Live-Virtual-Constructive Training Environment Analysis of Alternatives Lessons Learned

Eric Whittington, William Brobst
Johns Hopkins University / Applied Physics Lab
Laurel, MD
eric.whittington@jhuapl.edu,
william.brobst@jhuapl.edu

Byron R. Harder
U.S. Marine Corps Training and Education Command
Quantico, VA
byron.harder@usmc.mil

ABSTRACT

The Marine Corps Systems Command (MCSC) and Training and Education Command (TECOM) recognized the need to develop a detailed analytic methodology to justify fiscal decisions for procuring and fielding live-virtual-constructive training environment (LVC-TE) capabilities. The analytic challenge was a unique endeavor for a complex system of systems with no prior analog identified, and external guidance demanded more concrete analysis and return on investment metrics. The Marine Corps LVC-TE Analysis of Alternatives (AoA) began with a training and readiness (T&R) based requirements analysis and the definition of a measures of effectiveness hierarchy. This paper will summarize lessons learned from the LVC-TE AoA and the associated methodologies that were developed. The AoA's analytic methodology traced capability requirements to the T&R training basis, and the metrics hierarchy captured current training requirements, future training requirements, institutionalization of enterprise capabilities, and compliance with external requirements. The analysis covered all four elements of the Marine Air-Ground Task Force for both home station training and service level training, linking mission essential tasks with T&R events across collective training audiences. The analysis used workshops, interviews, and briefings for primary stakeholders to gather data. Distinctive, strategic technical alternatives were determined, refined, and assessed against the measures of effectiveness and cost to complete the analytical framework. The technical alternatives spanned a wide range including connecting current Marine Corps systems, using existing LVC solutions across the DoD, and developing a new fully customized solution. Lessons learned from this comprehensive effort have applicability to broader requirements and acquisition audiences requiring analysis of similar training capabilities, and should be applicable to ensuring adaptability of training systems to meet evolving technology capabilities. The draft AoA final results have been briefed and accepted by the milestone decision authority and TECOM, and MCSC is pursuing procurement actions consistent with the AoA analytic methodology and metrics hierarchy.

ABOUT THE AUTHORS

Eric Whittington is a senior research analyst at the JHU/APL in Laurel MD. He is a retired Marine Corps modeling and simulation (M&S) officer with a master's degree from the Naval Postgraduate School in Modeling, Virtual Environments, and Simulations. His background includes 24 years of combined military experience and M&S policy analysis within the Marine Corps. Currently, he serves as an M&S subject matter expert within the National Security Analysis Department. Mr. Whittington has led analysis efforts for standards supporting the Marine Corps M&S Office (MCMSO) and the Navy M&S Office.

William Brobst, Ph.D. is a member of the senior professional staff at Johns Hopkins University Applied Physics Laboratory (JHU/APL), working in the areas of readiness and training in the aviation, surface, and ground combat communities. Prior to JHU/APL, he spent 29 years as an analyst and team leader at the Center for Naval Analyses (CNA). Major analytic themes include understanding how training influences real-world performance, the development and sustainment of tactical proficiency, and optimizing the contributions of different training formats (e.g., live fire, force-on-force, and simulation). He holds a Ph.D. in Physical Chemistry from the Johns Hopkins University.

LtCol Byron R. Harder, Ph.D. is the Synthetic Training Integration and Management Branch Head at the Marine Corps Training and Education Capabilities Division in Quantico, VA. He is an active duty modeling and simulation (M&S) officer with a Ph.D. in Modeling, Virtual Environments, and Simulations. His background includes 20 years of military experience, including acquisition, requirements, and resource sponsorship positions. His current duties are focused on the modernization of the Marine Corps Synthetic Training Enterprise and the requirements and resource sponsorship of ground training simulations.

Live-Virtual-Constructive Training Environment Analysis of Alternatives Lessons Learned

Eric Whittington, William Brobst
Johns Hopkins University Applied Physics Lab
Laurel, MD
eric.whittington@jhuapl.edu, william.brobst@jhuapl.edu

Byron R. Harder
U.S. Marine Corps Training and Education
Quantico, VA
byron.harder@usmc.mil

BACKGROUND

Although certain fundamental properties of state and non-state conflicts are constant, their expression through technology and tactics continues to change across the range of military operations. United States Marines must be able to conduct operations on a dispersed battlefield under decentralized command and control (C2), performing coordinated tasks across multiple mission areas. They will only be successful if training keeps pace with the demands of future operating environments. While live training for units can never be replaced, training opportunities can be optimized using the full range of virtual and constructive training tools—before, during (integrated with), and after live training events. The objective of the live-virtual-constructive training environment (LVC-TE) is enhanced planning, preparation, execution, and assessment capabilities for the Marine Air Ground Task Force (MAGTF), leading to greater combat readiness (Training and Education Capabilities Division, TECOM 2015).

