A Roadmap to Immersive Training

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ABSTRACT

Prior paradigms for Marine Corps training are established in the context of live, virtual and constructive domains. The objective of this paper is to introduce a new agenda for discussion of training in the domain of mixed reality (MR). Research, experimentation, and prototype demonstration currently underway provides growing understanding of MR experiences; showing how augmented reality (AR) and augmented virtuality (AV) extend real world presence. Alone; however, they do not fulfill the understanding of analysis, preparation or planning for training necessary to achieve authentic, meaningful, and simultaneous immersion for a Company of Marines operating in the synchronized manner to be achieved by Enhanced Company Operations.

The Marine Corps is drawing on lessons from traditional training systems and capabilities through the Squad Immersive Training Environment (SITE) Initial Capabilities Document (ICD), the DoD Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration (JCTD), and expanded employment of its Infantry Immersion Trainers (IIT) to define the capabilities, methods, and resources necessary to accomplish MR domain training. This paper proposes a roadmap to support the development of immersive training systems all the way up to a Company of Marines conducting Enhanced Company Operations.

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INTRODUCTION

This paper proposes a road map to address the challenges of creating immersive environment training capabilities using mixed reality to support up to a company of Marines conducting Enhanced Company Operations. PM Training Systems believes transitioning the aviation community's instrumented air combat maneuver range concept to those immersive environments expected to support the small units of the infantry fight holds much promise and this paper addresses the application of that transition.

This paper: reviews some of the timeless challenges associated with training and proposes capabilities for immersive environments to mitigate these challenges, discusses some of the similarities and the one major difference between ground and air instrumented ranges, addresses exercise controller skills and the need to develop organic exercise controllers within the operating forces to support cost effective training without the need for contracted labor, highlights the need for comprehensive after action reviews (AARs) which can mitigate the limitations associated with even the most capable immersive training capabilities envisioned, and proposes methodologies that can assist AAR facilitators to evaluate the mental decision-making actions of the training unit. These insights cumulatively form our community's roadmap for design, test, and fielding of the mixed reality training system itself. This paper focuses on the small unit kinetic fight primarily because the kinetic fight capabilities desired within immersive training environments offers the foundation upon which to build non-kinetic skills.

TIMELESS TRAINING CHALLENGES

Before reviewing challenges associated with training environments focused on mission execution it is appropriate to review "Why We Train" individually and in teams. Fundamentally, Marines train to improve and expand their warfighting skills. As individual members of any small unit improve their personal warfighting skills, the team containing those individuals is presumed to demonstrate increased proficiency at the next collective training event testing those skills; thus increasing the team's mission readiness. As the team becomes more proficient in even a single collective task, the team members become more comfortable and confident of one other and the team's collective confidence increases. This increase in collective confidence helps the team overcome greater challenges. As the team overcomes greater challenges their warfighting skills increase and the unit becomes capable of supporting additional missions. In other words, we train to increase not only our individual and collective warfighting skills but to also increase the shared confidence in our team's collective ability to adapt and overcome challenges. This final benefit is important because though we subscribe to the concept that "a Marine's first engagement should be (perceived as) no worse than their last practice," reality is that the next engagement will never be exactly like the last practice and unexpected challenges will routinely occur (Mattis, 2009). Team confidence combined with increased skills will help the team overcome these surprises.

The term immersive commonly refers to training environments that provide comprehensive stimuli to the senses of the trainee in order to achieve a high degree of fidelity with the actual operating environment. Though sometimes used almost interchangeably in building training systems, the quality of being immersed it not synonymous with the goal we seek to achieve which is the subjective psychological response of cognitive presence (Slater, 2003). While our goal is cognitive presence we describe the training environments as immersive because it is an attribute that is more easily measured in objective terms. Achieving a truly immersive training environment requires a considerable investment of resources that must be justified by the quality of the training provided. A growing body of research supports the assertion that when used properly immersive training environments produce better task performance than non-immersive training environments (Gruchalla, 2005).

Numerous challenges exist when creating a training environment whether live, virtual, or constructive. Mixed reality immersive environments must address these issues.

•   Transitioning a novice to an expert in the most effective and efficient manner remains a fundamental challenge. A training system offering timely remediation can assist units overcome this challenge. A system generated AAR must be available within just a few minutes after exercise completion. AARs available this quickly encourage units to consider attempting additional trials of the same training event. The repetition of critical skills moves novices towards experts more quickly (Newell & Rosenbloom, 1981).

