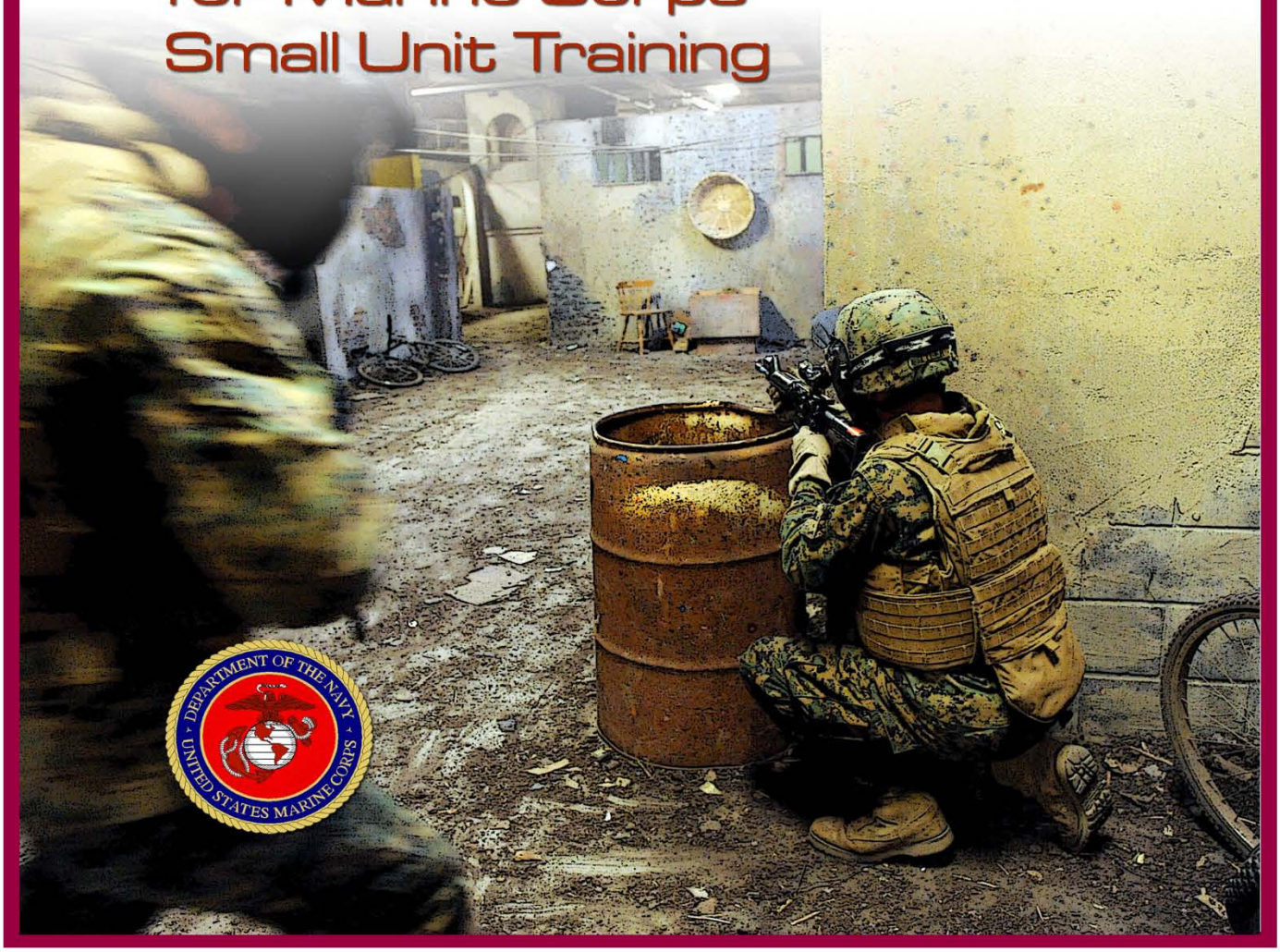
NRAC
Naval Research Advisory Committee

September 2009

Naval Research Advisory Committee

Immersive Simulation for Marine Corps Small Unit Training



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This report is a product of the U.S. Naval Research Advisory Committee (NRAC) Panel on Immersive Simulation for Marine Corps Small Unit Training. Statements, opinions, recommendations, and/or conclusions contained in this report are those of the NRAC Panel and do not necessarily represent the official position of the U.S. Navy, or the Department of Defense.

Cover : Infantry Immersion Trainer (IIT) located at the I Marine Expeditionary Force Battle Simulation Center Camp Pendleton, CA. (U.S. Navy Photo by John F. Williams).

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Executive Summary

Background

The challenges and risks to US ground forces in the contemporary operational environment (COE), particularly with respect to Irregular Warfare, are well known. Since the end of World War II, there has been a disproportionate burden in casualties born by the Infantry relative to other branches of the US military. It is believed that virtual simulation, with proven effectiveness in training Airmen and Sailors, can improve the safety and effectiveness of Marines and Soldiers by aiding them in developing complex and intuitive decision skills under conditions of stress. Additionally, the phenomenon of "strategic compression", pushing responsibility for decisions with far-reaching consequences to the lowest echelons of military organizations, requires the means of developing effective cognitive decision-making capabilities for US ground forces small unit leaders.
With the objective of studying concepts of immersive training simulation for Marine Corps Small Units, a Naval Research Advisory Committee (NRAC) study was commissioned by Mr. Sean Stackley, Assistant Secretary of the Navy (Research, Development and Acquisition) and Lt General George Flynn, USMC (Commander, Marine Corps Combat Development Command). The Terms of Reference included six principal areas of concentration: (1) the decomposition of the small unit immersive simulation training problem, (2) Identifying the desired effects of this training, (3) examining the metrics necessary to gauge training effectiveness, (4) reviewing current and developing virtual training methods, (5) evaluating current science and technology (S&T) initiatives and (6) recommending technology solutions, investments and developments.

NRAC leadership composed a panel of NRAC members including representatives with industry, medical, military, academic and acquisition backgrounds including retired USMC General Officers and Naval Flag Officers. The study engaged stakeholders and participants in Government, academia and industry.

Findings

At the outset, the panel found that there is no broad consensus on the meaning of *immersion*, with some in the "presence" research community favoring a set of objective criteria (spanning the number of senses addressed and the fidelity of sensory impressions) and others favoring a definition relying on a subjective impression of engagement and suspension of disbelief. The panel favored the later definition in its deliberations.

The panel adopted a learning hierarchy framework for training USMC small units spanning (a) declarative knowledge of facts, (b) consolidation and acquisition of procedural knowledge and (c) higher order skills and team organization. Against this, the panel considered a range of virtual simulation alternatives.

Virtual reality, in which the user experiences a synthetic environment exclusively, typically involves a desktop, large-format or head-mounted display (HMD) interface for increasing levels of immersion. Mixed reality includes augmented virtuality, in which the user experiences a synthetic environment with selected real-world components that appear in scene graph masks (i.e. holes in the scene image), typically with a see-through optical HMD. In augmented reality, the user's primary experience is of the real world with synthetic objects occluding the real-world, typically with a see-through optical HMD interface.

This range of virtual simulation alternatives suggests a potential fit with the hierarchy of training challenges. Thus an augmented reality capability, with the ability to move freely in a physical, three-dimensional space, might be a good fit for learning higher order skills and organization while desktop virtual reality might be suited to learning declarative knowledge of facts. Whatever the level of training, however, the inherent non-sequential nature of simulation training more naturally supports the development of higher-order cognitive capabilities than linear task and part-task training.

There is, perforce, an issue of the maturity of the enabling technologies for some of these virtual training approaches. Augmented reality, for example, relies on accurate position-location information (PLI) along with practical, see-through optical HMD's. The

panel determined that PLI, at a scale in footprint and number of participants required for USMC small unit training, was not yet available. Similarly, lightweight, inexpensive see-through optical HMD's will require additional S&T investment.

For current and upcoming virtual training solutions, there is the additional challenge of a general lack of metrics for determining the effectiveness of alternatives. This has contributed, the panel believes, to a lack of consensus of the value of simulation training for USMC small units. Notwithstanding the current availability of several virtual simulation tools, there is no actual guidance on their employment in the USMC Infantry Training and Readiness (T&R) manual. Without metrics, it is difficult to provide guidance about the value of virtual systems as an alternative to, for example, live training exercises. Moreover, the Mission Essential Tasks (MET's) in the T&R manual do not include the cognitive aspects of irregular warfare. Thus there are currently no tasks against which to consider virtual training tools that might, for example, build meta-cognition skills.

The panel found potential for addressing the absence of metrics for virtual simulation products in a study conducted by Canadian researcher, Dr. Paul Roman of the Royal Military College of Canada. In a study published in December 2008, Dr. Roman found that the cognitive decision-making skills of Canadian tank commander students increased dramatically with a portion of the conventional classroom curriculum was re-directed to virtual simulation exercises.

His metrics, however, derived exclusively from the subjective assessment of trained, experienced evaluators. The dependent variable in this experiment was the pass/fail outcome for the students in the course. The experimental group in the Roman protocol passed the course earlier and in greater numbers than the control group.

Until other, possibly computationally-based, automated approaches may be found, the panel believes that the systematic application of assessment by trained evaluators considering the outcome of training events will provide the hard data necessary for evaluating training alternatives.

Notwithstanding the limitations of available technological components and metrics, the USMC has seized the initiative, building an Infantry simulator at Camp Pendleton, the Infantry Immersive Trainer (IIT). With limitations in throughput and availability, the IIT is intended to inform a planned Program of Record, the Squad Immersive Training Environment (SITE). According to users, much good has already come of this pioneer effort. The panel noted some immediate enhancements (e.g. sound design/reinforcement) that could add to the immersive qualities of the IIT.

In future implementations, the requirements of IIT-type facilities could benefit from cognitive task decomposition: teasing apart the desired training end-states from immersive simulation training events. This would enable trainers to maximize the effect of time spent in IIT-type facilities and modulate the training that the facilities would be required to provide.

Recommendations

For immediate action, the panel recommends (a) the implementation of systematic, subjective assessment methods to evaluate simulation alternatives, (b) the development of cognitive, irregular warfare-related MET's, (c) various enhancements to the IIT along with (d) cognitive task decomposition to support an "end-to-end" training solution.

With an eye to the future, the panel considered the current USMC S&T investment ("Code 30" in the Office of Naval Research Budget) in addition to the broader Department of Defense technology investment. The panel found that the current portfolio is under-resourced in terms of supporting the technology components required for practical augmented reality, the likely next step in immersive small unit virtual simulation training. The panel also determined that the SITE program needs an integration laboratory (most likely at Camp Pendleton's IIT) to validate the development of technology components as they become available and the ways these tools will be used in the SITE program.

With this approach, the panel believes Marines, in the future, will face their first combat in a simulator: not on the battlefield. The panel believes further this will make a great difference in avoiding casualties and saving lives.