The Marine Corps recognized the need for LVC-TE in 2008 through a capabilities based assessment, which informed an initial capabilities document (ICD). The ICD was approved by the Marine Requirements Oversight Council in 2010 (Headquarters, USMC 2010). Subsequently, Training and Education Command (TECOM) formed a Working Integrated Planning Team (WIPT) together with the Marine Corps Systems Command's (MCSC) Program Manager for Training Systems (PM-TRASYS) and representatives from the operating forces. In 2014, the Marine Corps' annual Large Scale Exercise—a traditionally live Marine Expeditionary Brigade training event—was used to demonstrate and test LVC interoperability using the simulation systems available at that time. Although it showed the technical feasibility of an integrated training environment, it also highlighted several challenges with providing a long-term solution with repeatable processes, including the lack of programmed resources, the need to base integration investments upon prioritized training objectives, and the constraints and restraints of cybersecurity (including multi-level security for simulations with different classification levels). The WIPT produced a Concept of Operations (CONOPS, most recently signed by Commanding General, TECOM in 2015), a set of Department of Defense Architecture Framework operational and system views, and a draft capabilities development document, but the effort stopped short of moving forward as an acquisition program, stymied by a constrained resource environment and debate about whether LVC-TE should even exist as a separate and distinct program—the alternative being a set of interoperability standards and requirements levied across several already-existing simulator programs.

Despite programmatic challenges, demand for LVC-TE continued to grow. Local simulation centers invested their own limited resources to create "linked training events" where possible; for example, Marine Aviation Weapons Training Squadron 1 took its Supporting Arms Virtual Trainer out of programmatic configuration management control to integrate it with local flight simulators. But cybersecurity continued to be a nearly insurmountable hurdle without enterprise-level support, and solutions were not resourced well enough to be maintained and shared across sites in a consistent way. Meanwhile, the other services were establishing their own LVC programs and networks: the U.S. Army's Live Virtual Constructive Integrating Architecture, the U.S. Navy Continuous Training Environment, and the Air Force Distributed Mission Operations Network. In 2015, a Front End Assessment by the Deputy Commandant for Programs & Resources recommended that a separate Marine Corps Program Code (i.e. a tracked funding line) be established for LVC-TE (Program Analysis and Evaluation Division, Headquarters, USMC 2015). The Deputy Commandant for Combat Development & Integration conducted a three-phase LVC-TE Network Study, drawing lessons learned from the other services and recommending governance and network approaches for the Marine Corps. Strategic documents, such as the 2015 Commandant's Planning Guidance and the 2016 Marine Corps Operating Concept, continued to call for LVC-TE. In 2017, TECOM and MCSC agreed to conduct an Analysis of Alternatives (AoA) for LVC-TE to inform a decision on transitioning the effort into the Defense Acquisition System.

One of the challenges with an LVC integration program is the expectation that it will be "all things for all people." To help clarify the scope of the analysis—and the program—TECOM defined the Marine Corps Synthetic Training Enterprise (MCSTE) as the entire set of capabilities (across multiple programs) for training the MAGTF, including ranges, simulators, services, and data. Within the framework of the MCSTE, it defined LVC-TE as an enabling program for the MCSTE, focused on interoperability solutions, shared tools, and common services. Even with this scope clarification, the LVC-TE Network Study had shown that the number of possible combinations of training audience types, training objectives, command and control systems, and training systems were intractable (in the millions) for an exhaustive analysis (JHU/APL 2017b). One of the first decisions that the AoA team made was to limit the study to a representative set of training scenarios for user communities with approved Training and Readiness (T&R) Manuals (or mature drafts, where necessary, at the study director's discretion). Given the general organization of training needs into individual, collective, and staff categories, the team further constrained the study to collective and staff requirements, since those were more likely to be addressed by LVC interoperability (JHU/APL 2019).

The AoA team organized into four working groups (WGs) to address different aspects of the analysis: Operational Concepts and Scenarios (OCSWG), Effectiveness (EWG), Technical Alternatives (TAWG), and Cost (CWG). The remainder of this paper discusses how the working groups analyzed training requirements; defined technical alternatives to meet those requirements; determined measures of effectiveness for the alternatives; compared the alternatives with respect to effectiveness, schedule, cost, and risk; and presented the results of the analysis to senior leadership for decision. We conclude with a summary of lessons learned from the effort. The remainder of this paper contains information cited from the Johns Hopkins University / Applied Physics Laboratory (JHU/APL) 2019 AoA final report listed in the references.