•   Measuring the professional growth of the training participants is especially challenging since professional growth remains fundamentally a mental process. It is impracticable to get inside the mind of individuals receiving the training using self-reporting measures so our data collection capability must obtain the most appropriate physical data to assist the inference of a participant's situational awareness and decision-making throughout the exercise (Aptima, 2009). Evaluating performance against an objective or even a defined subjective scale is necessary. Linking performance evaluations to common standards increases training consistency and also helps teach the desired behaviors by making them clearly known in advance of training (Aptima, 2010).

•   Limited practice opportunities will remain a training constraint. No unit possesses unlimited resources. If not fiscally constrained, even the most resourced unit does not possess unlimited amounts of time to prepare. Overcoming the challenge of limited practice opportunities requires the immersive environment training system (i.e. irregular warfare simulator) to address as many variables as possible and offer the greatest return possible to the training unit per iteration (Mattis, 2009). One of the best training improvements available is realistic feedback both during the event and as facilitated feedback during the post event AAR.

•   The influence of chance or luck on the results obtained during each trial of an immersive training event can be beneficial but must be understood. For example, most training systems use damage models and most damage models use randomness in some fashion, i.e. "die rolls" to determine results. This means from time to time the results will not appear as expected and this can lead to negative training to participants even when the results originate from valid damage models. The training system needs to assist the exercise controller to identify situations where outcomes appear lucky rather than good based upon the execution of high percentage choices. Trying to do the right thing is more important than results based upon luck.

•   Possessing only limited amounts of ground truth data to support AAR discussions severely impacts the quality of the AAR. Ground truth or the depiction of "what happened" remains vital to quality after action review discussions. Objective data collection and later playback based upon the objective data fundamentally shapes the quality of the AAR. Opinions are out of place when reconstructing events, but opinions possess great value during discussion or root cause analysis of the event once reconstructed. Tracking of behaviors to avoid in addition to tracking the desired actions is critical to an effective AAR. The immersive system needs to explicitly recognize and track the high percentage behaviors to encourage, actions to avoid at all times, and actions encouraged but executed out of context. This capability assists controllers to evaluate performance.

•   The availability of experts rarely matches the local training need and not all experts possess the same knowledge level. The use of rules to evaluate geometries, timings, resource consumption, and other countable factors during execution offers many benefits to the immersive training environment such as the quantification of risk and evaluation standardization. (Pedersen & Roby, 2006). The limited observation opportunity available to controllers during live training also reduces their training effectiveness; a condition only exacerbated in the urban environment.

INSTRUMENTED MANEUVER RANGES

Many similarities exist between immersive ground environments and the air ranges instrumented to support kinetic engagement training. Both stress testing and developing the cognitive and decision-making skills of the participants. Both desire to replicate the effects and conditions of the battle-space in a realistic manner. Each desires to provide real time feedback to the training participants so they can Observe, Orient, Decide, and Act (OODA) under conditions of sensory overload. Each intends to take advantage of extensive data collection in order to recreate movements, engagements, and communications during the exercise replay.

However, one noticeable difference exists. Instrumented aviation ranges supporting air combat maneuver and engagements collect very detailed aircraft performance and sensor data at high update

rates. When combined with a three dimensional display this information can present the crew's situational awareness over time with much fidelity. This detail allows AAR facilitators to transition from, "What happened?" to "What were you thinking?" to finally "What should you have done?" in a rapid and objective manner. Unfortunately, our ground immersive environments do not currently possess a similar capability. Ground combat immersive training environments do not yet assess performance by evaluating situational awareness or "cockpit S.A." at the individual level. A step in the right direction, an enhanced company will possess a small operations center with C4I details presenting a situational awareness display. This display; however, will have a time delayed view of situational awareness at the company level. This view does not contain nor is it expected to contain the level of entity behavior specifics possessed by an aircraft and its sensors. This significant difference places the burden on the immersive training system's data collection capability to obtain evidence of each participant's situational awareness within the environment. Collecting execution details on individual Marines and role players operating within the ground immersive environments must occur if we expect to support focused AARs. Objectively presenting what happened during a training event remains one of the cornerstones to a comprehensive after action review.

GROWING EXERCISE CONTROLLERS

Quality training requires resources and the more capable the exercise control staff the greater the chance of conducting quality training (DHS, 2005). Exercise control staffs fulfill many important and critical functions for each training event. At the time of execution they perform four critical exercise support functions: presents stimuli to the training unit, tracks the training unit's responses to the stimuli to ensure training evolves to support the training objectives, manages the data collected used to track responses, and prepares the AAR.