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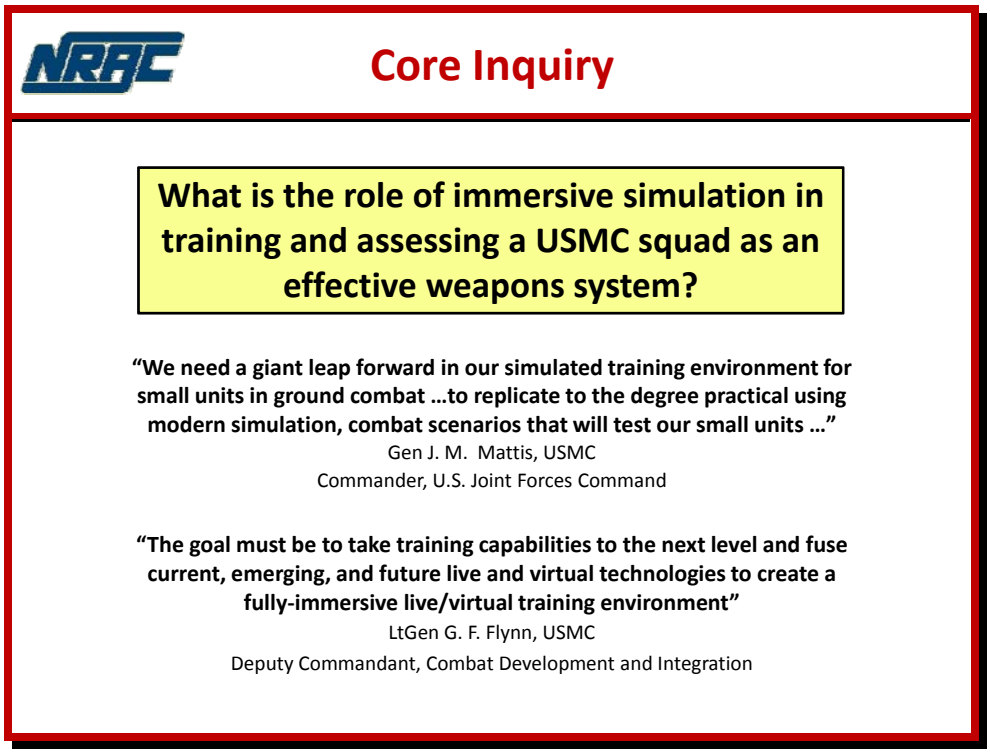
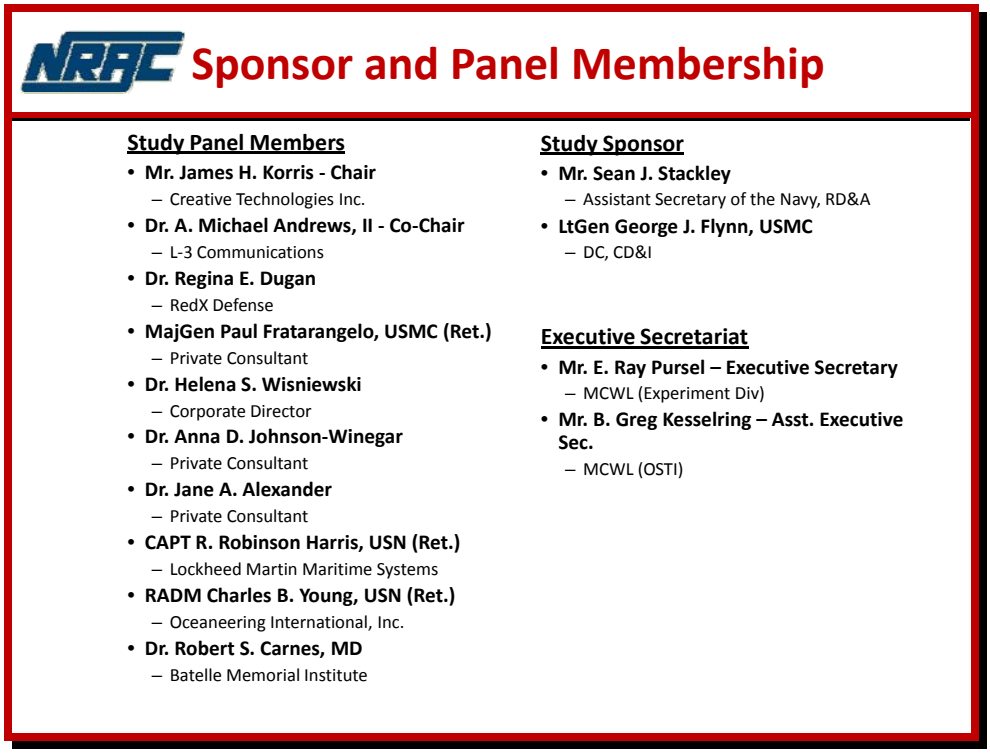


Combat operations commencing in Afghanistan (2001) and Iraq (2003) have been marked by irregular warfare involving Marines and Soldiers fighting insurgents employing improvised explosive devices (IEDs), roadside bombs, handheld antitank grenade-launchers firing RPGs (Rocket-Propelled Grenades), suicide bombers, small arms fire and mortars. The vast majority of U.S. causalities have been sustained in small unit ground combat operations.

The Panel focused on the question of what role immersive simulations ought to play in training and assessing Marines prior to entering the irregular warfare environment. We looked at current and emerging immersive simulation techniques and technologies that might enable young Marine squad members to become better decision-makers: better critical thinkers.

As shown in the above quotations, senior leadership fully expects that the research efforts supporting the infantry – both Army and Marine Corps – should shape evolving immersive simulation developments to address their complex training

requirements. Whether it is the “leap-ahead”, that General Mattis (USJFCOM) seeks or the secular evolution of fused capabilities that Lieutenant General Flynn describes, remains to be seen. In this study, the panel investigated ongoing efforts in this area with an eye to understanding the remaining barriers to fully immersive small unit simulation training for the COE. With an understanding of these remaining challenges, a way ahead can be formulated to realize the vision.



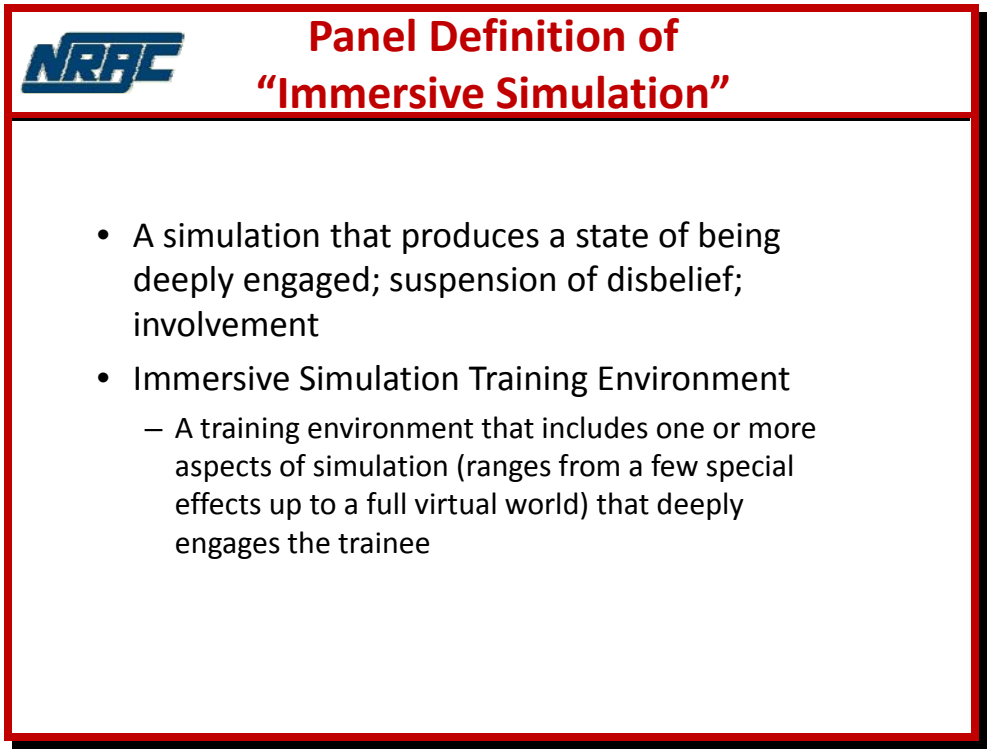
The Panel – with individuals from industry, medical, military, and acquisition backgrounds – brought a broad range of technical expertise to this Study.

Our Marine Corps study sponsor, Lt General Flynn, USMC, ensured Panel access to all of the key players and existing systems that were relevant to the fact-finding phase. The sponsor-designated Executive Secretaries provided the Panel with exceptional support including key insights into the state-of-the-art training capabilities of the Marine Corps.

The NRAC Study Panel cast a wide net in terms of fact-finding. The Panel made every effort to talk to everyone who had a stake in, or who was active in the area of immersive simulation. Briefings were received from a wide variety of organizations and individuals in the Marine Corps and Army acquisition and technology offices, government and academic researchers, other defense community members, and representatives from small, medium and large for-profit companies. As, particularly in industry, the field is highly fragmented and generally populated with a large number of small businesses, the panel sought a representative sample of these stakeholders in relevant disciplines including virtual worlds, artificial intelligence, virtual simulation middleware, authoring tools and displays.

The Panel was surprised by the lack of mature information on research and application of metrics in the area of immersive simulation and its training effectiveness. There were exceptions – including areas of research sponsored by the Office of Naval Research and the Canadian Military. Dr. Fidopiastis from the University of Central

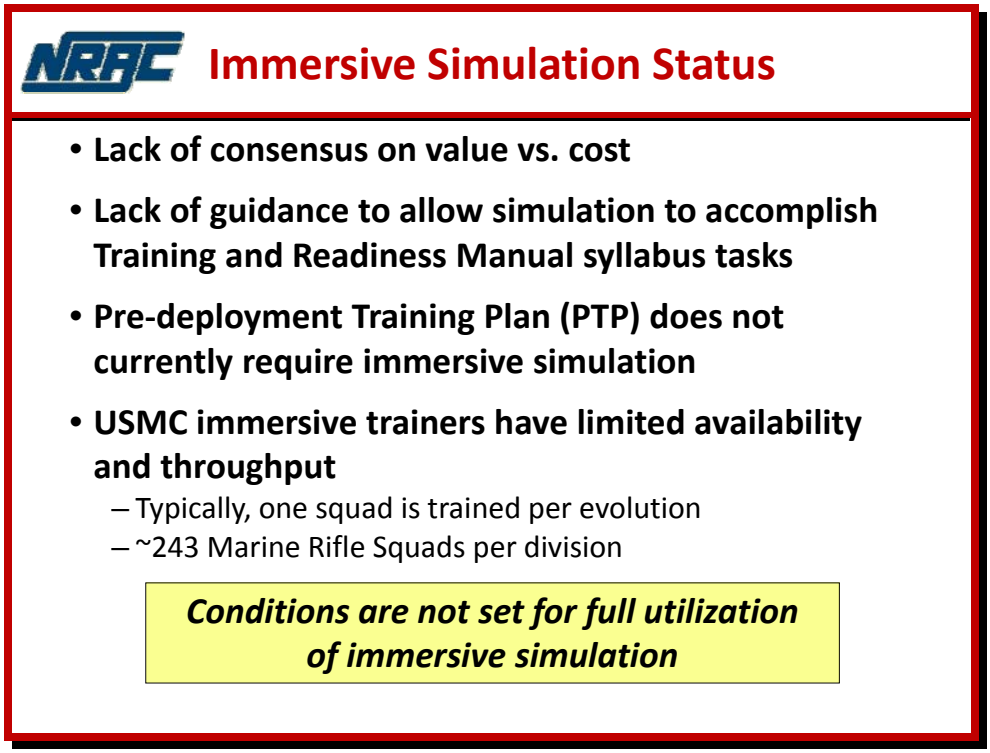
Florida had performed work in the measurement of human response to stressful conditions in a simulated environment. Dr. Roman of Canada's Royal Military College reported on the use of training metrics to measure the impact of simulations for Tank Commander training. CAPT (sel) Schmorrow and LCDR Cohn, previously assigned to ONR, presented their work over a number of years that provided the panel with a deeper insight in the area, and challenges of metrics.



As the Panel received its various briefings from the experts in the field, a working definition of "immersive simulation" was formed as shown above. It is necessarily subjective, as it applies to individualized human stimulus and response. Later in this report, as the status of immersive simulation is discussed, we note that no single definition has emerged to which all parties can agree.

It is interesting to note that the application of immersive simulation to the training challenge can take a number of paths – from a fully "digital" virtual-world simulation to one that combines a real and virtual environment – providing the trainee with a level of engagement not replicated in other forms of training.

The Panel began its work by examining and embracing the fundamental, foundational Marine Corps training principles, in particular the first one, "Train as you fight". Marines want to train with their own equipment (e.g., rifle, eye wear, helmet) with freedom of movement to employ their combined arms capabilities.