REQUIREMENTS ANALYSIS

The first phase of the analysis involved the definition of training scenarios, i.e. use cases. The OCSWG had two sources to draw from: the 2015 CONOPS and the 2017 Network Study Phase II Report. The team rationalized the two different descriptive approaches of both documents and merged overlapping scenarios. It should be noted that *scenario* is an overloaded term; in the world of training delivery organizations such as a battle simulation center, a scenario is a very specific and detailed product built or tailored for a specific unit's training event. For the AoA, a scenario is a more generic artifact comprised of the following:

- The set of Mission Essential Tasks (METs) to be trained
- The set of training audiences that need to work together for collective MAGTF tasks
- The list of community specific T&R Events relevant to the scenario for each training audience
- Aspects of the operational environment that must be represented to each training audience to set the conditions for effective training
- Equipment, such as weapon systems or command and control systems, that the training audiences need to operate effectively in order to meet training objectives
- Response cell requirements: descriptions of the entities that the training audiences must interact with but will not be represented by other training audiences, and therefore must be "played" by the training support staff

The study team ended up with seven total scenarios, ranging in unit size from a reinforced infantry company to a Marine Expeditionary Force (three-star command) staff. The OCSWG developed each scenario using the process depicted in Figure 1, documenting structured output (METs and T&R Events) in scenario spreadsheets and less structured output in word processor files. Due to time constraints, some scenarios were developed in parallel. This required a surge in AoA personnel support, both for military subject matter expertise and for data collection. The bulk of the work was done over the course of a two-week workshop, with some detail gap-filling and refinement in the following weeks.

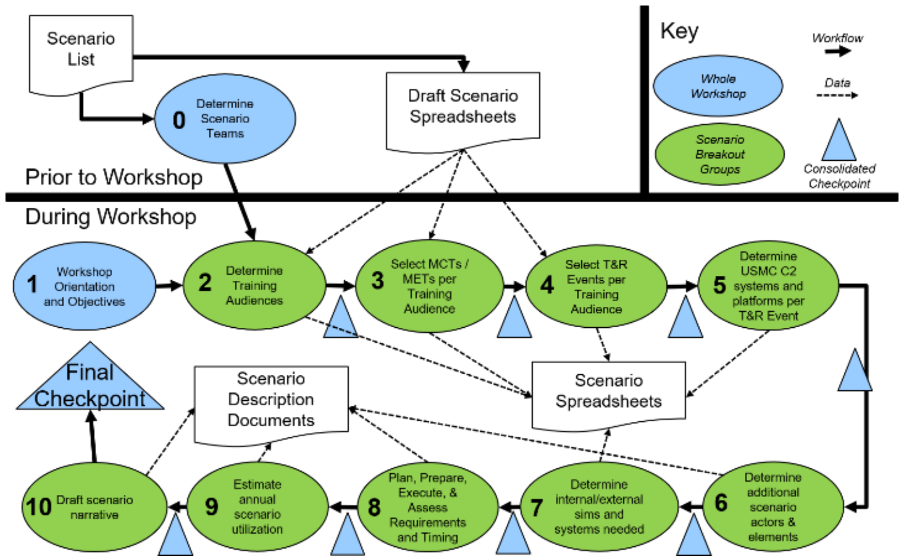

Figure **1**. Scenario Development Process

METRICS

The EWG conducted a series of technical exchange meetings with members from the TAWG to understand the technical variations that may be useful in comparing one alternative against another. In addition, the OCSWG output artifacts helped to frame the hierarchy of metrics for comparing alternatives. The metrics were grouped into four major aggregations that were useful in the final comparison:

- <u>Today's documented requirement</u>. These metrics directly related to the OCSWG scenarios development and the percentage of T&R events enabled by the alternative for each scenario grouped by three echelons of training audiences (Marine Expeditionary Brigade and Marine Expeditionary Force level; Marine Expeditionary Unit level, small collective unit level). They also addressed the time to achieve a training standard and the ability to easily modify the software—challenges that today's trainers face.
- <u>Tomorrow's undocumented / unknown training requirement</u>. These metrics focused on being prepared to add new or replace outdated capabilities to accommodate new training requirements that currently do not have a validated training basis, such as a T&R manual. Alternatives were scored on their compatibility with modular open systems approach (MOSA), ability to connect multiple classification enclaves in a single training environment, and scalability with respect to geographically distributed training audiences.
- <u>Enterprise requirement to plan, prepare, execute, and assess</u>. These metrics measure the ability to have common and automated enterprise management services to conduct design, control, and after action review and analysis activities across the entire Marine Corps. In addition, they measure the numbers of weighted automated services that enable LVC-TE and have a large impact on the types of environments that can be represented and the quality of "fair fight" between participating simulations.
- <u>External constraints</u>. These metrics measure the alternative's compliance with several constraints that are levied on the Marine Corps and other DoD components, such as lower infrastructure footprints and reducing the number of supporting staff required to operate the training capabilities.

