A Tale of Two T's: Enabling Testing Through Reuse of Training Services

Dr. Robert Cox	Scott Nix, Robert Carpenter	Thomas Kehr	Kevin Gupton, Dennis Glover
US Army PEO STRI	General Dynamics	Cole Engineering Services, Inc.	University of Texas Applied Research Laboratory
Orlando, FL	Orlando, FL	Orlando, FL	Austin, TX
robert.m.cox14.civ@mail.mil	Scott.Nix@gd-ms.com	thomas.kehr@cesicorp.com	kgupton@arlut.utexas.edu dennis.glover@arlut.utexas.edu

ABSTRACT

US Army Training and Testing activities can look conflicting when viewed by the uninitiated observer, but deeper analysis can reveal that these requirements often converge towards commonality among the two communities. As a result, the Training and Operational Testing communities historically maintain separate hardware and software capabilities to meet their needs, which can lead to unnecessary technical redundancies. To overcome this challenge, the US Army Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) and the US Army Operational Test Command (USAOTC) have worked to map commonality and differences across Training and Testing requirements. This analysis found that many of these requirements overlap and a large portion of those that do not readily overlap can be achieved with minor modifications to existing training capabilities.

Based on this analysis, the US Army material developers for live Training and Operational Testing are collaboratively developing products utilizing a Product Line Management and Engineering approach. This collaboration allows developers within both environments to synchronize development efforts for the reuse of services, software, and hardware to enable the Operational Test environment. This reuse of components has resulted in significant cost avoidances for software development and maintenance activities within a set of products having significant overlap in requirements across the two domains. In addition, the superset of requirements raises the bar for both test and training capabilities, offering more realistic environments for both domains by collectively providing systems that address human factors, realistic entity behaviors, and battlefield effects. Through the application of the Live Training Transformation (LT2) Product Line approach, the Integrated Live, Virtual, Constructive Test Environment (ILTE) program was able to deliver a hardened Version 1 capability to the USAOTC based on reuse of mature training services.

This paper provides a thorough analysis of the common requirements that enabled reuse of existing training solutions and standards, as well as where we found requirements that could easily be met by adapting training solutions to meet similar testing requirements. This analysis is presented through the lens of the Version 1 ILTE capability development and delivery activities to show real-world application of our approach.

ABOUT THE AUTHORS

Dr. Rob Cox is a member of the US Army PEO STRI Program Manager for Instrumentation, Targets and Threat Simulators (PM ITTS) Instrumentation Management Office (IMO) and is the program manager for the Integrated Live Virtual Constructive Test Environment (ILTE) and Test Modernization (TNM) programs. Dr. Cox has an earned Doctorate in Atmospheric Sciences and Meteorology from Texas A&M University and has over 60 publications.

Scott Nix is the current General Dynamic's Program Manager of the ILTE effort. He has been developing or managing development of tactical and live, virtual and constructive training products for the US Armed Forces for the last 25 years.

Robert Carpenter is the General Dynamics Mission Systems (GDMS) Lead Engineer on the PM-ITTS project: Integrated Live-Virtual-Constructive Test Environment (ILTE). Mr. Carpenter is licensed Professional Engineer (PE) with over 30 years of experience in systems engineering, project management, and team leadership. He has a Bachelor's a degree in Electrical Engineering and a Bachelor's degree in Music from Northwestern University.

Thomas Kehr is a Senior Systems Engineer at Cole Engineering Services Inc and a Certified Modeling and Simulation Professional (CMSP). He is currently finishing his PhD studies in Modeling and Simulation at the University of Central Florida (UCF).

Kevin Gupton is a systems architecture in the M&S Engineering Group at the Applied Research Laboratories, The University of Texas at Austin (ARL:UT). He has over 18 years' experience in enterprise system engineering, data modeling, and knowledge management in the simulation domain. Projects with which he has provided system architecture and data management expertise include Common Data Services, Enterprise Data Services, the US Army Synthetic Training Environment, Integrated LVC Test Environment, and NATO MSG-164 Modeling and Simulation as a Service. Mr. Gupton holds a Bachelor of Science in Mathematics and a Master of Science in Computer Science from Texas A&M University

Dennis Glover is an Engineering Scientist at the Applied Research Laboratories, The University of Texas at Austin (ARL:UT). Dennis has been actively involved with US Army testing and training for over 30 years and has held positions in both academic and corporate environments. Areas of expertise focus primarily on instrumentation of tactical/C4ISR communications, tactical engagement simulation systems, and data analysis. Dennis holds a B.S. in Mathematics from Northern Arizona University and an M.S. in Statistics from the University of Arizona.