The coordinated presentation of stimuli to the training audience literally drives the training. Should the training unit not recognize the initial stimuli the controller staff must either present additional stimuli or be faced with the option of restarting the training sequence in order to meet the exercise objectives. The development of this exercise controller skill may appear as an art, but a quality training system can assist controllers implement this behavior.

It is our assertion that staffs assessing training currently implicitly evaluate the professional growth of

the participants by use of a Sense, Assess, Decide, Plan, Act (SADPA) like paradigm, since this mirrors each training participant's Observe, Orient, Decide, Act (OODA) cycle or "OODA loop." Korean era fighter pilot Col John Boyd believed the successful pilot was the one who changed the situation more quickly than his opponent could update his orientation to it. Thus success hinged upon "getting inside" the opponent's OODA loop. The OODA loop concept described by Boyd for air combat engagements also applies to the small units operating within immersive environments even though the variables considered between air combat and the small unit close fight contrast sharply. A detailed data collection plan which takes full advantage of the objective data identified when implementing the SADPA paradigm can assist controllers to evaluate the professional development of the training participants. This process helps exercise controllers focus upon tactical actions of significance during the AAR presentation.

The SADPA paradigm used by exercise controllers to evaluate the training participant's OODA loop contains the following components:

1. Sense – Detect a sight, sound, touch, taste, or smell stimuli. Was the stimuli detected?

2. Assess – Sensed stimuli recognized as data then transitions to information. Is the stimuli recognized as useful information?

3. Decide – Assessed information manipulated until a decision is reached. What was the decision?

4. Plan – The course of action selected to implement the decision. What was the plan?

5. Act – The implementation of the plan. Was the plan attempted and implemented?

When evaluating a member of a fire team, steps two through four may be completely mental and take place within a second. As a fire team leader coordinates the actions of the fire team, communications in the form of voice and / or other body movements such as hand and arm signals may occur. Capturing the communications used assists evaluators to understand the fire team leader's orientation to the situation and his decisions made. Ultimately, the greater the fidelity of the objective data collected the easier to infer which portion of the OODA loop requires remediation.

Personnel trained to operate the training equipment and manipulate that equipment in order to obtain the

greatest training advantage for the unit need to exist at the unit level. The target unit should be the company. The company's leadership possesses enough qualified personnel by structure to design, implement, and supervise training. Additionally, this is the lowest unit level which maintains individual training records. The system selected to support training should possess the ability to operate in conjunction with existing and future immersive environments as well as independent of those environments. When operating independently, the system need not require contractor support for routine operations. This key performance parameter (KPP) noticeably reduces the cost to field the system and remains clearly within reach given the off the shelf technologies available today.

TRAINING FEEDBACK

Only two sources provide feedback to the training unit; the perceived cause and effect the members of the unit experience during the event and the feedback received by the unit during the AAR. Today's small unit instrumentation often uses random draws or die rolls to determine outcomes. Even when training systems use

extensive and validated models the results achieved do not always match the expectations of the training unit. For example, when an expert describes the benefits of a specific action within a tactic, technique, or procedure (TTP) the randomness built into the training system will not by design always provide that benefit at every iteration. In real operations, the same may occur for a variety of reasons but all outcomes can fall into three general categories; "lucky & good" which is considered better than expected, as "expected," or "unlucky & bad" which would be considered worse than expected. Novices are expected to make more mistakes than experts. Often the reason for the larger number of mistakes can be attributed to the knowledge differential between novices and experts. This means novices attempt actions they believe will help them succeed even if they are not certain the action is one recommended by an expert. Also, experts recognize and understand actions considered high percentage. High percentage actions mitigate risk, are considered successful in the long run, and require less chance for the results to appear as expected. This combination of expert perspective, training unit awareness, and event outcomes generates Table 1 below.

Table 1. Training Feedback

AARs of the future need to be able to address each cell in the table. Reading Table 1, there are two states of "SME" or expert perspective: <u>Encouraged Actions</u> – high percentage actions that mitigate risk; these actions possess a high probability of contributing to mission success in the long term. <u>Discouraged Actions</u> – low percentage actions; these actions rely heavily upon chance in order to contribute to mission success or stated differently these actions increase risk in the long term. There are also two states of Training Unit Actions at the time of execution: <u>Knowingly</u> – at the time the training participant executes the action the training unit understands the expert's perspective of that action. <u>Unknowingly</u> – at the time the training participant executes the action the training unit did not understand the expert's perspective of that action. Within the table each cell's results appear in two parts; "Event Acceptability to the Training Unit" at the time of occurrence and the "Long Term Affect on Learning Experience" if left unaddressed during the AAR.

