersive vignettes using both VME (with and without physical controls) and SME.

### VME without Physical Controls

STE VME immersive capability without physical controls can replace the existing ITE virtual capabilities. This capability provides an augmented virtuality environment where physical objects and people are represented as synthetic objects and avatars that can interact with the synthetic environment in near real-time. Assumed DoDIN constraints (e.g., bandwidth available, latency) may require a local processing capability (node) to process and stream the training content from the cloud to the user. This is because the immersive capability has a very low latency tolerance (~15 milliseconds) to prevent simulation sickness. An approach is to implement a local processing capability (node) and immersive equipment sets at facilities that host existing virtual capabilities.

The immersive equipment set will provide user interfaces for sight, sound, and touch (e.g., head mounted display, speaker, microphone, motion tracker, camera, and haptic clothing). The immersed experience tracks the Soldier's motion. The Soldier's avatar mirrors the Soldier's motion and operates the VME. The VME immersive capability provides transitional points of view of the digital representation of the ME (VME), and the synthetic environment (See Figure 15).

The pilot checks out an immersive equipment set consisting of a helmet (illustrative) that includes a head mounted display, noise canceling speakers with surround sound, and a microphone; haptic clothing; and a motion tracker. After donning the equipment, the pilot logs into the STE and joins the exercise based on his user role (e.g., pilot in command, co-pilot). Figure 12 is an example of the pilot with the immersive equipment set in the physical environment sitting in a chair.

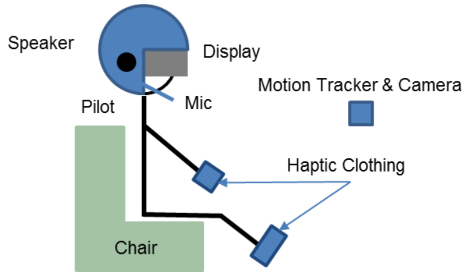


**Figure 12. Physical Environment; Pilot with Immersive Equipment Set.**

The immersive equipment set enables the pilot to see the synthetic environment, the digital representation of the ME (VME), and aspects of the pilot's avatar. The pilot's motions control the point of view the pilot sees and the avatar mirrors the pilot's motions. The pilot, via the avatar, controls the VME. Figure 13 is an exemplar of the pilot's avatar in the synthetic environment. VME objects (i.e., helicopter) are displayed in light brown (e.g., seat, cyclic, pedals, main console, windscreen, and overhead panel). Haptic clothing provides the pilot feedback when the avatar touches or moves VME controls and switches.

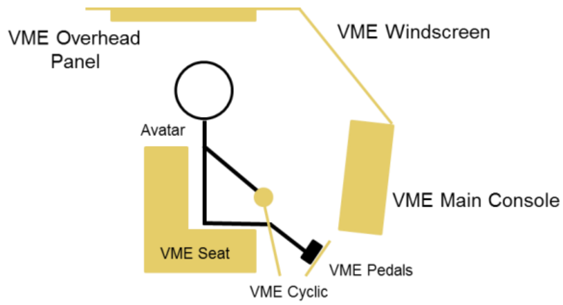


**Figure 13. Synthetic Environment Pilot Experience.**

The immersed experience provides the pilot a seamless view of the synthetic environment that follows the pilot's head and body movements. Figure 14 shows example pilot points of view in the synthetic environment.

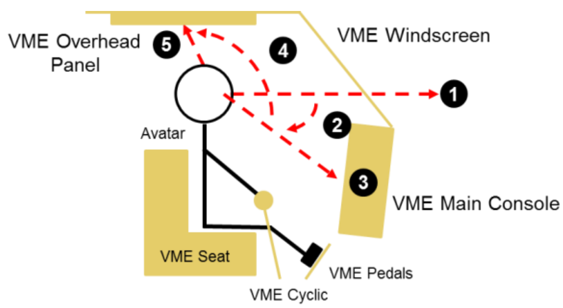


**Figure 14. Synthetic Environment Pilot Viewpoint.**

In this example, the pilot's line of sight (LoS) is initially through the VME windscreen (1) providing a view of the synthetic representation of the real world. The pilot then transitions his LoS (2) from the windscreen to the main console. This is a dynamic and transitional view where the pilot sees part of the synthetic environment through the VME windscreen and part of the main console. The rate of transition is controlled by the pilot's rate of movement (see Figure 15) as sensed by the motion tracker. As the pilot's LoS transitions to the main console, the pilot sees less of the synthetic representation of the real world and more of the main console. The pilot begins a rapid cross check of VME gauges and instruments while focused on the VME main console (3).