A Tale of Two T's: Enabling Testing Through Reuse of Training Services

Dr. Robert Cox	Scott Nix	Thomas Kehr	Kevin Gupton, Dennis Glover
US Army PEO STRI	General Dynamics	Cole Engineering Services, Inc.	University of Texas Applied Research Laboratory
Orlando, FL	Orlando, FL	Orlando, FL	Austin, TX
robert.m.cox14.civ@mail.mil	Scott.Nix@gd-ms.com	thomas.kehr@cesicorp.com	kgupton@arlut.utexas.edu dennis.glover@arlut.utexas.edu

INTRODUCTION

US Army Training and Testing activities can understandably look inherently different to outside observers as each has its own mission, scope, stakeholders, and objectives. For personnel internal to these communities, it can also be hard to draw parallels between the two without a true Army enterprise perspective. Training activities largely focus on measuring and improving soldier and unit performance, while Testing measures performance and effectiveness of a target platform system, or software. As a result of these perceived differences in objectives, the Training and Testing communities have historically maintained separate capabilities to meet these objectives, such as scenario generation and after-action review capabilities. These redundant capabilities lead to increased lifecycle costs across both domains.

The US Army Operational Test Command (OTC) and the Program Executive Office Simulation, Training and Instrumentation (PEO STRI) Project Manager Instrumentation, Targets and Threat Simulators, and SOF Training Systems (PM ITTS) recognized these redundancies and have pioneered a major technology investment program to establish and fund common test and training capabilities, known as the Integrated Live-Virtual-Constructive (LVC) Test Environment (ILTE) (Scrudder, Gupton, & Diem, 2017). ILTE is continuously seeking to reduce lifecycle costs by merging new capabilities into existing Government Off the Shelf (GOTS) products. These capabilities improve the user experience of operational test personnel and integrate capabilities into a system of systems with easily managed interfaces. ILTE can simulate battlefield effects with improved combat realism by leveraging and integrating existing and evolving testing and training LVC capabilities.

In an effort to more efficiently manage the development and integration of these common capabilities, PM ITTS has partnered with the PEO STRI Project Manager Training Devices (PM TRADE) to collaborate on the hugely successful Consolidated Product Line Management – Next (CPM Next) program. Through this collaboration, PM ITTS and PM TRADE have been able to jointly exploit the overlap in Testing and Training capabilities of the US Army through deliberate application of Product Line Management and Engineering processes and tools based on a joint training and test/evaluation architecture. This partnership had led to the successful fielding and acceptance of the ILTE Version 1 system at Fort Hood, TX in February 2019.

TECHNICAL APPROACH

The CPM program has been an exemplar on the implementation of Product Lines throughout the United States Department of Defense (General Dyamics Mission Systems, 2015). The CPM construct incorporates a Second Generation Product-line Management and Engineering (PLME) paradigm that breaks divergence, and enables an automated production-line process of generating one or more products within the Live Training Transformation (LT2) software product-line from a common set of core assets and feature profiles. Rather than each product team customizing a new configuration baseline, resulting in exponential complexity growth, the CPM solution builds products using innovative configuration and variation management tools plus automated production processes. This eliminates uncontrolled growth in complexity management and ultimately reduces sustainment and operations maintenance cost, and allows this saved time, cost and effort to be invested instead into innovations in the LT2 product-line (Lanman, Kemper, Rivera, & Krueger, 2011). This LT2 PLME approach provided ILTE with a rich hardware and software baseline to draw upon, reinforced with mature governance, processes, and tools as depicted in Figure 1.