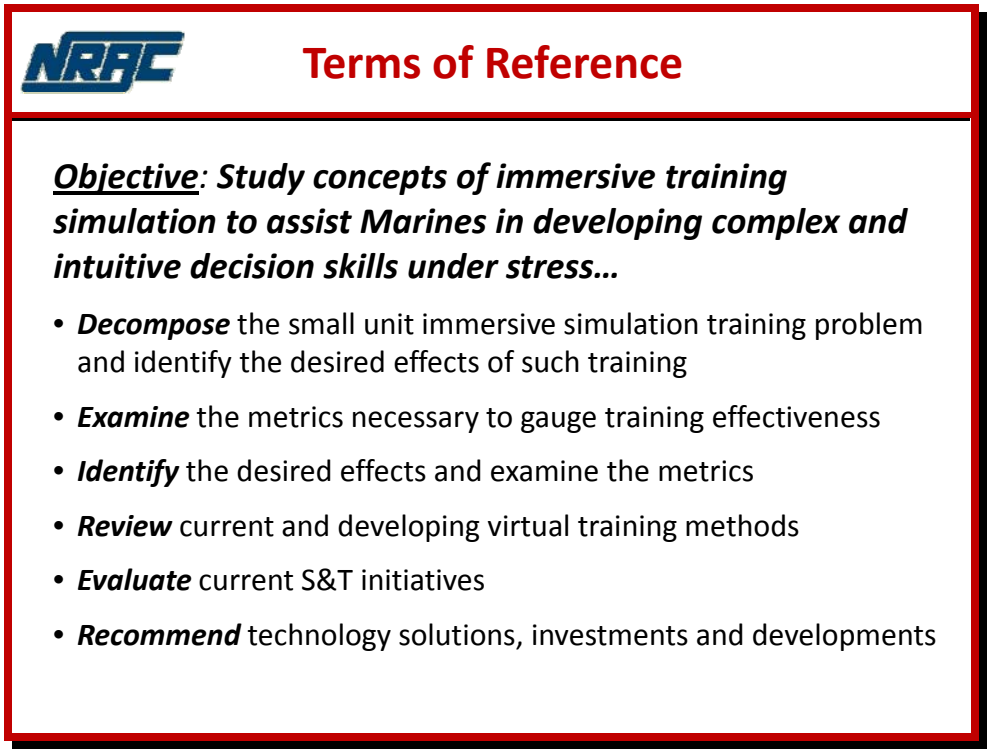


The Panel learned that conditions are not yet set for full implementation and utilization of immersive simulation training in the infantry services, including the USMC. The Panel noted several significant barriers or obstacles.

The first barrier is a notable lack of consensus over the value of the current simulation training methods and technologies. Also, the very definitions of "immersion" or "immersive" are their own kind of babble. Today, the terms are so overused as to be almost meaningless. It is the adjective du jour for contractors who have any kind of training or simulation system to sell. It is often taken to mean a product that users will find particularly engaging and compelling – and whether it accomplishes that through objective, measurable means or through just the quality of the experience – the net result appears to be the same. It's something that really engages the user, but its value has been controversial among USMC leadership.

A second barrier is a clear lack of guidance or any documented requirement to utilize simulation as a means to accomplish the tasks in the USMC Training and Readiness (T&R) Manual. The latest revision of the T&R manual discusses simulation and encourages its use as an effective and efficient way to meet the training requirement – but there is nothing about how to use it or its value to the training effort.

This leads to a third barrier. The Pre-deployment Training Plan (PTP) does not require immersive training. This is probably due to the lack of close-by immersive simulation facilities for each MEF – the fourth significant barrier noted by the Panel. With only one Infantry Immersive Trainer located on Camp Pendleton, it is neither convenient nor cost effective for East Coast or Hawaii-based USMC units. And, even for West Coast Marines, there is limited throughput available in the IIT.



These are study Terms of Reference (TOR) in bullet form. The full text TOR is provided as Appendix A.

The Panel's fact-finding over a six month period provided the background to: decompose (i.e., tease apart) elements of the training problem; identify the presence and suitability (or lack thereof) for immersive simulation performance metrics; and review the existing set of virtual training systems as well as those in development. Next, the Panel reviewed the DOD Science and Technology investment – focused primarily on the Naval S&T portion. Finally, recommendations for the near and farther term were offered.

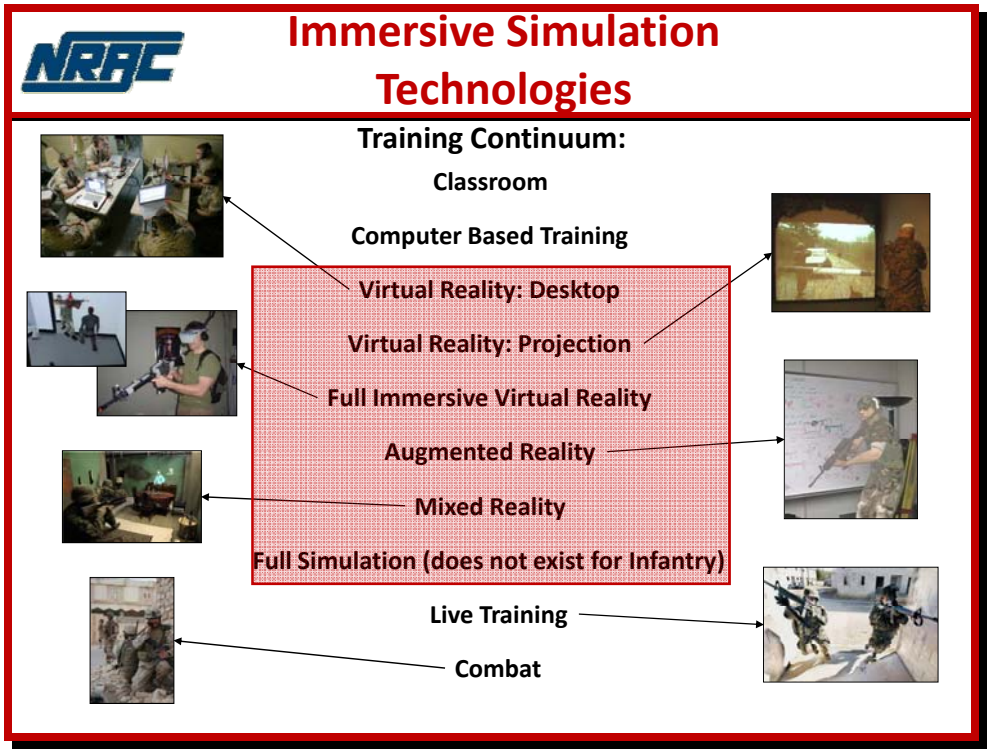
Findings

The Panel felt that it was particularly useful to consider the "training continuum" in order to determine the issues involved with the application of simulation training products for cognitive decision-making for Marine small units.

The straightforward transfer of information in a classroom or lecture setting ("declarative knowledge") for example, imparts some knowledge of the presented facts but offers little opportunity to practice skills or consolidate that which was learned. "Hands-on" training allows a single student to begin memory consolidation – stabilizing a "memory trace" for easier recall. But this procedural knowledge of a hands-on skill is usually limited in complexity and lacks cross domain, strategic knowledge components.

Collective training generally requires a more complex environment that imparts higher order teamwork skills. The current I MEF Infantry Immersive Trainer, is an example of such a facility. It is, however, burdened with the cost of numerous cultural "role players", limited student throughput and difficulty in changing the fixed physical

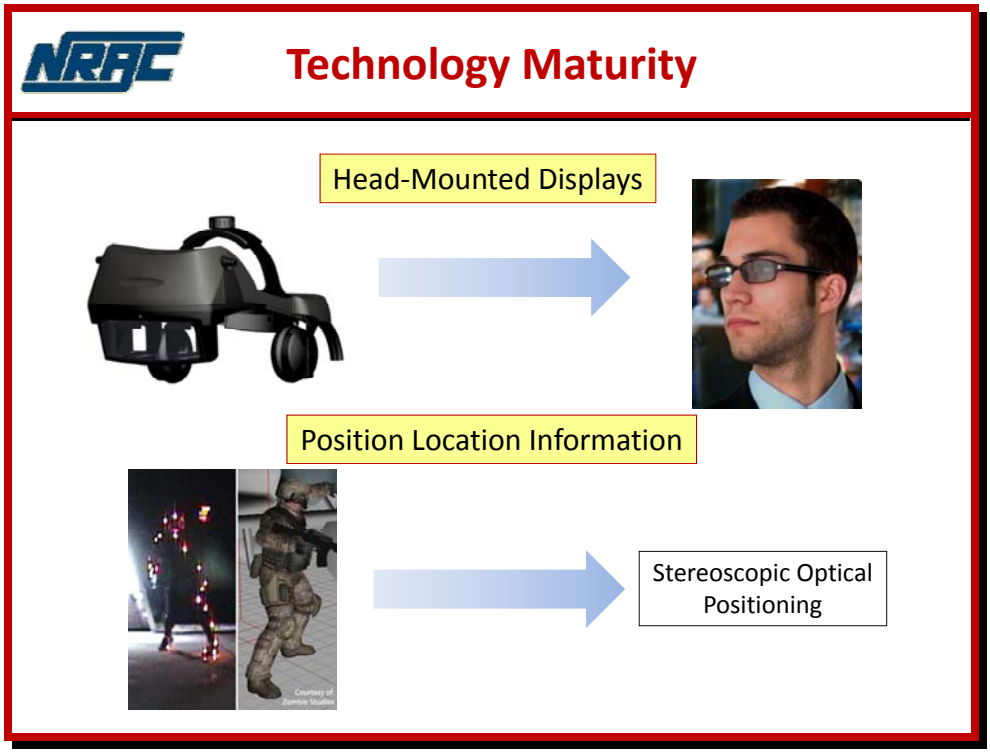
plant to simulate various operational environments. The addition of training elements that imbue a subjective strategic knowledge skill set is a challenge. This type of subjective knowledge permits decision-making under severe time constraints and pressure. If not properly controlled, this type of training can overwhelm an individual at the outset, and distract the reminder of the training sequence.



There is a spectrum of technologies that align with the training continuum in the previous chart. At the simplest level, that of the classic training venue of the classroom, to arguably the most immersive – that of on-the-job training in live combat – exist a range of technology applications. The Panel considered those in the shaded area i.e., those that provide some level of reality simulation by computational means.

The following descriptions may be unfamiliar to the reader. Full Immersive Virtual Reality utilizes an occlusional head mounted display (HMD). The user is presented exclusively with a view of a computer-generated virtual world and none of the physical world that surrounds him. Conversely, Augmented Reality is a simulation approach where the user sees the real physical world around him combined with synthetic (computer generated) objects inserted into this "real world". The HMD, in this case, is an optical or video "see-through" device allowing the visual transmission of the ambient environment to the user. Spatial masks block the passage of the ambient setting with tracked rendered portions of the virtual scenegraph displayed in the HMD.

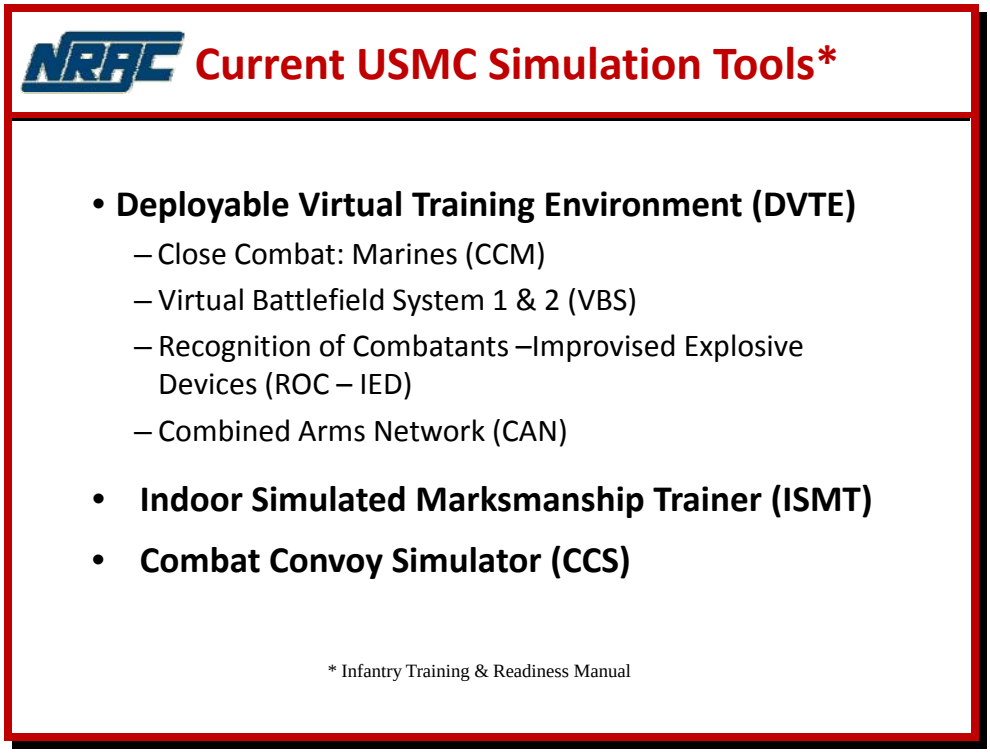
Augmented Virtuality is a further refinement of Augmented Reality. In this case, the user's primary experience is of a synthetic environment with masks creating an interruption in the scene graph to allow the transmission of real world visual stimuli. In one approach to Mixed Reality, synthetic objects are integrated into a real-world setting with discrete displays. Thus a monitor displaying an avatar in a physical environment is an implementation of Mixed Reality.