Each metric was weighted in a pairwise comparison at various echelons within a nested hierarchy (see Figure 2) by key stakeholders from across the Marine Corps and then reviewed by the EWG for inconsistencies. Each alternative was measured for each metric, and effectiveness value scores were calculated per utility curves that the EWG defined. The score for each alternative was the weighted sum of its effectiveness value scores.

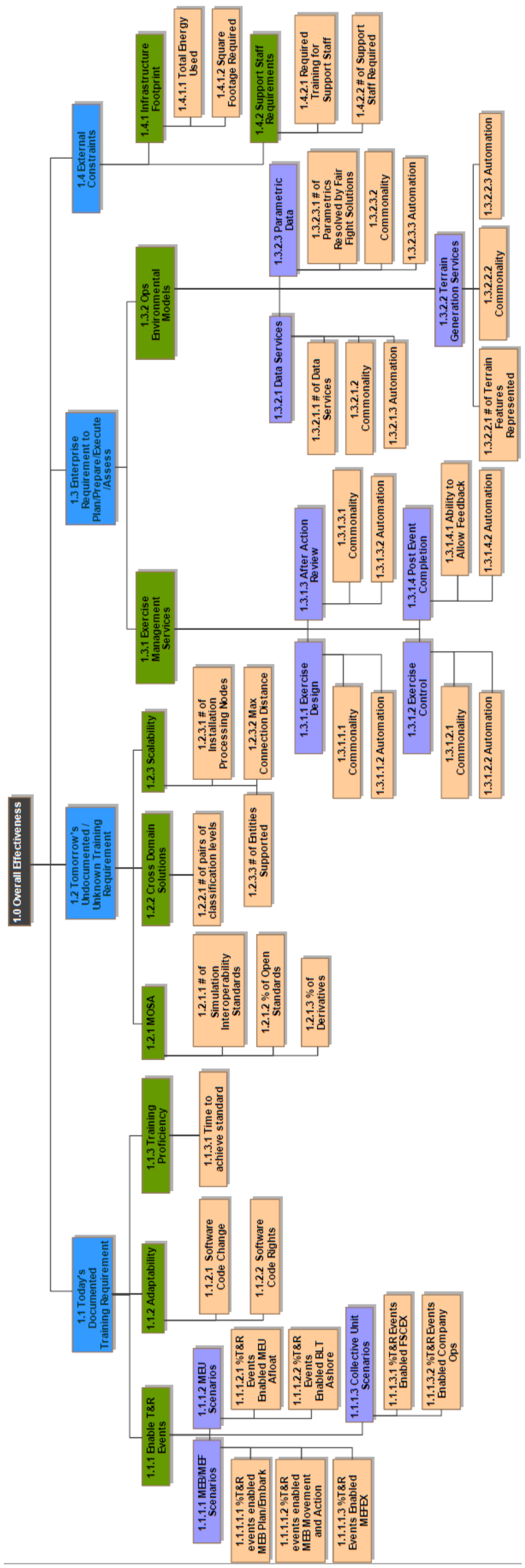

Figure 2. Final Metrics Hierarchy

ALTERNATIVE DEFINITIONS

The TAWG identified and assessed alternatives with respect to supporting the training environment (see Figure 3). The dimensions of an alternative included:

- Training devices, simulators, simulations, and C2 systems, collectively called *leaf nodes*
- Architecture to connect the leaf nodes
- Governance[1] to provide effective management
- Enterprise services and capabilities, such as exercise design, exercise control, and after action review

