Maximizing U.S. Army Return on Investment Utilizing Software Product-Line Approach

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ABSTRACT

The Live Training Transformation (LT2) Software Product Line (SPL) team established a mature live training SPL within the U.S. Army's Project Manager Training Devices (PM TRADE), allowing for the realization of significant improvements in cost savings and cost avoidance in development and sustainment of live training systems. Through sustained commitment and determination, the LT2 SPL team, worked with the live training acquisition leadership and training product teams to transform the PM TRADE organization from a collection of mostly stovepipe products into an SPL-oriented organization focused on systemic software reuse, standards, common solutions, processes, tools, and governance. This continuing transformation has generated a significant return-on-investment to date within PM TRADE's live training system acquisition portfolio generating over three hundred million dollars in cost avoidance across the development of live training systems to include Combat Training Centers Instrumentation Systems, Home Station Instrumentation Systems, Instrumented Ranges, and Targetry.

The LT2 SPL strategy maintains the combat edge and builds resilience in our forces by providing state-of-the-art training systems to the Warfighter using common reusable software components, architectural infrastructure, interfaces, standards, processes, and assets. With over 150 systems fielded globally, LT2 successfully employs technical and acquisition strategies that significantly reduce fielding time, minimize acquisition costs, enable total ownership cost reductions across the Live Training domain and Live, Virtual, Constructive-Integrated Training Environment (LVC-ITE), and enhance training benefits afforded to the Warfighter. This paper provides an overview and lessons learned from the LT2 SPL accomplishments and benefits of the holistic approach that the LT2 SPL team has achieved. Furthermore, key historical, on-going, and future challenges in managing a successful SPL within the Department of Defense acquisition environment will be addressed.

ABOUT THE AUTHORS

Mr. Michael Dillon is the PM TRADE Project Director for the Common Training Instrumentation Architecture (CTIA), the LT2 Consolidated Product Line Management (CPM) contract, and the LT2 Integration and Development Environment. His experience includes 26 years supporting the Army Live Training Domain as a software engineer, systems engineer and program ,manager within both Industry and DoD acquisition service. He has been involved with the LT2 Software Product Line and the CTIA program since 1999 in various capacities including; CTIA engineer, product team product line customer, and LT2 and CTIA program management.

Mr. Jorge Rivera is a chief engineer working for General Dynamics C4 Systems who leads live training efforts and provides technical guidance for the execution of the CPM contract. His experience includes 25 years of DoD acquisition service with over 15 years of experience in the live training domain. As the assistant project manager for LT2. Mr. Rivera championed the LT2 product line and managed the CTIA & FASIT efforts.

Mr. Barry Clinger is the Chief Technical Officer for Riptide Software, Inc. and the product line architect for the CPM product line. He is an experienced software solutions expert who specializes in the design and architecture of large-scale distributed near real time systems. Barry has over 25 years of commercial, DoD, and NASA software development experience. He holds multiple software design and architecture certifications from industry.

Mr. Rowland Darbin is a product line manager and software architect at General Dynamics C4 Systems. He has spent nine years supporting Commercial-Off-The-Shelf products for virtual and constructive simulation and three years supporting live training. Mr. Darbin is currently the product line manager for the Consolidated Product Line Management (CPM) Product Line.

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INTRODUCTION AND LT2 BACKGROUND

Live Training Transformation (LT2) is the product line strategy put in place by the United States Army Program Executive Office for Simulation, Training and Instrumentation (PEO STRI). Through the use of LT2, Product Manager Training Devices (PM TRADE) builds and maintains live training systems in support of homestation training, deployed training, urban operations training, Maneuver Combat Training Center (MCTC) training and instrumented live-fire range training.

Prior to the implementation of the LT2 product line, live training systems and devices consisted largely of products developed separately by a variety of different manufacturers to comply with disparate requirement sets and were designed and implemented without a common framework. Commonality was not attempted and interoperability among systems was rare, difficult and costly to achieve. Configuration changes to both hardware and software were often performed on-site as part of the sustainment effort making configuration control virtually impossible.

Recognition of the commonalty of requirements between training systems and the degree of redundant work effort among contractors led to the establishment of common architecture frameworks, Common Training Instrumentation Architecture (CTIA) and the Future Army System of Integrated Targets (FASIT) that drastically improved the reusability of developed training components. These components formed a technology shelf that enabled a high degree of reuse between products. As the number of products using the technology shelf increased, so did the corresponding complexity of managing the common software baselines and product feature sets.