As the Panel evaluated critical technologies and their maturity, two areas set the current limitations that will ultimately enable practical augmented reality. The first is the area of display capabilities. The top left image is a current state-of-the-art, see-through optical head mount. The user is able to observe the real physical world around him as well as see computer-generated synthetic objects at the same time. A manufacturer's end-state example is shown to the right – the form and fit of a pair of reading glasses. The first typically weighs more than a pound while the glasses are measured in ounces. There will be significant R&D to achieve the end-state. (Affordability is always a key factor – today these glasses cost about $15,000 each. The target price would be under $500.)

Similarly, but perhaps less obvious, is that the precise location of every object in the "scene" must be accurately known in order to juxtapose and combine the real world with the synthetic world. Today this is achievable – but it's only achievable at significant expense and in small interior venues. For a two, three, or five-acre outdoor MOUT site, a

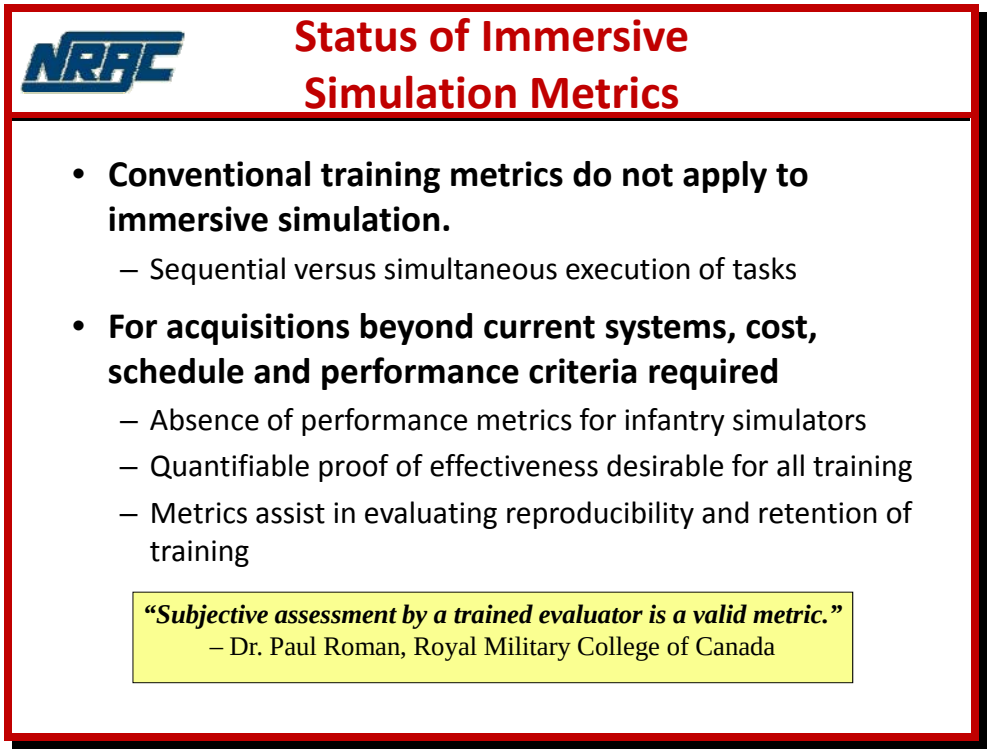
different kind of technological approach is required. Unfortunately, there is limited progress in that direction, and substantial R&D will once again be required.



An important part of our research involved reviewing current and developing virtual training methods, and how they are being employed in the Marine Corps. Identified in the USMC Infantry Training and Readiness (T&R) Manual are extant simulations available for commanders. These are primarily desktop computer courses: the Deployable Virtual Training Environment (DVTE); the Indoor Simulated Marksmanship Trainer (ISMT); and the "immersive" mixed reality environment Combat Convoy Simulator (CCS). The CCS is decidedly "vehicle-centric" with some dismounted training opportunities.

A key finding is that the T&R Manual provides no guidance to USMC Commanders regarding the use of individual training simulations. It does not prescribe or recommend where simulations belong in the training syllabus, what other proscribed training events they may replace or of what enhancement of training readiness they

provide to the commander who chooses to employ them in his unit's pre-deployment training syllabus.

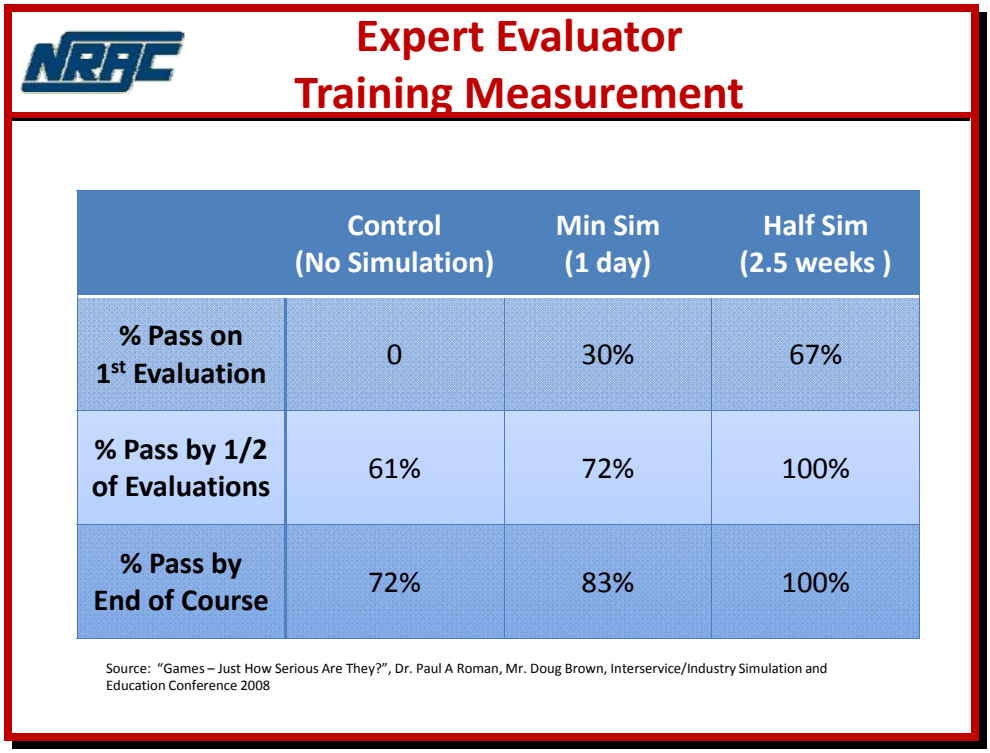


The Panel was disappointed by the lack of metrics for immersive simulation. Despite significant interest in many quarters, little has been done in this area. Most briefers stated that developing realistic metrics was just "too hard." The operating assumption is that because conventional training is sequential and immersive simulation is not, that conventional metrics do not apply.

In a typical task evaluation, a student's performance is checked off as he proceeds through a sequential evolution. In a simulation environment, there can be lots of things happening at once and it's difficult to measure the training results with the various stimuli – hence no metrics.

The current set of immersive simulation training systems in use by the military were acquired without benefit of metrics used to support trade-off analyses. Despite the current use of training simulations, there remains a lack of performance metrics to show their cost/benefit. Without valid metrics, there cannot be an evaluation of alternative solutions or approaches.

Dr. Paul Roman of Canada's Royal Military College took a different approach in addressing the need for metrics in evaluating cognitive decision-making training aids. In a series of experiments to test the usefulness of training simulations for Canadian Tank Officers, he developed performance metrics based on the "subjective assessment of trained evaluators". Although his method appears obvious – not a particularly innovative idea – its application to a simulation product is, in terms of the panel's findings with respect to ground forces training, novel.

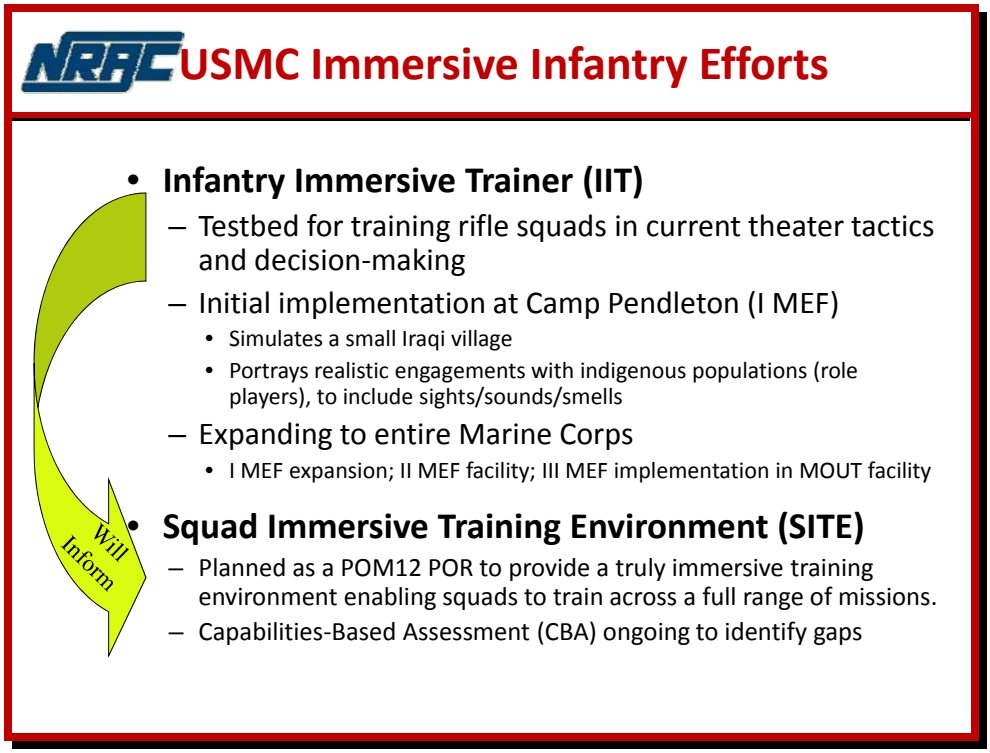


The above spreadsheet of Dr. Roman's "% pass" results clearly shows the benefit derived from employing simulation training (i.e., an interactive, free-play tank commander desktop trainer) as part of the six-week Tank Training Course, conducted at the Canadian Combat Training Centre. The columns represent the amount of simulated game based training and the rows the percent of the subject groups that passed the course. Performance was based upon student success rates as defined by the proportion of students that passed the demanding course and the number of real-world traces (evaluations or battle runs) needed to demonstrate proficiency. The results from three consecutive groups taking this course are represented.

The first column represents a control group that had no simulation-based training, having only the conventional classroom course curriculum. The second column represents the trainees that experienced one day of simulation activity and 5.5 weeks of classroom training. The third column group experienced 2.5 weeks of simulation training with only 3 weeks of classroom instruction.

When the students completed their first evaluation or “trace”, the pass rate for students in the two experimental groups with a simulation-augmented curriculum showed a higher pass rate than the control group. The pass rate increased with a rise in the proportion of simulation time in the course.

Although these results are supportive of the value of simulation-based training, the Panel found the data compelling because they suggest a usable metric *framework* that could be adopted by the Marine Corps.