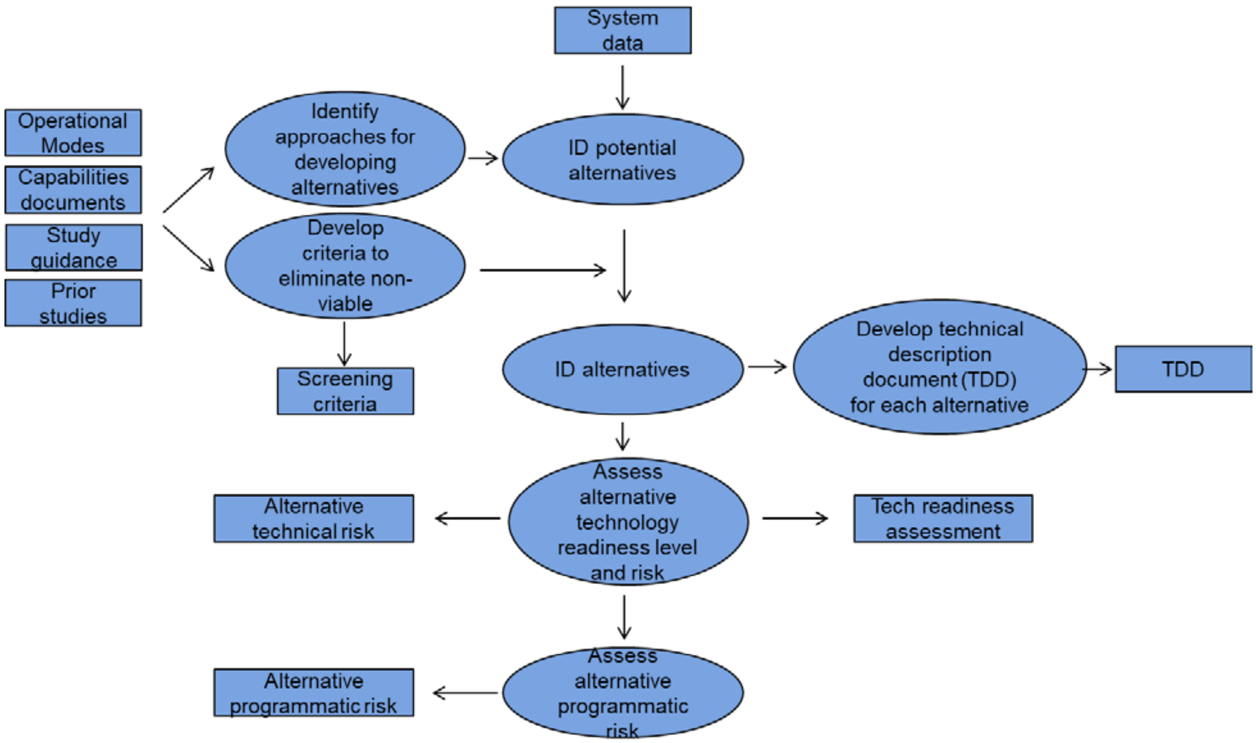

Figure 3. Alternatives Development Methodology

The AoA study guidance specified a set of existing and future service training environments to consider as an initial list of potential alternatives. The study team developed additional alternatives through a brainstorming workshop. The TAWG then screened the range of potential alternatives, using criteria developed from the ground rules, assumptions, and constraints listed in the study guidance. Examples of such criteria include the ability to operate on the Marine Corps Enterprise Network and the ability to preserve interoperability with live operational platforms and C2 systems. Alternatives that did not meet all of the criteria were screened out, resulting in the following list[2]:

- Alternative 1 – Joint (J7). Integrate selective United States Marine Corps (USMC) training solutions with the Joint Staff (JS) J7's LVC solution. Adapt JS J7's enterprise capabilities to include USMC requirements. Conform to the JS J7's roadmap for cyber security and cloud implementation plans.
- Alternative 2 – Joint (J7) plus Army Future Synthetic Training Environment. Build on Alternative 1. Monitor Army future research and development for improving training capabilities, integrate viable virtual training solutions and enterprise capabilities, and retire some of the USMC legacy virtual ground trainers.
- Alternative 3 – New Development. Plan to discard all legacy USMC training solutions and build a custom integrated LVC MAGTF training capability. Develop all new simulations, links to virtual/live platforms, and

[1] The study team analysis showed that the governance dimension is identical across all alternatives considered.
[2] The numbering of the alternatives is for informational purposes only and the figures in this paper are not intended to be ordered the same.

enterprise capabilities to be cyber compliant and fielded in the cloud where appropriate. All of the corresponding legacy solutions will be retired at full operating capability (FOC).