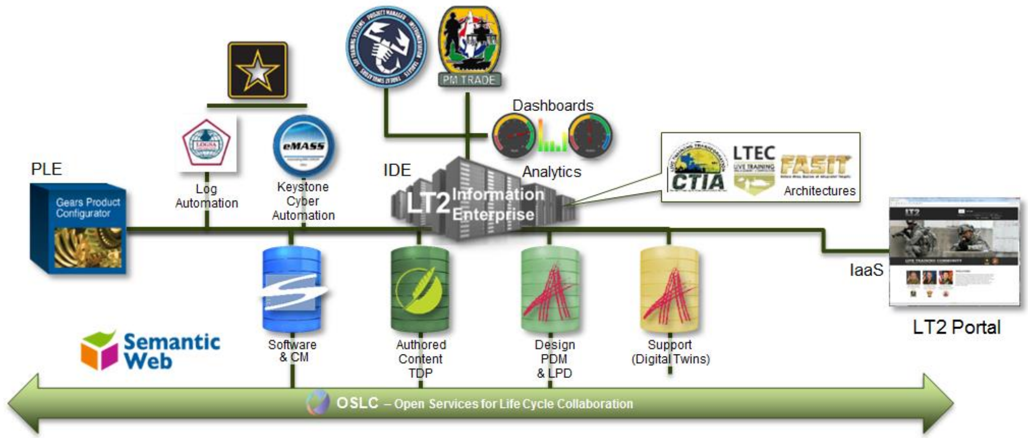

Figure 1. Product Line Management and Engineering Landscape of CPM

LT2 Product Line Management and Engineering

Product Line Management and Engineering (PLME) of a product line results in a superset of requirements, designs, hardware/software components, and documentation from which any single product in the product line can be produced. The instructions and processes to perform a product production are also captured and automated in PLME. Embracing the fact that different products in the product line have overlapping requirements but still require some uniqueness and variation is a key enabler. Many attempts at a product line fail by trying to have one size fits all components. While the traditional software product-line paradigm has proven successful in reducing stove-pipe development and the initial cost of deploying products, there are inherent complexity challenges during maintenance and evolution due to baseline divergence of the reusable software components that have been downloaded and tailored for the different product configurations. With each new product team that creates a new baseline, the cost and effort grow exponentially for merging software features and patches from the products back into the core assets and then out to other members of the product-line, leading to high cost and unmanageable complexity (Lanman, Kemper, Rivera, & Krueger, 2011). Product line governance is required to manage the variations. A properly executing governance board is equally responsible for recognizing and enforcing common components and implementation as well as allowing variation and uniqueness where each is appropriate.

The ILTE CPM implementation of PLME embodies a well-defined and repeatable process, centered on a strong factory paradigm with three major tenets: 1) Features express product variation, 2) Shared assets come from all lifecycle phases, not just the software, and 3) Industrial-strength automation is employed in the form of a configurator (Clements, et al., 2014). Each product is described by giving a list of its features. Features are used to express product differences in all lifecycle phase artifacts which streamlines the development process and allows all stakeholders speak the same language. In large-scale product lines like CPM, automated production of whole and consistent sets of lifecycle artifacts is essential. Under PLME, all supporting assets are considered equally important; software plays the same role as any other artifact. The configurator tool is able to take the feature-based description of a product and exercises the variation points in the shared assets to produce an artifact set that supports the named features. Figure 2 illustrates these distinguishing features of PLME.

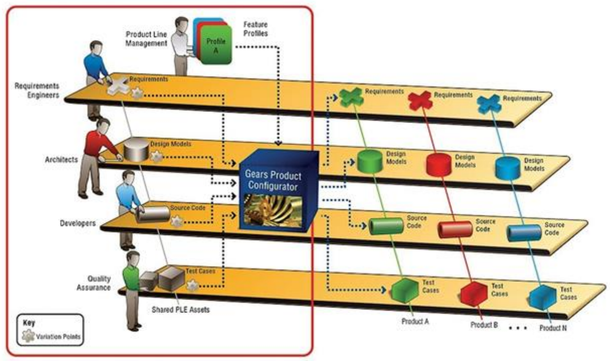

Figure 2. PLME Factory Paradigm (Ohlhorst, 2015)

PLME in Practice through ILTE

In staying consistent with PLME best practices, the ILTE program employs a number of innovative processes and tools that enable successful collaboration between testing and training organizations that have significant but not complete overlap in objectives and requirements, including:

- Product line governance provides a mechanism for identifying and exploiting opportunities for reusing hardware and software components amongst the products of a product line.
- Variation management processes and tools allow individual components to adapt to the varying requirements of the different products in the product line.