A discussion on Cell 3: At the time of execution experts encourage this action since it is considered a high percentage activity and routinely contributes to mission success in the long term. The training unit knowingly took this action during the training event because they knew the action was encouraged by SMEs. Unfortunately, in the eyes of the training unit the results achieved seemed to contradict the SME's expectations. The training unit may not realize their outcome legitimate and that they were simply unlucky when they obtained these results. The training unit may depart the exercise believing they had listened to the SME, attempted to apply the SME's guidance, but had been unjustly punished based upon the results they received or stated differently they make believe, "Either the SME does not know what he is talking about or the training system is broken." Either inference would be considered "negative learning" since experts explicitly encourage the behavior.

A Cell 3 Example: In accordance with the unit's TTP, the fire team prepares to clear a room by first tossing a grenade into the room. Immediately after detonation the lead Marine enters the room, yet he immediately finds himself in a gunfight with the room's occupants. The fire team members expected the grenade to provide a suppressive/destructive effect of the room's occupants long enough for at least two Marines to enter the room and establish positions of dominance before engagements began. This apparent contradiction in grenade effectiveness compared to the expected results can hinder learning even though the results come from validated sources.

Only cells 2 and 8 would not require comments at the time of the AAR because in these cases what the expert recommendations, the training unit expectations, and the results experienced by the training unit all match. All other combinations require a comment during the AAR to address the inconsistencies. Even cells 1 and 9 may generate the need for comments during the AAR because the results achieved were more extreme than expected.

THE AAR SEQUENCE

To maximize the benefits of the training experience AARs should follow this sequence:

Prior to the AAR the AAR Facilitator reviews exercise events. The system itself should assist the Facilitator by filtering on three types of SME designated behaviors; actions to encourage, actions to discourage, and actions to encourage but executed out of context. A system with this capability places the SME knowledge into the system. This capability adds standardization to the evaluations and consistency to training for all units who use the training system(s). Overt time the development of standard performance evaluations based upon relative scale is not difficult with this capability within the training system.

The Facilitator of the AAR then presents the selected events. For each event selected the Facilitator and the training unit must first AGREE on "What Happened." This agreement is critical. Should the training unit and AAR leader not agree on what happened the AAR loses much of its training value. The more objective the information used to determine what happened, the less chance for disagreement during the discussions. The less chance for disagreement, the more likely a constructive dialogue occurs during the AAR. The more constructive the dialogue, the greater the potential for a constructive training experience. The more constructive the training experience, the more likely the unit improves their warfighting skills due to the training. However, should the AAR presenter and the training unit not agree on what happened an adversarial situation can develop when each group perceives the event from noticeably different points of view.

Assuming agreement between the two groups, the identification of the participants per each issue or action discussed occurs. During the discussion the AAR leader focuses on pattern improvement within the unit more than event outcomes during the training. Attempting to implement high percentage decisions is more important than results based upon luck. The AAR leader strives to recognize and reinforce "good" actions, identify success based upon luck, as well as recognize

and discuss actions deemed "not good." For each "not good" action, the AAR leader helps the unit determine if changes to the unit's behaviors needs to occur. The AAR leader then works with the unit to determine if the issue addressed is a symptom of an existing behavior pattern requiring remediation.

Finally, if the need for change exists within the unit the AAR leader helps the unit internalize this need and assists the unit determine who within the unit will become the catalyst for the change.

A LIKELY AAR ENDSTATE

Given the technology available today we should soon be able to conduct comprehensive AARs at the company level and below which compare the commander's plan to the actual objective data collected during execution and to the command and control information contained within the operational C4I systems. This capability compares the commander's intentions to reality to the commander's perception of reality. Stated differently we are comparing "what the commander wanted to do" to "what happened" to "what the commander thought was happening." An AAR presentation could simply focus on the differences between the three views in order to highlight issues for discussion.
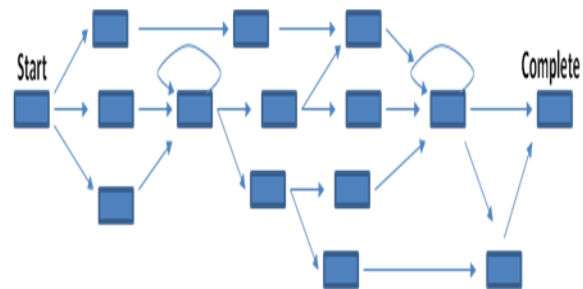
EVALUATING MENTAL ACTIVITIES