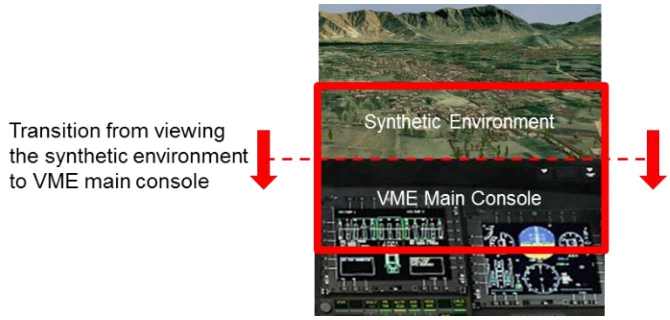


**Figure 15. Immersed Transitional Point of View. [15], [17]**

The pilot then transitions his LoS (4) to the VME overhead panel. During this transition the pilot briefly looks through the VME windscreen at the synthetic representation of the real world and then looks over his left shoulder, briefly seeing the co-pilot avatar, and then fixing his view on the VME overhead panel (5). The pilot reaches up to the VME overhead panel to move a VME toggle switch. The pilot sees his avatar hand moving toward the switch. A tingling sensation in the haptic clothing on his hand confirms his visual sense that the pilot has touched the switch. The pilot then toggles the VME switch forward. The pilot receives visual feedback that he moved the switch forward (sees switch in new position) and touch feedback (e.g., tingle) to indicate the switch was moved.

After starting the VME aircraft, the pilot calls the flight lead over the radio and lines the aircraft up with the flight in the tactical assembly area (TAA). The pilot maneuvers the VME helicopter into the flight formation by manipulating the VME cyclic, pedals, and other flight controls. As the pilot manipulates the controls, the VME helicopter raises off the ground and turns. The pilot sees this motion through the VME windscreen. Once oriented to the lead helicopter (another VME helicopter), the pilot maneuvers the VME helicopter forward to become chalk 2 in the flight. The pilot calls the flight lead on the radio to let the flight lead know he is set as chalk 2.

After the flight is formed, the flight takes off from the TAA. The pilot sees the ground move away from the helicopter as the helicopter ascends into the air and the lead aircraft in front of his aircraft. The synthetic environment ground moves underneath the VME aircraft as the flight transitions to contour flight level along their route to the landing zone.

## VME with Physical Controls

STE VME immersive capability with physical controls can replace the existing ITE virtual capabilities. This capability provides an augmented virtuality environment where physical objects and people are dynamically integrated into, and can interact with the synthetic environment in near real-time. Assumed DoDIN constraints (e.g., bandwidth available, latency) may require a local processing capability (node) to process and stream the training content from the cloud to the user. This is because this capability has a very low latency tolerance (~15 milliseconds) to prevent simulation sickness. An approach is to implement a local processing capability (node) and immersive equipment sets at facilities that host existing virtual capabilities.

The immersive equipment set will provide user interfaces for sight, sound, and touch (e.g., head mounted display, speaker, microphone, physical controls, front facing cameras, and augmented virtuality [e.g., Chroma Key] technologies). The immersed experience tracks the Soldier's motion. The Soldier operates the VME using the physical controls and the digital representation of the cabin/cockpit. The VME immersive capability provides transitional points of view of the digital representation of the ME (VME), and the synthetic environment.

After donning the equipment, and adjusting the physical controls the Vehicle Commander logs into the STE and joins the exercise based on his user role (e.g., Vehicle Commander, driver, etc.). The immersive equipment set enables the Vehicle Commander to see the synthetic environment, the digital representation of the ME (VME), the physical controls, and aspects of the Vehicle Commander's body and other crewmember's bodies. The Vehicle Commander's head motion controls the point of view he sees. For example, if the Vehicle Commander looks down, he sees the digital representation of the vehicle cabin floor around the physical controls and his feet on the cabin floor. The Vehicle Commander controls the VME using a combination of physical and digital controls. Visual and auditory feedback provides the Vehicle Commander feedback when he moves digital controls and switches.

After starting the VME vehicle, the Vehicle Commander calls the Platoon Leader over the radio and lines the vehicle up in the formation in the TAA. The driver maneuvers the VME vehicle into the formation by manipulating the physical controls. As the driver manipulates the controls, the VME platform turns and moves forward. The Vehicle Commander sees this motion through the VME view block. Once oriented to where the lead vehicle is in the TAA (another VME vehicle), the driver maneuvers the VME vehicle forward to become chalk 2 in the formation. The Vehicle Commander calls the Platoon Leader on the radio to let him know he is set as chalk 2.