The ILTE CPM PLME process is further strengthened through application of the Scaled Agile Framework (SAFe) coupled with a disciplined Model Based Systems Engineering (MBSE) practice. SAFe provides a structured development environment that promotes alignment, collaboration, and delivery across large numbers of agile teams. This is especially important in a PLME environment where agile teams are sharing common components as this allows teams to synchronize and scale appropriately across an enterprise based on the technical needs for a given Program Increment. MBSE provides ILTE an efficient way to explore, update, and communicate system aspects to Operational Testing stakeholders, while significantly reducing or eliminating dependence on traditional documents (Scaled Agile Framework, 2018). Although these models are never a perfect representation of the ILTE system, they provide feedback sooner and more cost-effectively than a direct software implementation approach.

The ILTE development cycle consists of four program increments (PIs) per year that roll into a new ILTE system version. PIs contain several Epics related to core ILTE capabilities. Each PI is broken down into three to four subsequent sprints to ensure measurable progress can be made on the larger PI capabilities. These sprints contain a number of stories to be completed by the ILTE Agile product team and tasks related to a given story are assigned to individual team members. The ILTE PLME process has matured into a continuous cycle that begins and ends with the OTC customer. This process is depicted in Figure 3. Immediately before the start of a PI, the customer provides a prioritized list of desired capabilities for each PI. These capabilities are delivered in the form of Lean Business Cases (LBCs), which describe the capability in plain English and include descriptions such as how the capability will be used, Minimum Viable Product (MVP) characteristics of the capability, and any out-of-scope considerations for the given capability. The first step for the ILTE product team is to interpret and revise the LBC with simple language and align it in the context of the CPM PLME to provide a shared understanding across all stakeholders. These revised LBCs are then reviewed and approved by all stakeholders. Once approved, these LBCs are used by CPM management staff for PI planning of resources and assets. LBCs are then used to articulate Use Cases for each capability, including Department of Defense Architecture Framework (DoDAF) diagrams that formally depict the required capabilities, required features, and target operating environments.