The product teams using CTIA were uncoordinated in their efforts resulting in redundant implementation that created similar features and resolved many of the same bugs. While still drastically more efficient than stovepipe development, it became evident that greater efficiencies could be gained by implementing a common governance strategy across the LT2 domain.

Reuse of core assets alone provides a substantial cost reduction in the development of new products but active participation in the lifecycle of the core assets assures that they remain relevant to future development and applicable to the breadth of the live training community. Controlled governance of core assets permits changes, upgrades and fixes developed for and by one product to be applied to others. This concept provides the inherent logistics support benefits that derive from commonality, standardization and interoperability including the reduction of total life cycle costs. This continuing transformation has generated a significant return-on-investment to date within PM TRADE's live training system acquisition portfolio generating an estimated $340M in cost avoidance across the development and sustainment of 150 Live Training Systems deployed systems worldwide.

The LT2 vision has created a family of live training systems using a common architecture with common data, standards, processes, and components. The LT2 focus currently is on the evolution of the product line to gain efficiency by tailoring the second generation product line methodology to the specific intricacies of the government contracting paradigm.

First Generation Product Line Engineering

Product Line Engineering (PLE) has roots that span at least four decades, going back as far as Parnas's seminal paper on product families in 1976 [5]. We characterize some of the early and long-standing approaches to Product Line Engineering as *first-generation.* First-generation PLE (1GPLE) includes:

- A strong dichotomy between domain engineering and application engineering, or core asset development and product development.
- Explicit inclusion of non-software artifacts in the collection of core assets.

- Focus on features as the language to describe a product line's domain and a way to discriminate products from each other
- Acknowledgment of configuration management as an essential practice under PLE without a strong distinction between core asset CM and product CM

These approaches have yielded a rich legacy of product line success, as evidenced by numerous case studies [4][6] [3][1]. The instantiation of a first-generation product line for LT2 took the form of multiple projects reusing core assets with governance administered through a common asset repository by each PM TRADE Product Manager. The Product Manager was responsible for the configuration baseline of their system throughout the product's total life cycle. As with any product line, the primary challenge is the management of the product line not the technological barriers. This means that the process by which PM TRADE manages products must be deliberate, disciplined and coordinated in order to maximize use of common assets, components and subsystems in the development of new products. It must synchronize the production of products to gain efficiencies, enable supporting efforts and maintain seamless interoperability between components, products and systems. Since each responsible management level for the product managers was disparate, the required coordination to ensure product line strategy was successful, albeit challenging and painful.

Adaptation of the first generation principals of LT2 was a huge success and evidence that greater gains could be attained and lead to embracing the product line philosophy even further by overcoming some of the obstacles that the first-generation product line could not solve in a DOD environment.

Second Generation Product Line Engineering

As the primary focus of 1GPLE is to effectively managing the core assets that compose the product line, the focus of second-generation Product Line Engineering (2GPLE) is not only on the management of the core assets but on the philosophy of how the management of core assets should be governed.

In the world of manufactured hard goods, a product line refers to the variations on a common theme, where multiple similar products are combined into one line that offers different sizes, colors, features and functions, with a common goal of filling customer need for a particular kind of item. The 2GPLE paradigm strongly embraces the factory analogy. Continuing the analogy to engineering a product line of hard goods, it is much more effective to view systems and software product line engineering as creating a means of production – a single system or "factory" capable of automatically producing all of the products in a product line – rather than viewing it as creating a multitude of interrelated products [3].

Figure 1 shows the single production line perspective for producing a product line; the focus is on the means of production. Products that emerge on the right side of the diagram are automatically produced by a singular means of production composed of:

- Feature profiles (top) that describe optional and variable features for the products in the product line where each product in the product line is uniquely defined by its own feature profile
- Shared assets (left) such as requirements, architectures, designs, models, source code components, test cases and documentation that can be configured and composed in different ways to create all instances of soft assets and products in a product line. Variation points shown within these assets are exercised to configure them for a product according to the features selected in the feature profile for that product. This results in feature-based variation management.
- Product configurator (center) that automatically composes and configures products from the shared assets, using the feature profiles to determine which shared assets to use and how to configure variation points within the assets

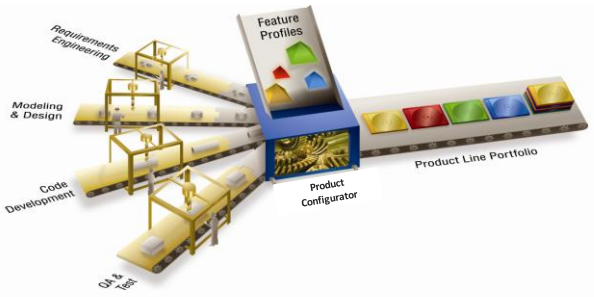

***Figure 1* - Second-generation PLE production line**

In terms of McGregor, Chastek, and Donohoe's advice for building a production strategy [2], embracing the factory paradigm combines at least *three* of their desiderata:

- "**Be automated**. Enable the engineers to carry out repetitive functions quickly and correctly…"
- **"Be generative**. Generate low-level artifacts such as source code and detailed documents from higher level models…"
- **"Be transformative**. Allow dissimilar data formats to be aligned…" A transformative production strategy results in a production method that uses a small number of meta-models, preferably one, as

the basis for models of various kinds of development information.

For LT2, 2GPLM meant migrating from managing the composition of core assets to managing the process and the elements of their composition. Stated another way; shifting focus from the capabilities of a core asset to the variations in features that define the core assets capabilities.

To effectively govern these variations, it was essential to develop the factory that would create the core assets from a single repository. Product teams shifted away from maintaining their own repositories, fixing bugs and adding features that would have to be merged later and instead, focused on defining the feature profiles that made their projects unique and distinct from the common baseline. New features and bug fixes were viewed holistically from the product line perspective in advance and immediately made available to the community instead of lagging until the beginning of the next development cycle when the previous development was merged into a baseline.

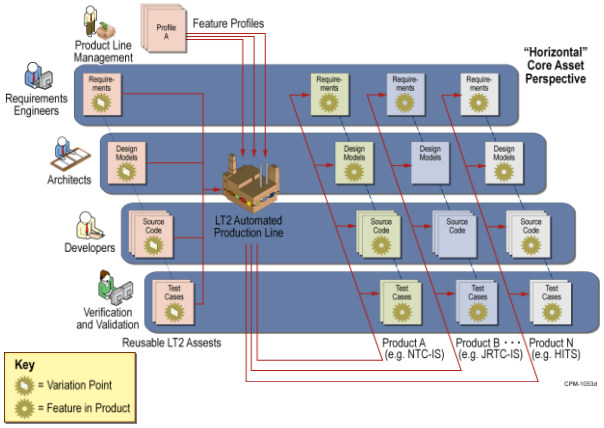

Figure 2 - 2GPLE applied to LT2

Adaptation of the 2GPLM strategies has been hugely successful for the product teams resulting in significant cost savings from elimination of configuration management, coding and testing associated with expensive baseline merges. Some of the governance problems experienced by the first-generation are still present but to a lesser degree, and not all core assets have had governance applied consistently. Though the governance of requirements and testing repositories still have not yet realized the benefits to the same degree as source code, standards, defects, metrics and configuration management. Redundant development and merging have been drastically reduced or eliminated entirely. Realizations of commonalities between products are greater than expected and variations are being used to tailor products in ways which target the core differences in needed capabilities while still retaining the benefits of industry collaboration.

CHALLENGES OF A SUCCESSFUL DOD SOFTWARE PRODUCT LINE

Several challenges must be overcome in order to make any product line strategy a success. Additional challenges exist when implementing the product line strategy within the DoD environment. The often cited commercial challenge of *changing the management philosophy that governs the development team* is amplified in the government setting and takes on an even larger role in the product line's success or failure.

For the purposes of ROI evaluation, the LT2 product line has been divided into constituent enablers that form the pillars of the product line's success. Each of these pillars represents challenges to a DoD product line. In this paper we have chosen the following nine pillars to focus on: having the right team, the Consolidated Product Line Management (CPM) strategy, using standards based acquisition, defining standard interfaces, leveraging common components and common services, providing an Integration and Development Environment (IDE), controlling governance/common process, using defined metrics, and finally leveraging a collaboration environment. The solutions to these challenges should enable those following to manage the changes that will allow the execution of a product line like LT2 in a DoD community.

Right Team is Key

Establishing the right team is paramount within a product line approach as the breadth of the domain is so much larger than any single project. Caution must be taken to ensure that the focus of the product teams' development isn't so narrow that it only solves the problem at hand. Instead, it is essential that it applies to the entire domain.

The right team includes a solid management team capable of communicating and measuring the strategic goals of the product line strategy to their superiors, product managers and industry teammates. This is a critical function as product lines require more upfront cost investment to establish than a single product. Return On Investment is realized at a slower rate in the first stages of product line development and management must establish accurate metrics to measure progress and create clear lines of communication reporting progress with the appropriate expectations set. The development team requires experts in the technical approach, a full understanding of the domain that the

product line will apply to, and forward thinking to account for product line expansion. Perhaps more important is the ability to define the boundaries of the system. This is essential in ensuring that initial goals are successfully realized and prevents the creation of a "Science Project" looking for problems to a solution.