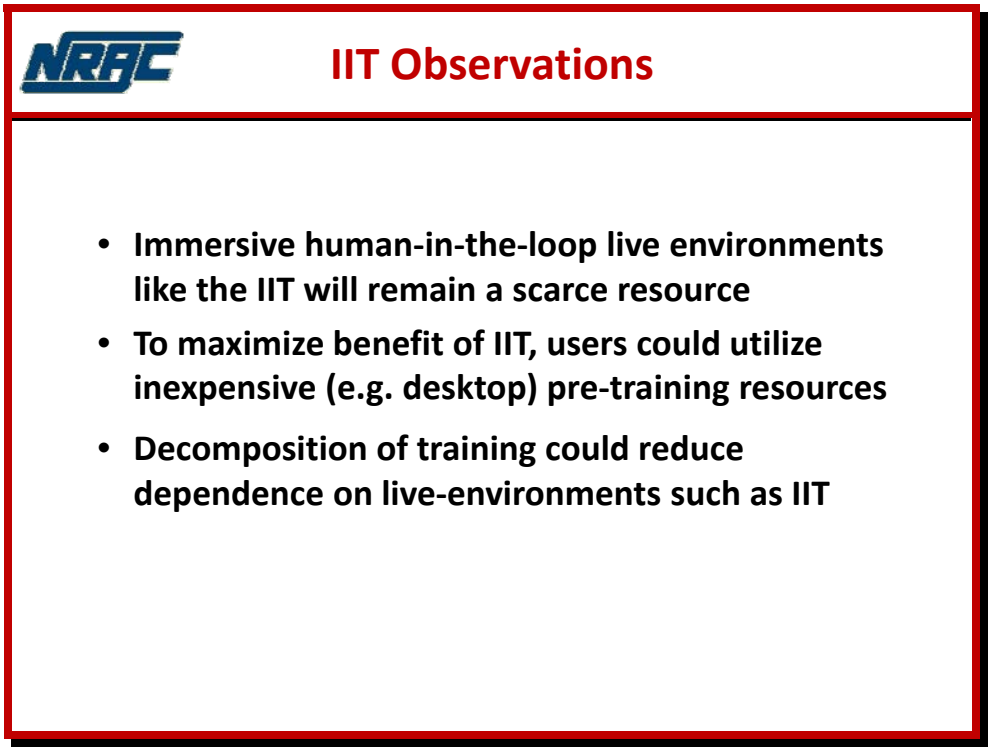


The Panel made a site visit to the I MEF Infantry Immersive Trainer at Camp Pendleton, CA. The IIT is the Marine Corp's flagship for immersive training for small units today – training numerous Marines before they deploy to Iraq. It's the "test bed" in which Marine rifle squads and other small units receive pre-deployment and refresher training in an environment that resembles an Iraqi village. There are role players in Iraqi wardrobe – encountered in their homes, mosques, and shops along with computer generated two-dimensional human avatars projected on walls, transcreens or displayed on flat panel monitors. There are simulated explosives – many of the elements of Southwest Asian Counter Insurgency operational venue permeated with realistic visual, auditory, and olfactory stimuli.

The IIT exposes the young Marine to the environment of indigenous sights, sounds and smells to practice small unit tactics and his decision making skills including "cueing" and "sense-making". Based on our own personal immersive demonstration at

the IIT, followed by discussions with the trainers and trainees, the Panel is confident that the training is vivid and realistic.

The current I MEF IIT will be expanded, and IIT-like immersive trainers are planned for II MEF at Camp Lejeune, NC; and for III MEF in Oahu, HI, in the next year. A 2012 Program of Record (POR) will develop an overarching immersive simulation toolset for the Marine Corps dubbed the Squad Immersive Training Environment (SITE). Lessons learned from the IIT training as well as from other developments will inform the development of SITE.



In April 2009, the Panel spent the better part of a day at the I MEF Infantry Immersive Trainer. The agenda included briefings by the trainers, a walk-through with example immersive effects, and an open discussion with selected IIT "graduates" from all ranks.

The IIT was converted from a former tomato-packaging plant into a 32,000-square-foot military urban training center at Camp Pendleton, California. It uses sets designed to simulate a Southwest Asian village (in sight and smell), an ambient sound system and special effects. Transcreen hologram-type displays and pyrotechnics (IEDs and RPGs) lend combat realism. Marine Rifle Squads are equipped with paint-ball style weapons. Marines walk through realistic dwellings, alleys and other settings, encountering civilians and enemy combatants.

For the foreseeable future, immersive, human-in-the-loop live environments like the IIT will remain a scarce resource due to the costs of live role players and the infrastructure investment required to design, implement and maintain the evocative

settings for exercises. Based on the comments of USMC users, the IIT appears to offer valuable training experiences.

Concluding the IIT visit, the Panel agreed with the observations of users that the greatest value of these training exercises is the trainees' interaction with the live role-players who act as Iraqi nationals, both as friendly civilians and insurgents. The panel believes that live role-players will remain at the IIT and similar trainers for the foreseeable future. Simulated humans at this level of cognition displayed in a compelling fashion are not in anyone's technology forecast, even when considering potential progress over multiple decades.

As a limited resource, the IIT's impact could, however, be augmented. The Panel sees a need to leverage what the IIT offers by more targeted pre-training in advance of Marines coming to the IIT. Today, all Marines receive training in a variety of individual skills that are required for a successful IIT evolution. What may be missing in pre-training for the IIT is in the area of higher-order, cooperative, decision-making exercises. This pre-training could involve squad-level desktop computer simulation. The Panel has no specific recommendations, but this should be reviewed.

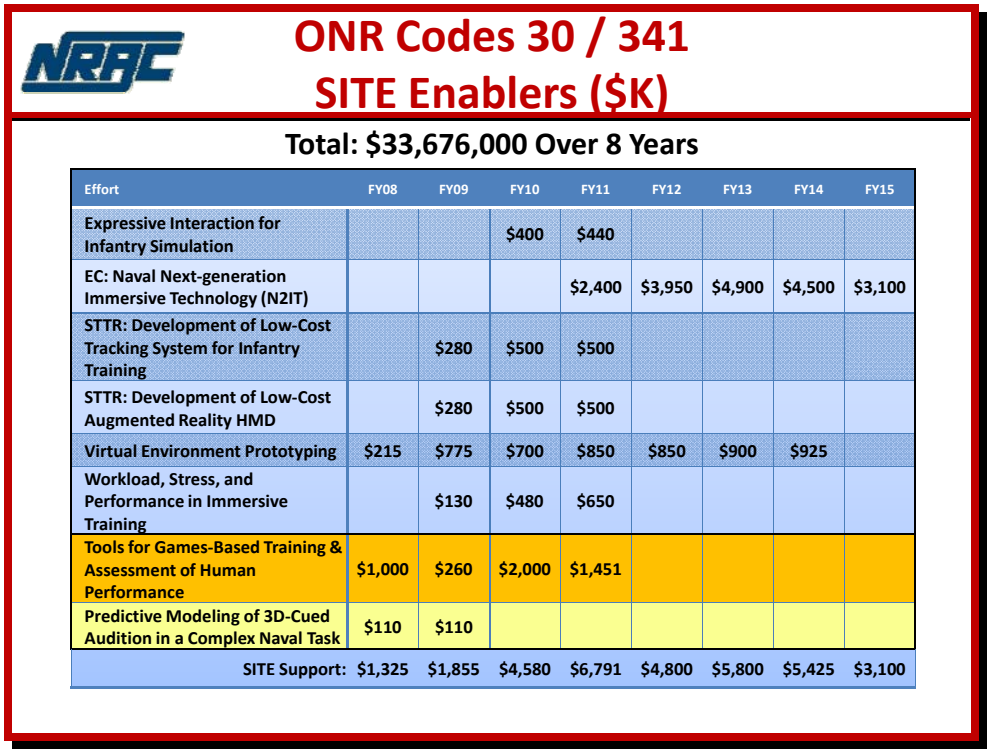
Additionally, the desired training effects – and corresponding cognitive skill capability required for exercises at the IIT evolution – could be "teased apart" to determine other means of accomplishing them. The next chart shows examples of this.

Training Decomposition: Example

TASK	EXAMPLE VENUE
Cultural "Norming"	Desktop
Cultural "Taboo"	Desktop
"Freezing" / PTSD	Virtual Reality
Decisions Under Stress	Mixed or Augmented Reality
Crowd Control	Mixed Reality

In this chart, broad categories of skills required for Irregular Warfare are listed with suggested possible cognitive training venues. In this case, all but Crowd Control could be experienced, the panel believes, in a meaningful way prior to exercise participation at the IIT.

Thus, while all of the items listed in this chart could be addressed in an institutional immersive environment like the IIT, the panel believes that students could maximize the benefit of their time in such exercises with prior experience in other, more modest, training venues. This could reduce USMC reliance on a scarce resource like the IIT.

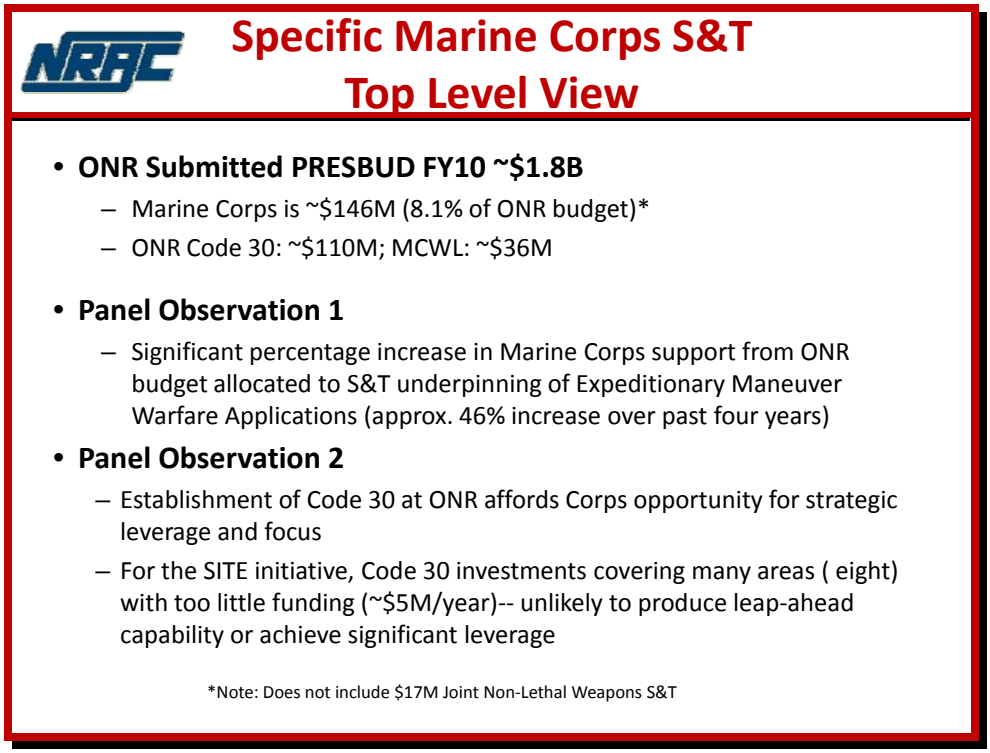


Effort	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Expressive Interaction for Infantry Simulation			$400	$440				
EC: Naval Next-generation Immersive Technology (N2IT)				$2,400	$3,950	$4,900	$4,500	$3,100
STTR: Development of Low-Cost Tracking System for Infantry Training		$280	$500	$500				
STTR: Development of Low-Cost Augmented Reality HMD		$280	$500	$500				
Virtual Environment Prototyping	$215	$775	$700	$850	$850	$900	$925	
Workload, Stress, and Performance in Immersive Training		$130	$480	$650				
Tools for Games-Based Training & Assessment of Human Performance	$1,000	$260	$2,000	$1,451				
Predictive Modeling of 3D-Cued Audition in a Complex Naval Task	$110	$110						
SITE Support:	$1,325	$1,855	$4,580	$6,791	$4,800	$5,800	$5,425	$3,100

What are the technology investments to support the required capabilities for the next generation of virtual simulations? To begin to answer this, the Panel reviewed the Office of Naval Research, Code 30 (Expeditionary Maneuver Warfare & Combating Terrorism Department) investment portfolio in the Human Performance Training & Education technology investment areas – primarily for support to the Marine Corps. Code 30 established a Science and Technology Objective (STO) that is specifically designed to support the previously-described SITE program, planned for 2012.

There is a broad range of S&T activity, however the level of funding for individual projects is quite small. For example, while there is some work to support the development of an augmented head-mounted display, the investment level could be categorized as "probing and discovery" rather than what would be sufficient to address the requirement.

The largest investment described is for a Future Naval Capability (FNC) that is focused on connectivity. It involves the ability for different simulation components to connect and also to collect large amounts of data for simulation runs. These are key requirements but will not address some the interface issues or the position location information challenges that are also essential for immersive simulation.