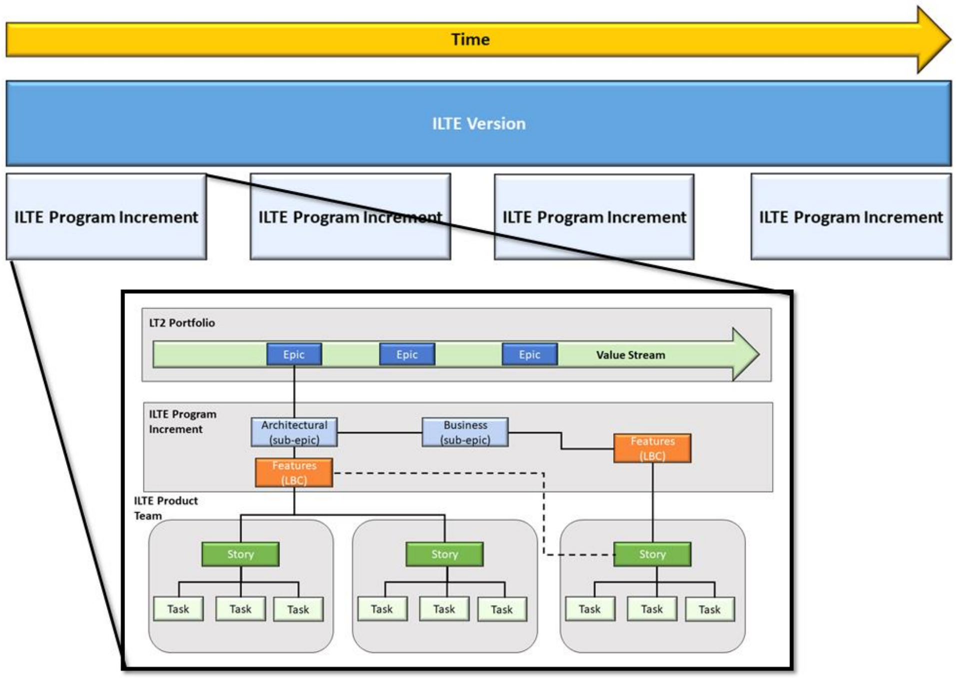

Figure 3. ILTE Program Increments within Agile SAFe

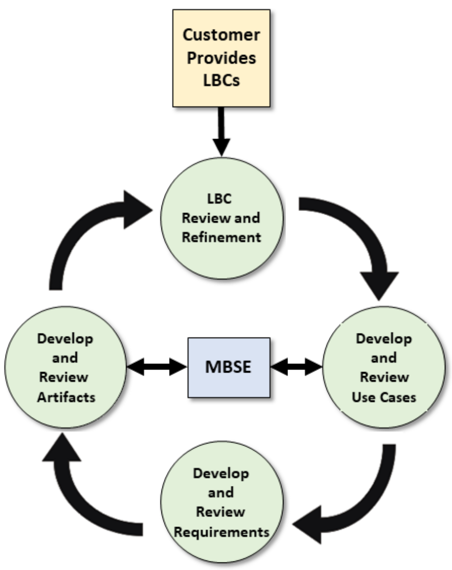

Figure 4. ILTE Continuous Process to Identify common components across the LT2 Enterprise

The ILTE product team leverages an extensive LT2 MBSE library to construct use cases for each ILTE capability within the increment. Use of the MBSE library allows the product team to quickly identify existing training (or testing) use cases for similar products that meet the scope of the requested OTC ILTE capability. Using these shared models, the product team can quickly mock-up Use Cases for the capability. These Use Cases are then peer-reviewed across the CPM enterprise before being approved by the Government stakeholders. Any new Use Cases are then made available through the MBSE library for future training or testing capabilities.

The ILTE product team uses the approved Use Cases to derive functional requirements for the increment capabilities. A requirements management tool is used to identify similar requirements across the CPM enterprise to promote reuse across common components. The remaining unique requirements are added as new requirements into the system after peer review and approval from both an Architecture Working Group and Common Asset Working Group (CAWG). The AWG and CAWG review Common Asset Change Proposals (CACPs) from the ILTE product team and provide governance along with additional feedback and considerations for reuse of common components across the CPM enterprise. Logic is also applied to these requirements within the requirements management tool to automate PLME configurator functionality.

Once requirements are finalized, the ILTE product team is able to create new systems engineering artifacts and updated existing ones. This includes development of detailed Systems Modeling Language (SysML) diagrams and other documentation needed for CPM software teams to begin development of ILTE increment capabilities. These artifacts are presented to Government stakeholders through an Increment Design Review (IDR) for approval prior to any software development activities. During ILTE software development activities, the ILTE product team constructs capability Test Procedures using the approved requirements and ILTE use cases. These are ultimately used after delivery of finished software products to verify and validate that they meet the required ILTE functionality.

APPLICATION

Version 1 of the delivered ILTE capability consisted of five major capabilities, each containing multiple subsystems and capabilities developed over four program increments:

- Test Monitoring and Control (TM&C)
- Test Planning
- Real-time Casualty Assessment (RTCA) Effects and Integration,
- Synthetic Environment
- Data Collection Reduction Analysis Visualization (DCRA&V).

The CPM PLME approach identified the common components from the CPM enterprise necessary to satisfy the OTC capability requirements and successfully deliver an initial ILTE capability to the field.

This initial ILTE capability provides the OTC customer with an operational system to begin test planning and execution efforts. This Version 1 ILTE capability is meant to operate in parallel with current Operational Testing systems and allows the end user to provide feedback on the overall initial capability and provides a live system to begin system familiarization. The high-level systems architecture of ILTE Version 1 is illustrated in Figure 5.