Product line development in the DoD environment often (and in our case) is aligned with funding that is tied to a specific fielding or project. Each of these development cycles must be executed using a product line methodology for the product line to be successful. This means solving the bigger problem, not necessarily the single use case that would allow a short-term success for the project but apply limited applicability elsewhere. For this reason a typical realization of up front development cost for new features is on the order of 20% to ensure that planned systematic reuse is applied[3]. This increased upfront cost for new development must be viewed in relationship to the entire software development lifecycle to understand what the additional cost is accomplishing. Imperative to product line acceptance is the understanding that in our case, between 60 and 90 percent of a product's cost is in post development maintenance and support, not initial development. The 20% upfront cost is eclipsed by the increased reuse across the product line and backend savings once the product is delivered.

For LT2 product development to date, the percentage of software reuse averages 91% of the live training code base. To draw the logical conclusion this means that the development team is spending 20% more but only on 10% of the final solution. Product teams do spend some of their development dollars updating and fixing existing components but this is significantly less expensive than developing new components from scratch.

In addition sustainment dollars which would typically exceed 70% of a product's initial development cost are subsidized by other product team's new development. This effect is a multiplicative ROI for the product line as a whole. Having the right team in place allows for this ROI to be realized.

Consolidated Product Line Management (CPM) Strategy

PM TRADE has established the CPM single award IDIQ contract to provide support to LT2 Product Line (P/L) programs in various stages of acquisition utilizing the delivery order approach. The purpose of the IDIQ is to establish a single entity whose primary objective is to manage the product line. Product line management is a highly complex environment requiring specialized product line management and technical expertise that was a criterion of the IDIQ selection. Performance measures of the contract must be evaluated against the execution of the constituent projects and the effectiveness of the product line as a whole. This is critical to ensuring that the focus of product development, which is to a single end goal, does not overshadow the long term business objectives of the product line.

Having one contractor team under the umbrella of the LT2 CPM Construct that works across programs has dramatically reduced management overhead costs. These savings come in the form of having less government to contractor interfaces which reduces both the government overhead required to manage independent contract vehicles and the contractor-side program management where resources from within the CPM team are leveraged across multiple efforts on the contract. Documentation, expense reporting, billing, work estimation and all other operational aspects are standardized across CPM under the single contractor team. This provides further efficiencies within the team as deliverables become consistent and both government and contractor's expectations are aligned.

LT2 projects are being consolidated under CPM. Since 2010 fourteen delivery orders (DO) have been issued with eleven currently active and three completed. The CPM strategy has been very successful and has gained broad acceptance. There is widespread leadership support within PM TRADE and other organizations that have utilized LT2 and CPM. Project Manager Constructive Simulation (PM ConSim) works in coordination with CPM providing the "live" element of the LVC-IA. The U.S. Marine Corps Project Manager Training Systems (PM TRASYS) has twice acquired programs utilizing and benefiting from LT2. Both the Marine Corps Instrumentation System (MC-ITS) and the Instrumented Tactical Engagement Simulation System (I-TESS) took heavy advantage of existing LT2 P/L assets as the basis for their training systems. The MC-ITS was developed reusing 87%, or 8,314,227 lines of code, from existing Army LT2 P/L software. The acquisition cost and schedule for building a new alternative system was quoted at $19M and nine years. The actual cost and schedule recognized by leveraging the Army's LT2 P/L assets was $8M cost, completed in two years. That's a cost savings of $11 million and seven years in schedule. The U.S Air Force Counter IED AAR System (CIEDAS) was able leverage the Army's LT2 P/L assets and field seven training systems to meet their IED training needs at four bases with very little developmental investment. Special Operations Command (SOCOM) has leveraged LT2 P/L assets in the acquisition of their Soldier Monitoring System

(SMS) for land navigation training, and USMC Training and Education Command (TECOM) has aligned their Command & Control Training Enhancement (C2TE) project with CPM as well.

Standards Based Acquisition

The live training domain consists of efforts within PM TRADE, across PEO STRI and the Army. Prior to introduction of the LT2 product line, there existed, as in any heterogeneous environment, a lack of or complexity of interoperability within products in PM TRADE. With the introduction of the LT2 product line, standards were introduced and vetted with industry and placed into the acquisition language in Request For Proposals (RFP).