- Alternative 4 – Army Legacy Integrating Architecture while New Development. Build on Alternative 3. Procure the current Army LVC Integrating Architecture and integrate four USMC legacy training devices for limited training improvement over the status quo, while waiting for the new development to be fielded. The temporary Army LVC Integrating Architecture will be retired when the new development is at FOC. Of note, the option of including the Army LVC Integrating Architecture could also be applied to other alternatives.
- Alternative 5 – New Development Using Contractor Owned Contractor Operated Concept. A special implementation of Alternative 3. In this alternative, the Marine Corps contracts out LVC-TE training as a service. The government will own and operate the live training ranges and simulation facilities. The contractor will own and operate all of the training devices, integrating architecture, and enterprise capabilities.
- Alternative 6[3] – Army Legacy Integrating Architecture while New Development Using Contractor Owned Contractor Operated (COCO) Concept. A special implementation of Alternative 5. Procure the current Army LVC Integrating Architecture and integrate four USMC legacy training devices for limited training improvement over the status quo, while waiting for the new development of all new simulations, live/virtual platform links, and enterprise capabilities to be contracted and delivered.

COMPARISON

Assessment metrics scores

The purpose of the AoA was to assess potential material solutions that address the validated capability gaps identified in the LVC-TE ICD. In developing the set of viable alternatives, the study team determined that each alternative addressed those capability gaps. Subsequently, the study team developed a more detailed approach to analyzing the effectiveness of the alternatives, employing the previously described metrics. Minimum standards were also identified for the LVC-TE alternatives from the study guidance. For example, the after action capabilities mandated the ability to allow real-time query during event execution. All alternatives would be required to have that capability and therefore it would not be a useful discriminator across the alternatives. Since it was required that each alternative will meet the minimum standards identified during the metrics development process, measures of effectiveness were not identified to assess those capabilities within the effectiveness methodology.

The effectiveness results were determined by scoring how the status quo and each alternative were expected to perform at FOC against each metric. The final effectiveness analysis is results are displayed, by alternative, in Figure 4. The final scores are displayed as a summation of each of the scores at the leaf node level, the architecture level, the enterprise level, and the suitability level. Two of the alternatives scored the highest, followed closely by a third, then the remaining two alternatives, and finally the status quo. This paper does not attribute the numbered alternatives to the final scores; the ordering in Figure 4 is arbitrary.

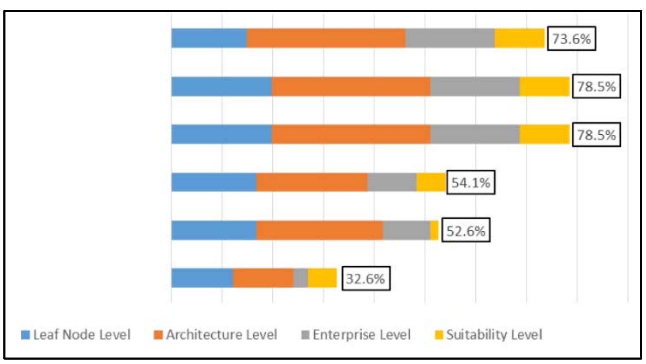

Figure 4. Total Effectiveness Scores by Alternative

[3] This alternative was a product of the study outbrief to the Milestone Decision Authority. As such, the LCCE was not performed since the AoA was complete. A follow on study will determine the return on investment of Alternative 6.

Cost evaluation summary

The cost analysis was based on an in-depth understanding of each system within each alternative. The study team relied on the integrated product team members, SMEs, and other stakeholders to identify the individual systems that together comprise each alternative. Then the cost team determined relevant data requirements needed to create a cost element structure for each alternative. The study team used, to the maximum extent possible, results of existing cost analyses and other relevant data sets to develop each alternative's life-cycle cost estimate (LCCE). When necessary, the team developed independent cost estimates using bottom-up, parametric, or analogous cost estimating methodologies commensurate with the current state of technical understanding of the alternatives, available data, and other relevant constraints.

The life cycle cost methodology was applied to analyze the available cost data. Three of the alternatives have relatively comparable life-cycle costs that are significantly greater than the remaining two alternatives. Within the top three, one alternative fields an interim capability, which accounts for a large portion of the difference from the others across all life-cycle phases. Another alternative's cost is moderately greater as it includes a time phasing profile unique from all other alternatives, based on estimates of the cost differences between a government-owned, contractor-operated (GOCO) operating strategy and a COCO operating strategy.