After the vehicles line up, the formation moves out from the TAA. The crews see the ground move by and the other VME vehicles as the formation begins maneuver to the objective area.

### SME

STE SME immersive capability can replace the existing ITE virtual capabilities. This capability would provide high-fidelity physical controls, "sticks and grips", and monitors to display the synthetic environment making this an immersive experience.

As per the training event schedule, the pilot arrives at the MTC (or other designated facility housing the STE capability), checks in, and goes to his assigned station. Enroute to his station, the pilot sees other members of his company moving to their assigned stations. The pilot dons his headset and microphone, logs into the STE, and joins the exercise based on his user role.

The station provides the physical controls (e.g., seat, cyclic, pedals, main console, windscreen, and overhead panel) for the pilot to control the aircraft. The pilot views the synthetic environment through the aircraft forward windscreen and windows (e.g., displays) and can see his co-pilot physically sitting next to him in the station.

After starting the SME aircraft, the pilot calls the flight lead over the radio and lines the aircraft up with the flight in the TAA. The rest of this vignette is similar to the VME vignette.

## Vignette 3 Mission Command Collective Training

The mission command collective training capability will replace the existing ITE constructive capability. Assumed DoDIN constraints (e.g., bandwidth available, latency) do not require a local processing capability (node) to process and stream training content for the brigade and above capability because this capability has a higher latency tolerance (~250 milliseconds). Commanders and Staffs could access this training capability using their MCIS or unit computers.

As per the training event schedule, the assistant Brigade S3 arrives at the Brigade Command Post located in the Home Station training range area (or other designated PoN). Using his MCIS he logs into the STE and joins the exercise based on his user role.

Once logged in, the assistant Brigade S3 joins a larger, geographically distributed, multi-echelon exercise (e.g., a Division Warfighter). The training audience can consist of Army units, opposing forces, joint, agency, and unified action partners (UAP). The training audience can participate in the exercise using both the live and synthetic (e.g., semi-immersive, immersive) training capabilities from different locations (i.e., multi-echelon, geographically distributed).

The training audience communicates with the STE (bi-directional communication) using their MCIS or with STE-emulated MCIS on unit computers. This provides the assistant Brigade S3 the ability to send and receive orders with both live and synthetic units. Artificial intelligence (AI) executes the synthetic unit maneuver in the STE based on these orders. Units, both live and synthetic (computer generated forces [CGF]), provide operational reports and intelligence to the assistant Brigade S3 as if it were a live training event or deployed mission (train as you fight).

The World Class OPFOR provides OPFOR role players. Army military units may be used as a surrogate OPFOR. OPFOR role players will use STE-emulated MCIS on their unit computers to command and control OPFOR units. STE emulated MCIS will provide peer, near peer for state, non-state, regional and asymmetric threats capabilities. The STE will also provide AI to assist in controlling synthetic OPFOR and other units (CGF).

The STE exchanges state synchronization information (e.g., movement, damage, supply status changes) between geographically distributed local processing capabilities and the STE copies in the Army Core Data Centers or other Data Centers. This reduces the burden on the network while maintaining a fair fight between the distributed Training Audience participants. This is transparent to the Training Audience.

# Recommendations

STE capability developers, materiel developers, and stakeholders adopt the ME Framework lexicon and relationships to describe, understand, and communicate the STE vision, CONOPS, capabilities, design, and system requirements. The framework and lexicon will remove barriers to communication by converging stakeholders on a common viewpoint and eliminating jargon. This framework is critical to clearly articulating capabilities, concepts, and requirements.

Adopting the framework can promote effective communications, broaden understanding, reduce cycle time, and enable development of solutions that meet the Warfighter's needs and expectations. Ultimately, this can help reduce the cost of acquisition. As the STE concept matures, new technologies become available, and as new research that bears on the problem becomes available (e.g., network latency constraints, frame rate constraints, etc.) TCM ITE should periodically review and update the framework.