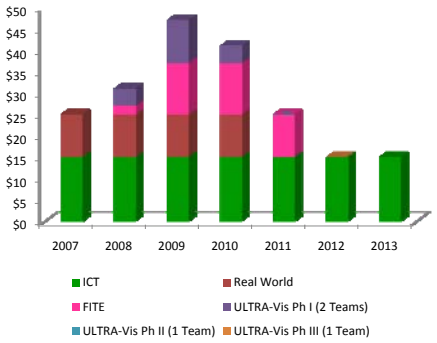
In 2005, the decision by ONR and the Marine Corps to establish Code 30 was an opportunity for strategic focus and leverage. Currently, about 8% of the total ONR FY10 Presidential Budget Request is allocated for Marine Corps S&T, approximately $146M. This amount is divided between the Expeditionary Maneuver Warfare and Combating Terrorism S&T Department (Code 30), and Marine Corps Warfighting Laboratory (MCWL). It represents a 46% increase over the funding of PBR2006. It is a result of the recognition by the Marine Corps and the Chief of Naval Research (CNR) to address the inadequate level of funding for developing Expeditionary Maneuver Warfare capabilities. In view of the importance that the Secretary of Defense has recently placed on the requirements of our ground forces, the Marine Corps and the CNR will need to increase their focus on these important requirements.

. In the Panel's judgment, the current array of SITE programs are mostly sub-critical investments and are unlikely to produce leap-ahead capabilities or enable other efforts in the Services or DARPA to be leveraged effectively. Code 30, with Marine

Corps support, should begin a prioritization of SITE products in order to focus on fewer, more significant higher-priority investments.

Other Current DoD S&T IS Investments

- **FITE JCTD**: An effort to integrate current capabilities to develop an overarching operational utility assessment. Emphasis is on scenario-based training.
- **ICT**: Army-backed university research center focused on the artificial intelligence aspect of the immersive simulation challenge
- **RealWorld**: DARPA program developing a simulation software application authorable by non-technical users



- **ULTRA-Vis**: DARPA program… While not focused on training per se, this effort to create a lightweight augmented reality display and gesture-based control system may have application in the training community; Funded in Phase I; Phase II? FY09-11

Beyond the ONR activities, the Panel also looked at other Department of Defense investments in this S&T area. While not directly related to the focus of the study, these developing programs may hold potential for advancing the required immersive simulation training technologies. The Joint Forces Command is sponsoring the Future Immersive Training Environment (FITE) Joint Capabilities Technology Demonstration (JCTD). As a technology demonstration, the FITE JCTD will determine what is currently possible, available, and able to be integrated into other training. It will provide a comprehensive market survey of the technology space – but will not actually advance the technology.

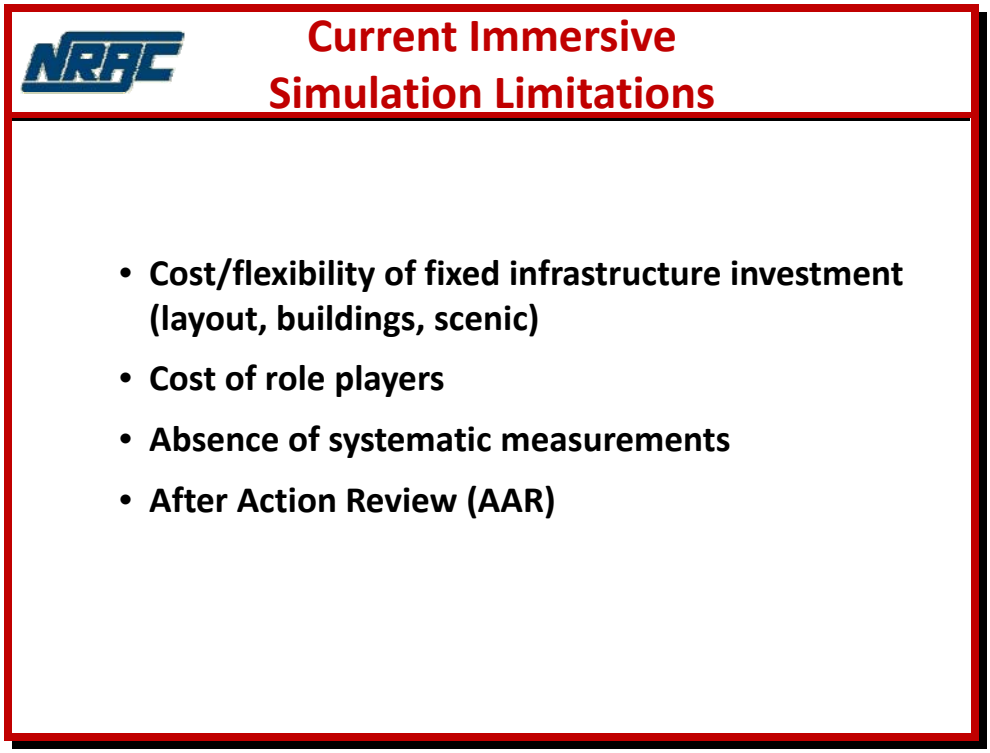
The Institute for Creative Technologies (ICT) was created by the Army in 1999 to revolutionize the learning experience through active engagement with the Entertainment Industry – attempting to leverage their significant investments. This would lead to the development of interactive digital media with a focus on advancing artificial intelligence (AI) for computer-generated virtual humans, photo-realistic computer graphics and learning technologies generally. The Army investment in the ICT is projected to continue, but most subject matter experts doubt that the actual transition of

comprehensive AI for avatars will occur for “decades”. Some experts will say “not in my lifetime”.

Real World was a relatively short-term activity at DARPA that produced a set of applications with a single goal – to make it possible for non-technical users to build their own simulations. This is important because, if an infantry commander wants to create a bespoke simulation (i.e. one custom-made to his own specifications), with a terrain mesh and activities to challenge his unit in particular, it’s an enabler. But, it doesn’t really solve those hard immersive simulation challenges that the panel determined were significant obstacles to Marine Corps small unit immersive simulation training.

DARPA’s Urban Leader Tactical Response, Awareness Visualization project (ULTRA-Vis) is a tactical (vice training) system that is currently approaching Phase 1 completion. One of its key components is a lightweight, head-mounted display. While it may not have the kind of acuity and optical characteristics that are necessary to produce a high quality, immersive training experience, it will likely advance the state of the art in head-mounted displays. However, follow-on work will be necessary – in a Phase 2 and possibly Phase 3 – to advance the technology for transition to a practical tactical system. Further work will then be required to develop an ULTRA-Vis based advanced immersive training display system.

Conclusions



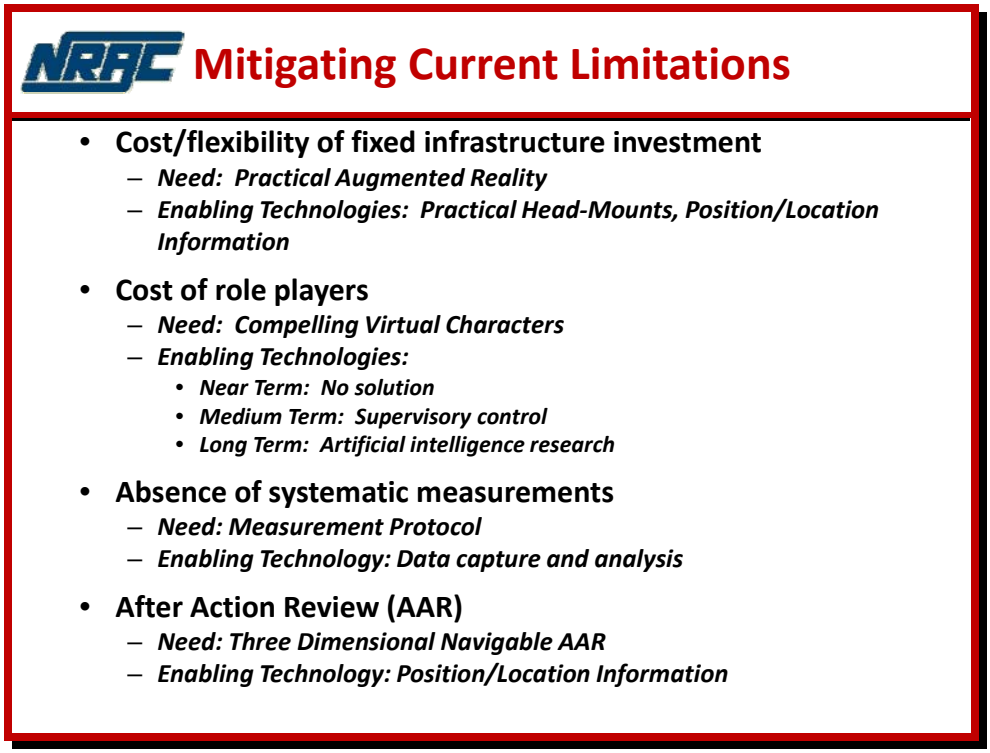
During the course of this study, the panel concluded that there are certain limitations in the current tools available for immersive simulation. As an example, when considering the Infantry Immersive Trainer, it will be noted that it is currently configured to simulate an Iraqi village. This involves environment-specific scenery, buildings, landscaping, and equipment. It stands to reason that making substantial changes to represent another geo-specific area (e.g. Afghanistan) will involve significant effort and cost. Considering the uncertain and continuously changing nature of future Marine Corps operations, it would be desirable to have more flexibility in configuring a structure for immersive simulation training.

In addition to the physical set utilized at the IIT, the extensive use of role players is a limiting factor. Participants who had experienced training at the IIT were unanimous in their agreement that the role players were the most important component of their rotation at the facility. The cost of role players is high, there are limitations on role

player availability, and the hours they can work. Recruiting and training more role players is potentially a time-consuming and expensive proposition.

To this point, there has been no systematic collection of data at the IIT. More extensive instrumentation is needed to provide baseline data for comparative evaluations of training goals and success. Additional metrics may need to be considered as well, perhaps along the lines that Dr. Roman suggested in his Canadian study.

The After Action Review is somewhat limited at the IIT. Basically, the AAR is a playback of network of cameras' video streams, like a civilian security surveillance console.. Although reviewing the videos provides some post-exercise evaluation opportunity, the process suffers from the absence of metrics.



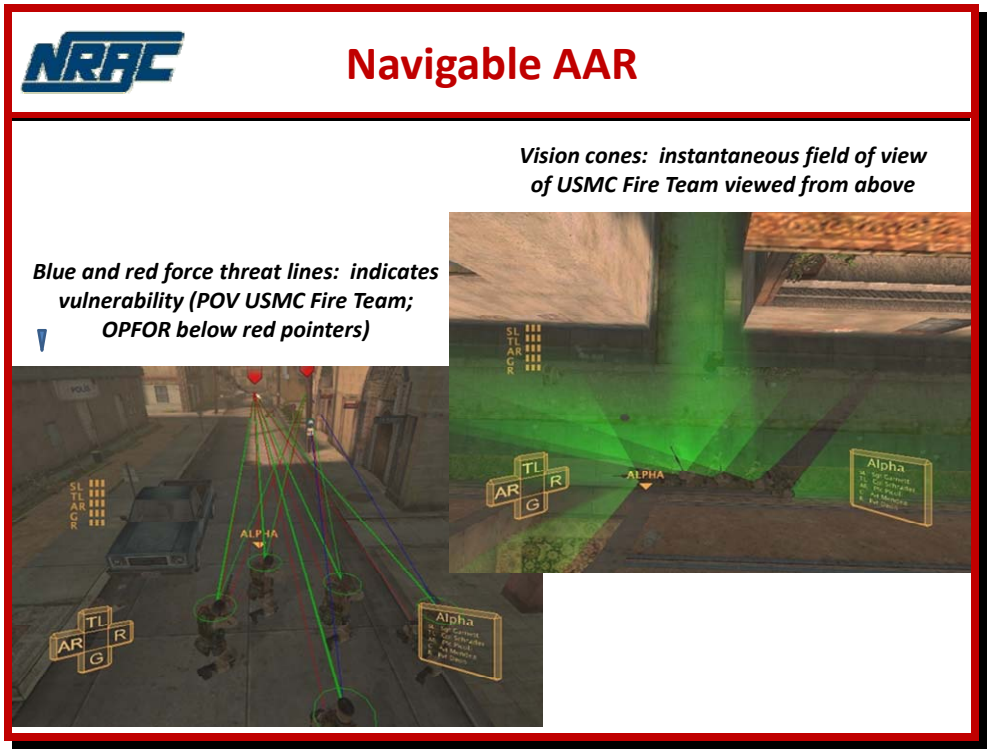
There are a number of possibilities for mitigating some of the limitations of the current IIT configuration. First, in order to avoid the high costs of Marine Corps' Military Construction (MILCON) for additional fixed infrastructure environments, better use of practical augmented reality is needed. For example, using head-mounted displays could create a system in which new environments could be projected for the user in the normal field of view. This approach, however, will require the development of practical and affordable lightweight optical see-through HMDs along with MOUT site-sized, exterior-capable high-resolution Position/Location Information (PLI) technology.