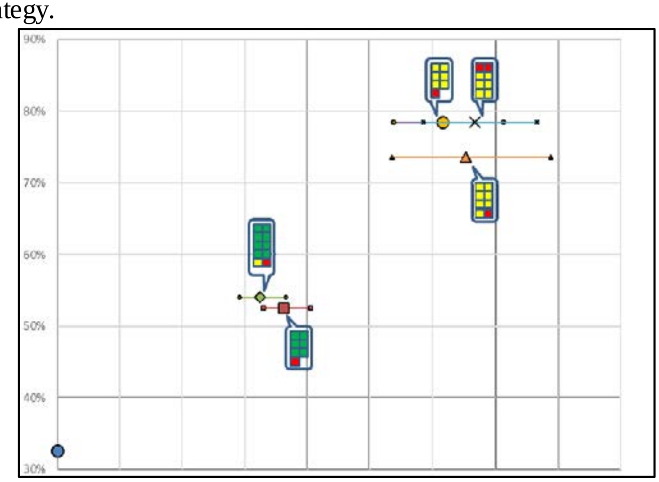

Figure 5. Relative Cost (x-axis) vs. Effectiveness (y-axis)

The life-cycle cost–effectiveness comparison of the alternatives is shown in Figure 5. Starting on the left hand side, one alternative provides slightly greater effectiveness at a lower cost than its neighboring alternative. Looking to the right hand side, the remaining three alternatives provide much greater effectiveness than the previous two alternatives, but at significantly greater cost. Within that triplet, two alternatives provide a moderately greater level of effectiveness than the third, but at slightly different cost. From a life-cycle cost–effectiveness perspective, therefore, preferences between the two alternatives on the left hand side and between the three alternatives on the right hand side are seen. But with the large difference in both life-cycle cost and effectiveness between the alternatives, additional factors were taken into account to identify the preferred alternative, including risk and schedule. Point estimates are indicated by the colored shapes and the corresponding cost uncertainty is indicated by the horizontal line. The "stop light" matrix is representative of the number of risks that corresponded to an alternative with the colors equating to low risk = green; medium risk = yellow; and high risk = red.

Risks

Risk for each alternative was assessed for acquisition, operational (including safety), and security categories. The methodology followed the Marine Corps Risk Management Order and the DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs. The study team assessed the likelihood of occurrence and level of consequence on a 5x5 point scale for each risk (see Figure 6 for an example matrix). The TAWG members provided the technical assessments and mitigation actions for a final risk assessment. Nineteen risks were identified across the alternatives with individual alternatives having differences in 7 to 10 areas. Figure 6 includes color-coded relative risk comparisons.

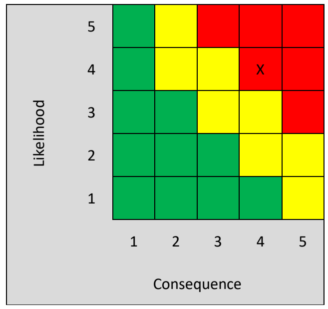

Figure 6. Example Risk 5x5 Scoring Matrix.

A safety risk workshop evaluated 43 potential safety risks for connecting and operating LVC-TE and developed mitigation for 16 of the risks that are valid for each alternative. The safety risks did not contribute to the selection of the alternative beyond contrast with the status quo, which does not have these risks. Ten risks were identified for further analysis, which involved human systems interface, ground and aviation range training policy, and potential post-traumatic stress events triggered by increased training realism.

LESSONS LEARNED

Requirements Analysis Lessons

Steps 0-4 from Figure 1 proceeded as expected, but the following steps involved "devils in the details."

Step 5: Although subject matter experts (SMEs) could name all of the operational equipment they would use to carry out the scenario in real world operations or live training, further analysis was needed to determine whether each system was worth the investment to integrate into the training environment.

Step 6: The SMEs were able to identify all of the people, units, and organizations that would need to be represented—either by a training audience or by the training environment and its support staff—to enable training in the scenarios. However, identifying all of the key attributes to be represented in the training environment would have required a step-by-step analysis of each T&R Event's conditions, standards, and performance evaluation checklist. Due to time constraints, TECOM modeling and simulation officers from the OCSWG worked with the TAWG to develop a list of important modeling attributes in each of the seven warfighting functions (maneuver, intelligence, fires, command and control, sustainment, force protection, and information) based on a general understanding of the training requirements for each scenario.

Step 7: The study team determined that there were multiple training systems available to provide to the training audiences of each scenario, with potentially different levels of effectiveness, support requirements, costs, and likely number of annual uses—live instrumentation versus virtual simulation being the most basic example. The team decided to separate the choice of training system suite from the definition of the scenario, defining the former as the *operational modes* for the scenario. Each training system was mapped to the specified training audience(s), and this ended up being a key organizational decision for the study with implications across all subsequent phases.

Step 8: PPEA requirements and timing. The main contribution of the Plan, Prepare, Execute, and Assess analysis was a rough idea of the amount of time required for a single iteration of each scenario from birth to completion. However, since the bulk of the time is spent in planning and preparing, the team had to follow up with training provider organizations through a data call. Most of the workshop participants came from the training audience population and did not have the experience to answer this question.