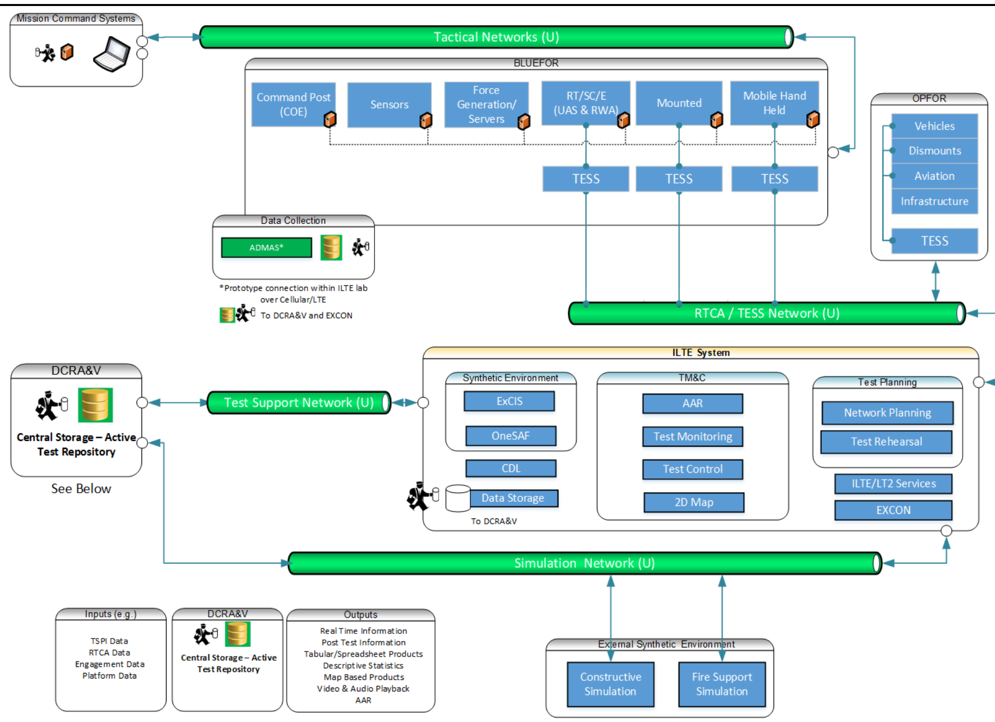

Figure 5. ILTE Version 1 Architecture System View

Common Component Analysis

Table 1 provides a high-level analysis of the LT2 common component reuse within ILTE based on implementation of PLME processes. Not all of these common components are unique, and many are shared between capabilities. Several detailed examples of the common component reuse and variation development within ILTE are provided in the sections below.

Table 1. ILTE Version 1 Common Component Analysis

ILTE Version 1					
Major System	**Subsystem**	**Number of LT2 Common Components**	**Number of Modified LT2 Common Components**	**Number of COTS / GOTS**	**Number of New ILTE Components**
Test Monitoring and Control (TM&C)	Test Control	2	1	0	6
	Test Monitoring	5	0	0	2
	After Action Review	0	5	0	0
Test Planning	Scenario Development and Generation	0	2	3	3
	Network Planning	0	1	1	4
	Test Rehearsal	0	1	2	4
Real-time Casualty Assessment (RTCA) and Integration	Battlefield Realism	13	0	0	0
	Instrumentation	8	0	0	0
	EXCON	6	0	0	0
	Collection / Playback	0	4	0	0
	Interoperability	2	1	0	2
	Exercise Planning	5	1	0	0
	Infrastructure and SYSCON	13	1	0	0
Synthetic Environment	Constructive Simulation	0	1	1	1
	Fires Simulation	0	1	1	1
Data Collection Reduction Analysis Visualization (DCRA&V)	Data Reduction and Analysis	0	2	0	1
	Total	54	21	8	24

Example: Data Collection Device

The ILTE Data Collection Reduction Analysis Visualization (DCRA&V) capability includes a Data Collection Device Control Manager functionality. It was determined that several services within the LT2 Exercise Control (EXCON) baseline nearly met all requirements for this capability. The 2D Maps and Data Collection services within the EXCON baseline were enhanced baseline to provide a graphical user interface to include Data Collection Device (e.g. ADMAS) status decorators to the entity information displayed on the 2D Map. A new "Data Collection Status" service was additionally created to provide an interface enabling near real-time status and control of Data Collection Devices. This new service is now available for use by other programs requiring Data Collection status or could be further modified to provide status for other external devices.

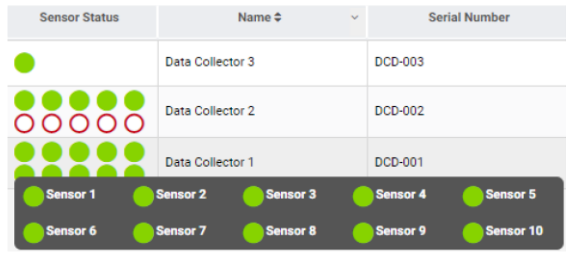

Figure 6. Data Collection Device Status Information displayed through the LT2 Web-Based EXCON and 2D Map.