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# Appendix A Acronyms and Key Terms

## Acronyms

| | |
|---|---|
| AI | Artificial intelligence |
| AR | Augmented Reality |
| AV | Augmented Virtuality |
| CCTT | Close Combat Tactical Trainer |
| CGF | Computer Generated Forces |
| CONOPS | Concept of Operations |
| COTS | Commercial Off-The-Shelf |
| CPoF | Command Post of the Future |
| CTC | Combat Training Centers |
| DoD | Department of Defense |
| DODIN | Department of Defense information networks |
| FFF | Form, Fit, and Function |
| FoV | Field of View |
| GFT | Games for Training |
| GOTS | Government Off-The Shelf |
| HCI | Human-Computer Interface |
| HMI | human to machine interaction |
| HW | Hardware |
| I/O | Input / Output |
| ITE | Integrated Training Environment |
| JELC | Joint Exercise Life Cycle |
| LOS | Line of Sight |
| MCIS | Mission Command Information Systems |

| | |
|---|---|
| MCIS | Mission Command Information Systems |
| ME | Military Equipment |
| MR | Mixed Reality |
| MTOE | Modified Table of Organization and Equipment |
| OPFOR | Opposing Forces |
| PoN | Point of Need |
| SE | Synthetic Environment |
| SME | Simulated Military Equipment |
| STE | Synthetic Training Environment |
| SW | Software |
| TAA | Tactical Assembly Area |
| TADSS | Training Aids, Devices, Simulators, and Simulations |
| TDA | Table of Distribution and Allowances |
| TOE | Table of Organization and Equipment |
| UAP | Unified Action Partners |
| VME | Virtual Military Equipment |
| WTSP | warfighter training support package |

**Key Terms**

**Aggregate (unit):** A group of entities or a group of other aggregates considered as a single unit. The substitution of the word "unit" is used to avoid phrases like "aggregate -aggregate." (IEEE Std 1278.1-2012) [10]

**Avatar:** A virtual object used to represent a participant or physical object in a simulation; the (typically visual) representation may take any form. [10]

**Augmented Reality (AR):** A type of virtual reality in which synthetic stimuli are registered with and superimposed on real world objects; often used to make information otherwise imperceptible to human senses perceptible. [10]

**Computer Generated Force (CGF):** A generic term used to refer to computer representations of forces in models and simulations that attempts to model human behavior sufficiently so that the forces will take some actions automatically (without requiring man-in-the-loop interaction). Types of CGF include: automated forces - computer-generated forces that require little or no human interaction. Semi-automated forces - computer-generated forces in which the individual platform simulation is operated by computer simulation of the platform crew and command hierarchy. [10]

**Constructive Training:** Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes. [1, p. 40]

**Cultural Feature:** Feature of the environment that has been constructed by man. Included are such items as roads, buildings, canals, marker buoys; boundary lines, and, in a broad sense, all names and legends on a map. (SISO-REF-002-1999) [10]

**Distributed Exercise:** An exercise enabled by distributed simulation where the training participants are at different locations (i.e., different cities, countries or continents). [10]

**Distributed Simulation:** A simulation that has multiple modules, which can be run on multiple processors. The processors can be co-located in the same room or located in remote sites.

**Entity Perspective:** The perception of the synthetic environment held by a simulation entity based on its knowledge of itself and its interactions with the other simulation entities. This includes not only its own view of the simulated physical environment, but also its own view of itself, the other entities in the synthetic environment, and of the effects of the other entities on itself and the synthetic environment. Syn: World View. (SISO-REF-020-2007) [10]

**Environment:** The texture or detail of the natural domain, that is terrain relief, weather, day, night, terrain cultural features (cities or farmland), sea states, etc.; and the external objects, conditions, and processes that influence the behavior of a system. [18]

**Environmental Entity:** A simulation entity that corresponds to dynamic elements of the natural state of the geographic, atmospheric, and bathyspheric environment, of the synthetic environment, that can be seen or sensed on a real battlefield; for example, craters, smoke, building collapse, weather conditions, and sea state. [18]

**Experience:** The process of doing and seeing things and having things happen to you. [19]

**Fair Fight:** A Fair Fight is when the performance characteristics of two or more interoperating simulations have significantly less effect on the outcome of a simulated situation than the actions taken by or the resources available to the simulation participants. [18]

**Form, Fit and Function:** Technical data (TD) pertaining to items, components, or processes for the purpose of identifying source, size, configuration, mating and attachment characteristics, functional characteristics, and performance requirements. [20]

**Fidelity:** The degree to which a model or simulation represents the state and behavior of a real world object or the perception of a real world object, feature, condition, or chosen standard in a measurable or perceivable manner; a measure of the realism of a model or simulation. [10]

**Field of View (FoV):** The angular extent of the observable world that is seen at any given moment. (DoD M&S Human Capital Strategy) [10]

**Gaming:** Commercial and government-off-the-shelf computer generated environment for interactive, semi-immersive training and education. [1, p. 40]

**Haptic:** Refers to all the physical sensors that provide a sense of touch at the skin level and force feedback information from muscles and joints. [10]

**Head Mounted Display:** Widely used as a visual device for virtual reality and personal video monitors. Graphic images are displayed on a screen or a pair of screens (one for each eye) in the helmet. A tracking sensor attached to the participant's head tells the computer system where the participant is looking. The computer quickly displays a visual image from the vantage point appropriate to the participant's position. Thus, the participant is able to look about a computer generated world in a manner similar to the real world. [18]

**Human Computer Interaction (HCI):** Discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."

**Human Machine Interaction (HMI):** HMI is an interface people use to interact with tools, objects, or robots. For example, a steering wheel (e.g., sticks and grips) in a vehicle simulator is an HMI.