To overcome the high cost of the role players, there is a striking need for compelling, interactive virtual characters. While some research is underway in this area, there is not a near-term solution evident and may, in fact, be decades away or longer. In the mid-term, however, use of supervisory control, as currently expressed in the robotics domain, could possibly enhance the use of virtual characters. In this scheme, a single human operator would control a number of virtual characters/avatars (specific limitations

to be determined), and would develop interactions among those characters as well as with other characters controlled by other humans, as well as with the participants in the immersive simulation training. As stated previously, absolute use of artificial intelligence to create life-like human avatars is extremely challenging and probably not possible for many decades.

In the opinion of the Panel, the most straight-forward improvement to the current IIT is to add *systematic* evaluation measurements or metrics. Having systematic metrics will allow commanders to better ascertain unit readiness and the relative value of a specific immersive training evolution. It does not eliminate the subjective evaluation of subject matter experts; rather it captures their observations and opinions in a systematic fashion that can be incorporated into a more rigorous evaluation. An example previously discussed was the work of Dr. Roman in assessing tank commander training. He utilized expert evaluators to compare student performance in two groupings – those with some exposure to simulation training and those who only had didactic training in a classroom. Even this admittedly basic systematic measurement scheme can provide the basis for comparisons of different immersive simulation environments – an eventual step forward for acquisition trade-offs.

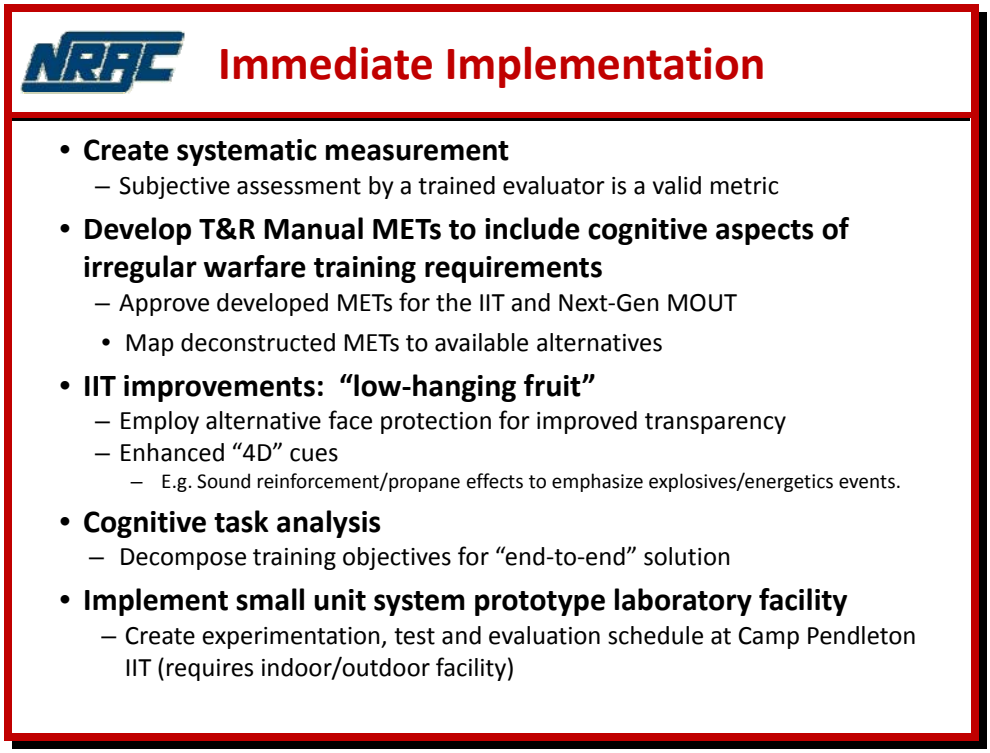
Finally, substantial improvements can be made to the After Action Review with the employment of a three-dimensional, high fidelity navigable system. This would incorporate the objective PLI capability previously mentioned, as well as implementing the systematic capture of the data.



Two examples of full 3-D AAR screen-shots are shown above. An instrumented, three-dimensional navigable system provides high data fidelity for accurate positioning and location of each participant.

Threat lines are displayed showing an individual Marine's vulnerability to OPFOR targeting and, conversely, his opportunities to return fire. A cone-of-vision view can highlight missed tactical surveillance coverage. This capability enables a comprehensive post-training assessment of the instantaneous threat conditions encountered by the squad or fire team during the session.

Recommendations



Any initiative to implement immersive simulation training across the Marine Corps will not likely survive without strong, vocal support from the top leadership. Additionally, the initial transition from S&T and/or the operational communities to an acquisition program is likely to be high-risk unless specific and measurable requirements are first established – along with the appropriate metrics.

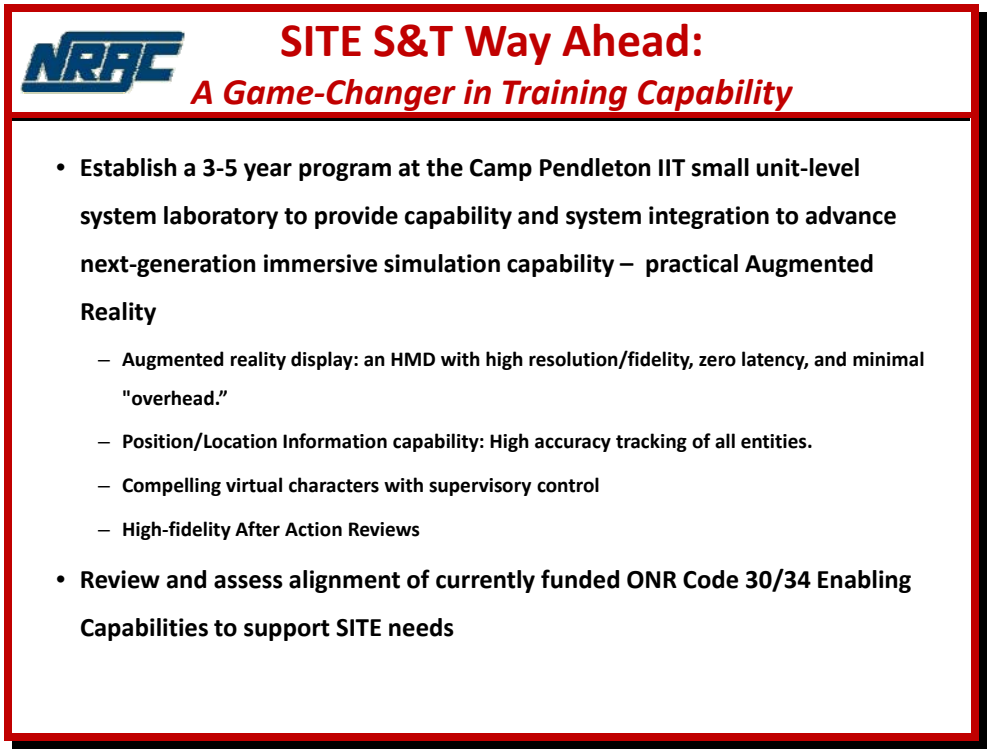
The Panel recommends the following: first, create a systematic measurement program for existing immersive training simulations; second, adjust the mission-essential tasks (METs) in the T&R Manual to include the cognitive decision-making aspects of irregular warfare. Then begin mapping the new, evolving METs into the available simulation training alternatives. These alternative training approaches can then be validated using the systematic measurement system.

Third, "Low-hanging fruit" opportunities exist today that can improve the effectiveness of the ITT. A fairly intuitive example is sound reinforcement to enhance

realism – not unlike the high-volume, surround-sound of a Hollywood movie. At present, when a simulated explosion occurs in the IIT – it's loud – but it lacks the full spectrum acoustical force that accompanies a real explosive event. By building up the IIT sound capability, the Marines would be offered the full infrasound (low frequency sound pressure) experience to gain a higher degree of immersive effect.

Fourth, attempt decomposing the basic training objectives – especially in the higher-order cognitive tasks – to discover which sub-tasks could be enhanced through simulation training. Initial studies done at the University of Central Florida, under contract to ONR, show that some task learning is better achieved using simulation training *than in the real world*.

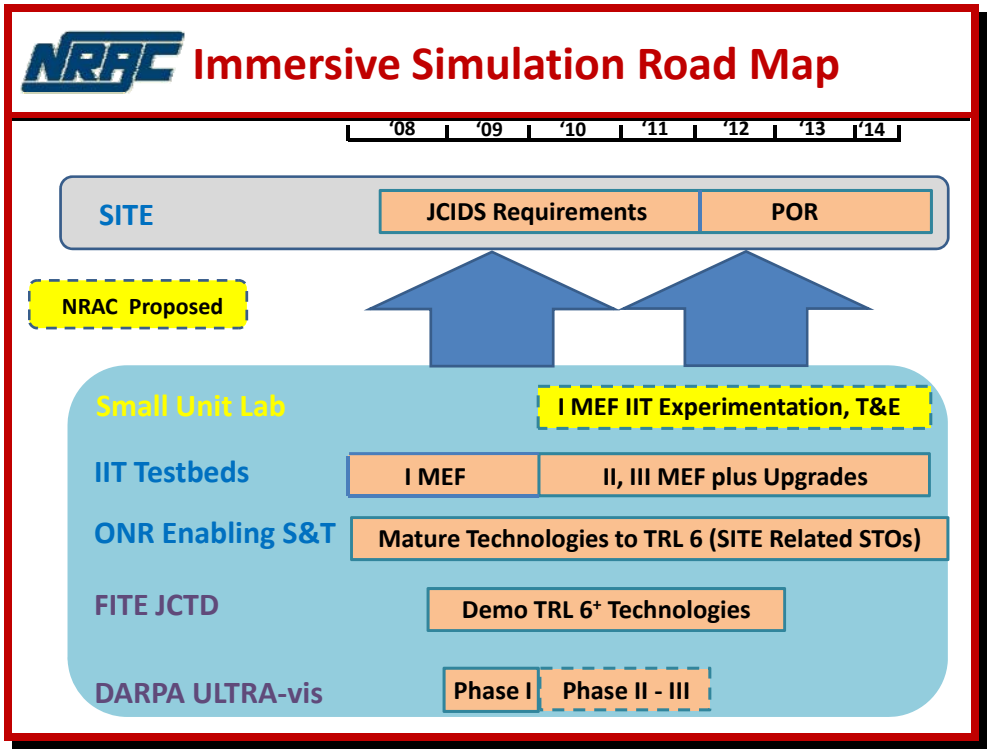
Finally, the Panel strongly recommends that the ITT be turned into a laboratory after hours. Operations currently end when it's quitting time – and everyone goes home. The ITT could easily be used during off-training hours to develop and test new training simulations, new training scenarios, and additional training effectiveness measures. This "laboratory at night" would require adequate resourcing for planning, staffing, and technology insertion.



As stated earlier, an immersive simulation training capability will probably not survive the Pentagon "budget battles" without strong and consistent senior Marine Corps leadership support.

That said, the NRAC Panel believes that the initiation of a significant immersive simulation training program for transition to the operating forces will be perceived as high risk to the acquisition community. Therefore, the Panel strongly recommends that the Marine Corps create a small unit training system laboratory or test bed – probably using the existing IIT facility during its daily downtime – to allow the early introduction of emergent, immersive simulation technologies to be integrated in an orderly systems approach. The ONR SITE Program will be investing in a number of requisite immersive technologies. The Army and DARPA also may have technologies of interest. But, even if individual immersive components are successfully developed – the community won't know – the Marine Corps won't know – if, in fact, they will work together to create a satisfactory product.