As small unit and immersive training environments enhance their data collection capabilities a fundamental challenge remains – How can we evaluate the professional growth or the OODA looping of each participant when we can only infer the mental components of the SADPA sequence at the individual level by tracking observable physical actions? The best training environments may never look inside the minds of the fire team members but we may be able to come close to a solution. The solution first requires us to identify the best physical measurements needed to infer the most accurate analysis of the mental activities. Since we are focusing on physical actions, these actions are collectable. The preferred measurement characteristics should be based on: physics, resource consumption, timing, and accepted planning factors such as acceptable geometries. Examples: Was the grenade thrown into the room at the best location to engage the occupants? How fast did the participants cross the danger area? How long after the sniper's engagement of the unit did the fire team leader begin directing the actions of his fire team? Was the grenadier inside the SAW gunner's surface danger zone at the time of the engagement? Fundamentally all these characteristics are quantifiable. The addition of

communication data will assist the evaluation of unit leaders as well. Next identify the best data types and its fidelity to support the measurements. Finally, build the desired data collection capabilities into the training system. Once the data is collected, the manipulation or filtering of the data based upon sets of SME rules allows the system itself to conduct a large portion of the evaluation. However, even with this capability in place we may never objectively evaluate mental activities, but we would possess training systems that would explicitly assist exercise controllers to efficiently and more effectively focus upon many actions that could require remediation. This capability improvement would assist us to transition a novice to an expert in a faster manner since the evaluation standards could be reviewed in advance and reinforced during the after action reviews.

ACTION SEQUENCE DIAGRAMS

The Action Sequence Diagram (ASD) can be the catalyst for defining the training system's requirements. Consider an ASD as a combination detailed execution matrix, representative use case, and TTP "playbook." From a systems approach to training perspective the ASD could appear as part of the learning analysis worksheet (LAW) development. The ASD represents what you would like the training unit to become "good at" upon completion of training. The greater the detail associated with each action the easier to build a comprehensive training system to support the training requirements (Folds, 2005). Figure 1 presents a representative ASD.

Figure 1 Representative Action Sequence Diagram

Each box in Figure 1 identifies an action possessing significance as defined by an expert. Each action must be measurable. Actions can include radio communications, movements, pulling the pin on a grenade, placing a tripod into position, detections, engagements, voice commands, re-engagements until a destruction criterion is met, etc., as long as the action is measurable. If it can be physically measured it can find a home on an ASD. Many actions possess multiple measurable components. The thresholds of acceptability for each measurement may change for the

same action as scenarios change or as the situation changes during the training.

There are many benefits to creating detailed use cases in this manner.

1. If an action appears on the diagram that action possesses tactical significance. This is something the unit needs to practice.
2. Defining objective measurements for each action helps identify the training system's data collection requirements.
3. Explicitly identifying the action assists exercise controllers determine the stimuli required to support the training of that action.
4. Identifying the stimuli required for step 3 assists exercise controllers construct the general conditions within which to create the stimuli.
5. Given the stimuli and general conditions for the exercise the exercise designers can better determine the data collection system to build.
6. Given the measurements required to evaluate the action the training system designers can better understand the AAR presentation requirements.
7. Given the AAR presentation requirements the training system designer can determine the data manipulation and filtering needed to support the AAR.
8. Units preparing for training can use the ASD to assist them understand how they will be evaluated during the upcoming exercise as well as amplifying instructions on how to execute a TTP.
9. Exercise controllers can use an ASD to assist them identify what actions the training system will capture. This can assist them focus other data collection efforts upon the specific actions not covered by the training system.

SUMMARY AND CONCLUSIONS

The development of immersive training environments that employ a combination of conventional live range training techniques augmented with mixed reality technology is a considerable investment of resources. Yet our ground forces who are directly confronting insurgents deserve the same quality of immersive training that is an accepted standard for the combat aviation community (Mattis, 2009). Using immersive technology simply as a substitute for live training shortchanges its potential unless it provides a deeper insight into the decision-making process of the trainees and a means to positively enhance the "tactical

cunning" by improving decision-making skills. Pairing high fidelity sensory stimuli that facilitates cognitive presence with the ability to collect and analyze objective performance data is essential to achieving the increased readiness and return on investment of next generation ground training systems. Distilled down to its essence, immersive training environments combined with a comprehensive AAR capability provides a synthetic experience that result in the acquisition of real and measurable skills that will enhance mission success on future battlefields.

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