Example: Network Planning

The ILTE program required a network planning capability to provide real-time visualization of network coverage to enable wireless tower placement to support Operational Test exercises. It was determined that no existing LT2 services met this capability, so new services would need to e created and added to the LT2 baseline. First, the existing LT2 2D Map services was modified to support the network coverage/heat map overlaid on the imagery from the 2D Map server. The third-party EXata tool was integrated into the ILTE baseline and is used as the core of the Network Planning capability as an advanced network emulator. Services were then created for Scenario Development, Tower Equipment Import/Export, Tower Placement, Network Coverage Analysis, and Map Layer Filter. This new network planning capability is shown in Figure XX.

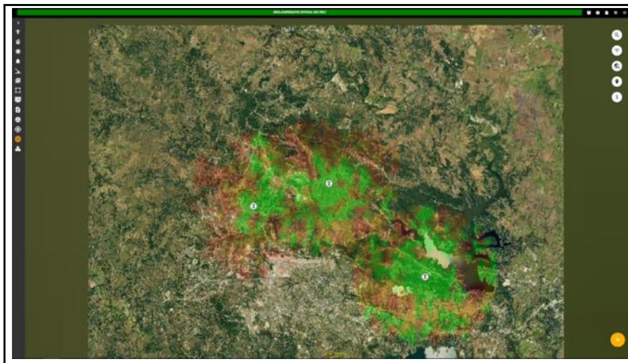

Figure 7. ILTE Network Planning Interface within the ILTE EXCON

Example: Synthetic Environment and Integrated COP

ILTE integrated constructive simulation tools OneSAF and ExCIS within the LT2 EXCON baseline to produce a Common Operating Picture (COP) that allows visualization of the instrumented entity location and that entity's MILES and Data Collection Device status. This information is depicted on a 2D Map display which provides context and quick look status for the entities and their instrumentation. In this effort, only the 2D Map service had to be updated and a new 3D Viewer service was created to enable three-dimensional viewing of terrain features and simulated entities within the ILTE system. Further, simulation control services were developed within the LT2 baseline to allow for limited control functionality of the integrated synthetic environments over web-applications leveraging inherent cloud capabilities and services within the LT2 Common Training and Instrumentation Architecture (CTIA).

PROGRAM IMPACTS AND RETURN ON INVESTMENT

In general, Product Line Management and Engineering provides the processes and technologies that enable an entire product line to be constructed from a single superset of hardware and software designs and products. This results in significant cost avoidance in both the maintenance of existing products and the development of new products. It also provides a smooth path for collaborative efforts between organizations that have been previously executing in silos. Engineering organizations experience these technical benefits:

- Higher productivity, lower overhead, and lower Non-recurring Engineering (NRE)
- Higher quality, and lower defect density
- Faster time to market for new features and new products

- Greater scalability of the product line

The application of PLME enabled PM ITTS to rapidly field an initial ILTE capability to operational testing users on an expedited timeline due to reuse of mature and existing LT2 common training components. This also allowed for simplified training of the end user since many of the interfaces were already well understood by users and well documented. Internally to the ILTE Product Team, the PLME process streamlines the systems engineering process since the majority of LT2 common components, services, and interfaces are well documented and organized within a structured MBSE repository.

PLME has resulted in cost avoidances of over $600 million to the training community since 2005 across 22 programs of record (Clements, et al., 2014). While application of PLME into the testing community is still relatively recent, PM ITTS and the ILTE program have seen cost avoidance in excess of $50M since 2017. Figure 8 illustrates the cost avoidances realized through PLME on the testing and training programs under CPM-Next.