Finally, the Panel encourages a detailed review of all ONR Code 30/34 enabling technologies to ensure the proper priorities are assigned to support SITE. The goal is to create practical augmented reality to provide a game-changing capability for Marine Corps training.



This chart shows a macro level road map for advancing infantry immersive simulation in the Marine Corps. It identifies the key science and technology enablers and activities currently underway in this technology space. It is not known if the DARPA ULTRA-Vis will be funded beyond Phase I, but the program merits support and needs to be monitored. The FITE JCTD will demonstrate Technology Readiness Level (TLR) 6 and above technologies that may be appropriate for transition into Squad Immersive Training Environment (SITE).

The ONR Code 30 and 34 enabling technologies relating to Human Performance Training & Education should continue to be funded and advanced. The Marine Corps has funding for and will stand up Infantry Immersive Trainer simulation centers for II MEF and III MEF during 2010.

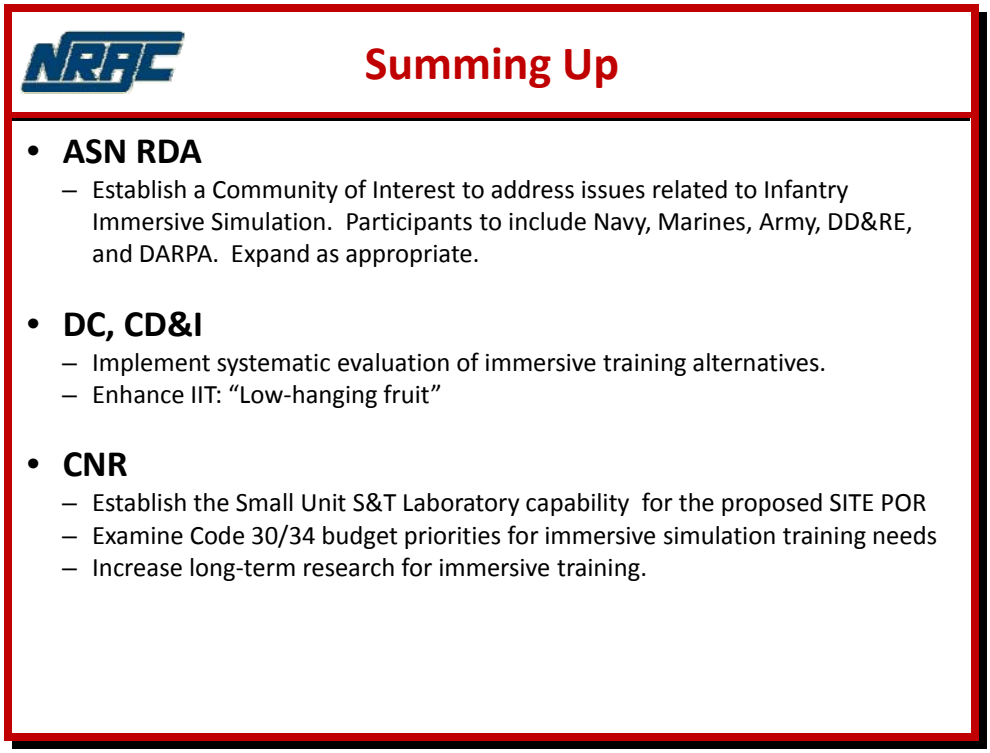
To support technology experimentation, and test & evaluation, the Panel recommends that the Marine Corps identify one of the IIT test bed's to be co-used as a

Small Unit Laboratory. Because the I MEF IIT will have the capability to support both indoor and outside training, we recommend the Lab be co-located at the current Camp Pendleton site.

The research community has undertaken many of the challenges associated with the development of the technologies for immersion simulation training. Today, there are cockpit trainers that are so immersive – for both pilot training and evaluation – that the Services and the Federal Aviation Administration (FAA) allow their substitution for much of the actual flying syllabus. Unfortunately, this level of maturity has not been reached for immersive small unit infantry training which necessarily includes an almost limitless variety of localities, environments, and threats.

The Panel found a number of early research efforts at ONR and elsewhere that – if fruitful – will enable simulations to become more realistic to enhance the learning process and to decrease the operator costs associated with humans-in-the-loop. As shown above, examples of these involve the automation of critical portions of the training environment: role-players, the training scenario itself; as well as individual mobility in an immersive environment. These are not easy problems but the investment in these areas should continue.

There are also areas that need more emphasis. These are longer-term scientific questions that get to the heart of military immersive training: what is stress, how can it be measured, how can it be safely induced in a training situation so it may “inoculate” the trainee to its worst physiological and psychological effects.



This figure shows the Panel's top-level recommendations, with appropriate assignments for action.

Because it is likely that the Marine Corps will continue to supply ground combat forces to various theaters for the foreseeable future, the ASN RDA should be the Pentagon advocate for the establishment of an immersive training "Community of Interest". As Lt Gen Flynn has stated, "the goal must be to take training capabilities to the next level and fuse current, emerging, and future live and virtual technologies to create a fully-immersive live/virtual training environment". This new group would address issues related to infantry immersive simulation with participation from the Navy, Marines, Army, DD&RE, and DARPA.

The Deputy Commandant for Combat Development & Integration (DC, CD&I) should implement a systematic evaluation of immersive training alternatives to make near-term capability improvements. This evaluation should address "low hanging fruit"

for the IIT such as the addition of enhanced acoustics and sound reinforcement which can greatly improve simulated reality effects.

The Panel's critical recommendation is for the CNR to establish the Small Unit S&T Laboratory to explore the development issues for a SITE capability. Also, the CNR should evaluate budget priorities in ONR for supporting Code 30; its current efforts are spread widely and seem unlikely to produce significant results.

If all of these recommendations are followed, then as GEN Mattis (Commander, US Joint Forces Command) stated "…a giant leap forward in our simulated training environment for small units in ground combat …to replicate to the degree practical using modern simulation, combat scenarios that will test our small units …" will have been addressed.

The objective at the end of the day is for a Marine – facing live combat for the first time – will have already experienced numerous engagements of equivalent intensity but without equal consequences. So that his first battles, the battles that harden and make him vastly more likely to survive, are virtual.

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Appendix A
Terms of Reference

Terms of Reference
Immersive Simulation for Marine Corps Small Unit Training
NRAC Summer Study 2009

Objective

Study concepts of immersive training simulation to assist Marines in developing complex and 'intuitive' decision skills while under the attendant conditions of physical and emotional stress. This study will examine how immersive simulations may have the potential to reduce the pre-deployment time required to train small unit leaders over that of other contemporary training approaches and methods. The study should expand on current concepts and provide insights on new Marine Corps training for the small unit.

Background

The complexity of the Contemporary Operational Environment and the enduring need for combat readiness across the full spectrum of conflict and environmental extremes place new demands on the decision-making skills of Marine Corps small unit leaders. Making the best tactical, legal and ethical decisions under conditions of emotional, psychological, and physical duress has stimulated great interest in new kinds of training and simulation to prepare these leaders for combat. With a goal of developing 'experienced' decision-making ability prior to actual deployment, new forms of immersive training simulation may assist Marines in developing these complex and 'intuitive' decision skills while under the attendant conditions of physical and emotional stress. Moreover, immersive simulations may have the potential to reduce the pre-deployment time required to train small unit leaders over that of other contemporary training approaches and methods. Simulating the most critical of combat conditions is both necessary and extremely challenging.

Specific Tasking

- Decompose this problem and identify the desired effects that must be produced by such training. With the problem deconstructed and fully defined, examine the attendant the metrics necessary to gauge solution (training) effectiveness.
- Review current and developing virtual training methods and technologies in the DOD, as well as other agencies and allies, both within and outside of the government.
- Identify and evaluate S&T initiatives (US and allies) that are being pursued and explore opportunities that should be accelerated.
- Recommend technology solutions, investments and developments required.

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Appendix B

Briefer List

Briefers	Office/Organization
Col Frank Kelley, USMC; Ms. Nancy Harmon	Marine Corps Program Manager for Training Systems
Mr. Jack Sparks	Marine Corps Warfighting Lab, Modeling and Simulation Branch
Mr. Dennis Thompson, Major Brent Goodrum, USMC, Mr. Earnest King	USMC Training and Education Command
Mr. Gary Fraas	Naval Air Warfare Training Center Training Systems Div, Advanced Simulation, Visual & Software Systems Division
Mr. Tim Sayers, Mr. Don Whitley, Mr. Rob Miller	Army PEO Simulation, Training, and Instrumentation
Dr. Charles Hughes, Professor	University of Central Florida School of Electrical Engineering & Computer Science, Media Convergence Laboratory
Mr. Jay Reist, Mr. Clarke Lethin, Mr. Pete Muller	Future Immersive Training Environment (FITE) JCTD
Col Chris Macedonia, USA, M.D.	Medical Science Advisor to the Chairman of the Joint Chiefs of Staff
Mr. George Solhan, Dr. Roy Stripling, Mr. Pete Muller	ONR Code 30 (Expeditionary Maneuver Warfare & Combating Terrorism Department)
Dr. Mike Macedonia, Mr. Bart Bartlett	Fortera Federal Systems
Dr. Steve Goldberg	US Army Research Institute
Mr. Kevin Cippant	L-3 Com, Link Simulation and Training
Mr. Dell Lunceford	Total Immersion Software, Inc.
Mr. Mark Bolas, Mr. Kim LeMasters	Institute for Creative Technology, University of Southern California

Briefers	Office/Organization
Mr. Jim Mowery, Mr. Tom Wilson	Training, Doctrine, and Combat Development, US Army Armor Center
Dr. Cali Fidopiastis	Applied Cognition and Training in Immersive Virtual Environments Lab, Institute for Simulation and Training, University of Central Florida
LTC Chris Niederhauser, USA	Fires Battle Lab, US Army
Mr. Jeff Singleton	Deputy Director for Research, Office, Deputy Assistant Secretary of the Army (R&T) SAAL-TR
Dr. Amy Vanderbilt	DARPA
BGen Murray, USMC	Marine Corps Warfighting Lab
Dr. Mark Livingston	Naval Research Lab
Dr. Jeff Wilkinson	MYMIC, LLC
Col Craig Langhauser, USA	US Army Development, Research and Engineering Command, Simulation and Training Technology Center
Dr. Jonathan Gratch	Institute for Creative Technology, University of Southern California
Ms. Julia Kim	Institute for Creative Technology, University of Southern California
Mr. Ryan McAlinden	Institute for Creative Technology, University of Southern California
Dr. Mark Core	Institute for Creative Technology, University of Southern California
Mr. Ken Falke	A-T Solutions
LtGen Flynn, USMC	Deputy Commandant for Combat Development and Integration
Mr. Jeff Bergenthal, Mr. Richard Boyd	Lockheed Martin, Sarnoff Labs
Dr. Sae Schatz	University of Central Florida

Briefers	Office/Organization
Mr. Darrell Smith, Mr. Rob Lechner	Boeing, Integrated Defense Systems Training Systems & Services
Dr. Michael Van Lent	Soar Technologies
Dr. Paul Roman	Royal Military College of Canada
Mr. Warren Katz	MAK Technologies, Inc.
Dr. Elaine Raybourn, Mr. Dan Small	Sandia Labs

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Appendix C

Acronyms

AAR	After Action Review
AI	Artificial Intelligence
ASN(RDA)	Assistant Secretary of the Navy for Research, Development, Acquisition
CNR	Chief of Naval Research
CCS	Combat Convoy Simulator
DARPA	Defense Advanced Research Projects Agency
DC, CD&I	Deputy Commandant for Combat Development & Integration
DVTE	Deployable Virtual Training Environment
FAA	Federal Aviation Administration
FITE	Future Immersive Training Environment
FNC	Future Naval Capability
ICT	Institute for Creative Technologies
IED	Improvised Explosive Device
IIT	Infantry Immersive Trainer
ISMT	Indoor Simulated Marksmanship Trainer
MCWL	Marine Corps Warfighting Laboratory
MEF	Marine Expeditionary Force
MILCON	Military Construction
MET	Mission-Essential Task
OPFOR	Opposing Force
PLI	Position/Location Information
PTP	Pre-Deployment Training Plan
RPG	Rocket-Propelled Grenade
SITE	Squad Immersive Training Environment
STO	Science and Technology Objective

T&R	Training and Readiness
TOR	Terms of Reference
ULTRA-Vis	Urban Leader Tactical Response, Awareness Visualization