Step 9: Annual scenario utilization, as it turns out, is highly dependent on the operational mode—not just the scenario. Since the operational modes were not clearly defined until after the scenario development workshop, annual utilization estimates had to be gathered through a subsequent data call, and proved to be extremely challenging. The milestone decision authority directed that a follow-on study continue to refine utilization requirements in parallel with system development to ensure operational capacity would be right-sized.

Step 10: The most important input to the scenario narrative that came from the workshop was a coherent sequence of events that walked the notional training audiences through all of the training objectives. This was important to ensure that each scenario could stand on its own; if broken into different events, the utilization of each of the smaller events might be different, affecting the results of the subsequent analysis. Of course, more writing was needed after the workshop to complete each narrative.

Metrics Lessons

The analytical hierarchy process was useful in comparing different alternatives along a unifying value scale, but it is critical to compare each alternative at the lowest quantifiable metric to fully understand what is "missing" from an alternative that is not at 100% of the final value.

After determining the utility curves and the maximum value for each metric, no alternative evaluated scored 100% of value, which means that there are significant gaps in the current state of the art and the desired value state.

Technical Alternatives Lessons

Analysis of technology development and fielding indicated that there is no rapid path to fully implement LVC-TE.

However, LVC-TE is a complex but scalable capability. Schedule and cost constraints could be addressed by prioritizing scenarios and collective tasks addressed, deferring some operational modes, and deferring some services and models to provide initial training capability more rapidly.

LVC-TE capability can only be met through a well-integrated combination of non-material (e.g., governance) and material solutions.

LVC-TE operational modes needed to be broken-down by the expected proficiency of the training audience ("crawl, walk, run" analogy) to balance the lower cost "sets and reps" senior leaders desire and the higher-cost live-fire and force-on-force events.

Cost Lessons

Cost analysis was greatly facilitated by close and continuing interaction between cost analysts, technology analysts, and operations and training analysts.

Cost data are limited. The cost team used, to the maximum extent possible, results of existing cost analyses and other relevant data sets to develop each alternative's life-cycle cost estimate (LCCE). When not available, the team developed independent cost estimates using bottom-up, parametric, and/or analogous cost estimating methodologies that are commensurate with the current state of technical understanding of the alternatives.

The limited cost data did not indicate significant point estimate differences between Government Owned-Government Operated versus Contractor Owned-Contractor Operated.

AoA Lessons and Conclusion

LVC-TE is a new initiative that is not a cost saving venture but rather an investment for increased readiness.

An AoA for a highly complex system of systems requires significant data and estimates from elements across the entire Marine Corps. The impacts of aligning schedules with a large and diverse group of stakeholders needed to gather data supporting the AoA increased initial schedule estimates of completing the AoA by 25%.

Given that technology evolves at such a rapid pace, requirements and effectiveness measures must include some measure of adaptability to account for future training requirements that are emerging but not yet well-formed enough to document precisely.

This AoA methodology and full engagement of stakeholders across the Marine Corps helped the institution understand the requirements basis much better than past efforts and can serve as a model for other AoAs of training capabilities across the DoD.

ACKNOWLEDGEMENTS

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or positions, either expressed or implied, of the U.S. Government, U.S. Department of Defense or any of its Components to include the U.S. Marine Corps.

REFERENCES

Headquarters, USMC. (2010). *LVC-TE Initial Capabilities Document* (MROC Decision Memorandum 48-2010). Washington, DC: U.S. Government Printing Office.

Headquarters, USMC. (2016). *Marine Corps Operating Concept*. Washington, DC: U.S. Government Printing Office.

JHU/APL. (2019). *USMC LVC-TE Analysis of Alternatives (AoA) –Final Report* (NSAD-R-19-001). Laurel, MD: JHU/APL.

JHU/APL. (2017a) *USMC LVC-TE Network Analysis: Phase I – Final Report* (NSAD-R-17-001). Laurel, MD: JHU/APL.

JHU/APL. (2017b) *USMC LVC-TE Network Analysis: Phase II – Final Report* (NSAD-R-17-043). Laurel, MD: JHU/APL.

Program Analysis and Evaluation Division, Headquarters, USMC. (2015). *Program Objective Memorandum-18 Front End Assessment*. Washington, DC: U.S. Government Printing Office.

Training and Education Capabilities Division, TECOM. (2015) *Concept of Operations for the USMC LVC-TE*, Washington, DC: U.S. Government Printing Office.