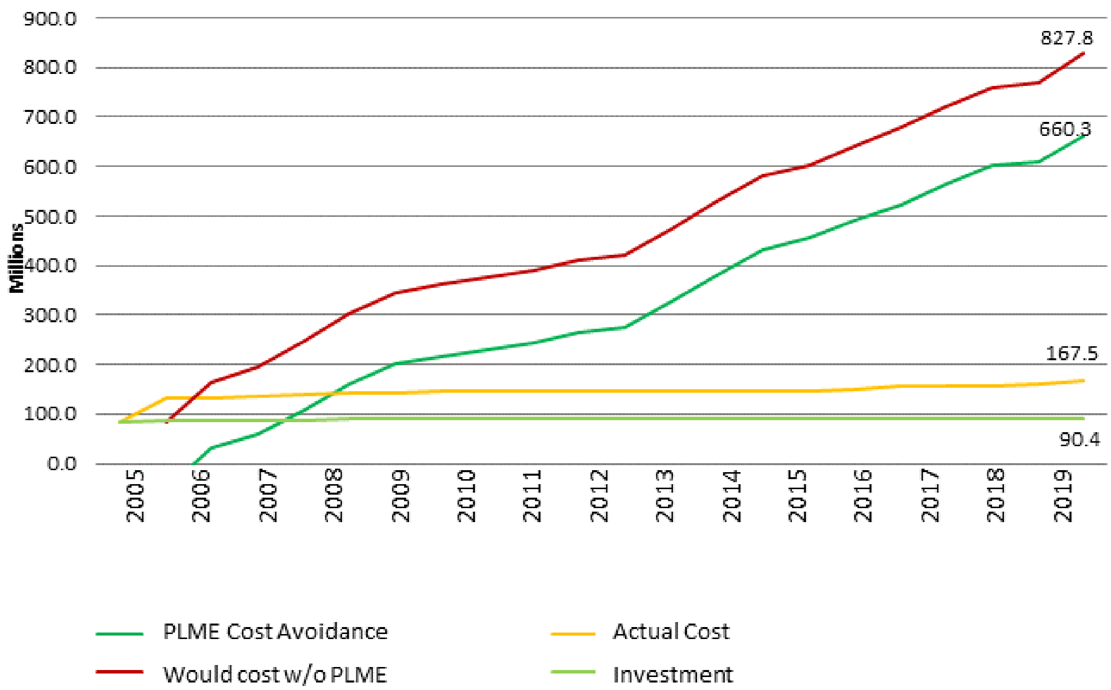

Figure 8. PLME Cost Avoidances throughout the COM Test and Training Portfolio

CONCLUSION

This paper provided an analysis of the common requirements that enabled reuse of existing training solutions and standards, as well as where we found requirements that could easily be satisfied by adapting training solutions to meet similar Operational Test requirements. This reuse of components through PLME has resulted in significant cost avoidances for software development and maintenance activities within ILTE. Our analysis showed that there was significant overlap in the requirements of training and testing products. This superset of requirements raises the bar for both test and training capabilities, offering more realistic environments for both domains by collectively providing systems that address human factors, realistic entity behaviors, and battlefield effects. Ultimately, Product Line Management and Engineering is a disruptive technology that allows organizations that previously operated separately to collaborate on a product line that satisfies both their shared and unique requirements. ILTE will continue to apply PLME to future program increments and is already integrating and adapting additional common components to enable future ILTE capabilities, such as a mission command adapter, exportable exercise playback, and a cross-domain solution. PM ITE and the Operational Test Command also continue to look across other training programs of record to identify further opportunities for common component reuse.

REFERENCES

Clements, P., Gregg, S. P., Krueger, C., Lanman, J. T., Rivera, J., Scharadin, R., . . . Winkler, A. J. (2014, Jan/Feb). Second Generation Product Line Engineering Takes Hold in the DoD. *CrossTalk Magazine*.

General Dyamics Mission Systems. (2015, September 16). Live Training Transofrmation (LT2) Product Line Management Overview (Unpublished Briefing).

Lanman, J. T., Kemper, B. E., Rivera, J., & Krueger, C. W. (2011). Employing the Second Generation Software Product-line for Live Training Transformation. *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2011* (p. 12). Orlando: NTSA.

Ohlhorst, F. (2015, November 2). *Product Line Engineering 101*. Retrieved from Digital Engineering 24/7: https://www.digitalengineering247.com/article/product-line-engineering-101/

Scaled Agile Framework. (2018, October 16). *Model Based Systems Engineering*. Retrieved from Scaled Agile Framework: https://www.scaledagileframework.com/model-based-systems-engineering/

Scrudder, R., Gupton, K., & Diem, J. (2017). Testing and Training Convergence – Common Scenario Generation Requirements and Solutions. *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2017* (p. 12). Orlando: NTSA.