**Immersion:** The placing of a human in a synthetic environment through physical and/or emotional means. [10]

**Synthetic Environment:** The integrated set of data elements that define the environment within which a given simulation application operates. The data elements include information about the initial and subsequent states of the terrain including cultural features, and atmospheric and oceanographic environments throughout an exercise. The data elements include databases of externally observable information about instantiable entities, and are adequately correlated for the type of exercise to be performed. Also known as virtual world. (IEEE Std 1278.1-2012) [10]

**Virtuality Continuum:** "The Virtuality Continuum is a continuous scale ranging between the completely virtual, a virtuality, and the completely real, reality. The reality-virtuality continuum therefore encompasses all possible variations and compositions of real and virtual objects." [2]

**Virtual:** An entity or data that is derived from a modeled or simulated representation of the actual or anticipated system. [10]

**Virtual Training:** A simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills, decision skills, or communication skills. [1, p. 43]

**Visualization:** The formation of an artificial image that cannot be seen otherwise. Typically, abstract data that would normally appear as text and numbers is graphically displayed as an image. The image can be animated to display time varying data. (SISO-REF-020-2007) [10]

**World View:** The view each simulation entity maintains of the simulated world from its own vantage point, based on the results of its own simulation and its processing of event messages received from all external entities. See: entity perspective. [10]

# Appendix B Peripheral Vision

Peripheral vision or side vision is the, "ability to see objects and movement outside of the direct line of vision". [21] Peripheral vision consists of three areas (see Figure 16) and is measured from the center of gaze.

- Near-peripheral vision: 0 to 30 degrees from center (60 degrees wide)
- Mid-peripheral vision: 30 to 60 degrees
- Far-peripheral vision: 100 to 110 degrees [22]

"A normal visual field is approximately 170 degrees around, with 100 degrees comprising the peripheral vision." [23]

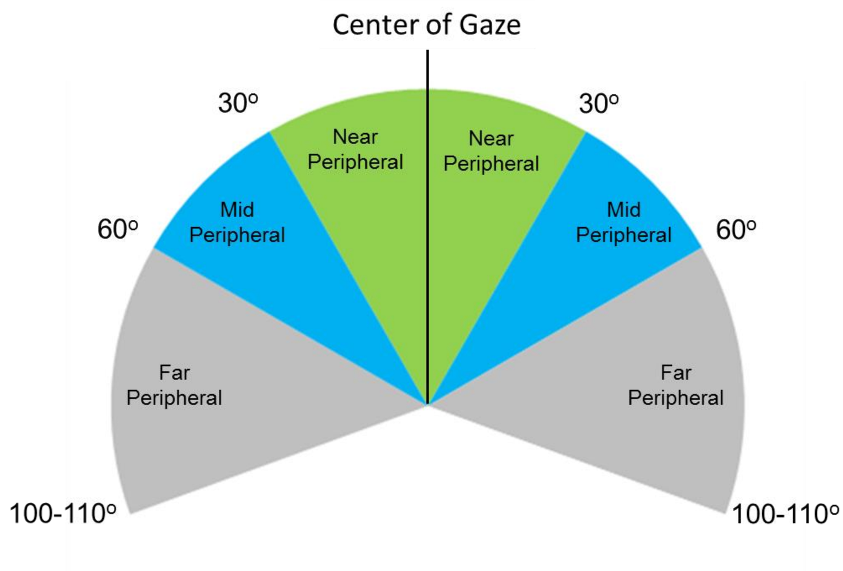


**Figure 16. Peripheral Vision.**

This effort used the above information to inform the field of view (FoV) values cited for the fully immersed and immersed training capability (Field of view >= 120 and <= 170 degrees). The maximum value is based on the normal visual field while the minimum value is based on the mid peripheral vision.

This effort informed the semi-immersed the field of view (Field of view >= to 40 degrees) using industry best practices for television viewing. Although dependent on distance from the screen and the screen quality, initial research indicated that a, "40-degree view angle provides the most immersive cinematic experience". [24]