The critical factor with any standard is adoption by industry. Having standards approved using the product line's established processes encourages openness and industry involvement in the development of the standard. It also yields early adoption because, as soon as the standard is published, it is immediately included in the baseline and can be included by product teams in its entirety or as a feature variation. Adhering to a published standard alleviates the interoperability dependency from new acquisitions and allows vendors to focus on their core capabilities. For LT2, standardization takes the form of published standards that clearly enumerate system interfaces and provided architecture frameworks that enable disparately developed applications to share and act on data at a domain level context.

Development of mature architecture(s), services, common software components, and standards is essential to foster interoperability and reuse. The success of the LT2 Product Line is based largely on the published interface standards available on the LT2 Portal and on three interoperable architectures:

- Common Training Instrumentation Architecture (CTIA) and CTIA services - allowing for the systematic development and composition of reusable software components
- Future Army Systems of Integrated Targets (FASIT) - the new common Army standard for automated target systems
- Army Tactical Engagement Simulation System (ATESS) - providing a standard for instrumented live players

Common Training Instrumentation Architecture (CTIA)

CTIA is the foundation architecture of the LT2 product line. The objective of any architecture should be to combine the common parts of software development in general such as logging, archival, retrieval and inter process communications and build it up to a level that combines the business logic common to the target domain such as, in the case of Live Training, entity addressing, entity filtering, and brokering control of instrumentation.

These frameworks succeed by providing a uniform and highly reusable feature rich environment that allows developers to focus on their primary objective of implementing business level use cases and not on repetitive implementation details. CITA's success can be realized by the fact that it forms an average of 50% of the code base for all live training systems deployed since 2006. Of the two million lines of code in the CTIA framework, LT2 products typically use 57% of it. For the eight actively fielded products listed on the LT2 Portal, this is a reuse factor of 4.5

Using the latest technology available during the design effort in 2001, CTIA was designed using the Common Object Request Broker Architecture (CORBA) interface definition language (IDL). It enabled a measurable compliance level without specifying an implementation language. The CORBA IDLs were aggregated into API-level Object Models providing methods and higher-level abstractions (e.g. proxies for remote objects). The CTIA Object Models have evolved to a point where they remain very stable and application development is almost universally tied to the OM implementation and not to the CORBA IDL. Additionally the universal adoption of the CTIA framework has negated the need for a compliance level. As a result CTIA has been able to separate itself from the IDL constraints and evolve to new technologies without affecting compatibility or external development.

As technology and the needs of the target domain evolve, the framework must also evolve in order to remain relevant. CTIA has been able to shed its IDL constraints and is currently addressing technology obsolescence and changing domain needs including: adopting Service Oriented Architecture (SOA), cloud computing, and virtualization. SOA migration using composable, reusable, and loosely coupled services will enable greater interoperability both internally and to external systems. Cloud computing will allow product-line architectural services, components, software applications, and software updates and upgrades to be readily available in a logically centralized repository where consumers can access them as needed. Virtualization will improve organization between

database servers and reduce hardware footprint. Some of these gains have already been realized and some are still in the process of development. These technology updates will allow CTIA to achieve greater ROIs by providing an inherent upgrade to previously fielded systems and enabling additional reuse. ROI numbers for CTIA have been calculated based on not needing to incur the initial development costs for the features provided on each deployed product. There is also significant cost savings by preventing the duplication of software sustainment costs for those portions projects.

Future Army System of Integrated Targets (FASIT)

FASIT provides the specifications, standards, and protocols for industry to construct live fire targets and targetry devices. This standard ensures that targetry manufactured by any vendor and delivered to the range will be interoperable with any other FASIT equipment delivered by any other vendor. FASIT provides the physical characteristics of the equipment, the power specifications, and all other specifications down to the physical connector.

Cost avoidance has been realized by the use of FASIT in the following areas:

- A single command, control, and feedback software system. With the establishment of FASIT, the Army was able to institute a government-owned software system capable of operating any FASIT-based range. The institution of the software has reduced training, fielding, testing, and maintenance costs significantly as the Army moves away from proprietary control systems and replaces these with a single system.
- Replacement equipment. FASIT compatible equipment may now be purchased from several vendors, not just the vendor who originally installed the targetry at a range. This allows the Army to purchase in higher quantities, "shop" for the best prices when purchasing spares and replacements, and provides the ability to leverage targetry inventory from one range location to another.

FASIT was introduced in 2006 and now has complete acceptance in the target industry. FASIT is in use by all three force-on-target LT2 products, and has been adopted by TRADOC Capability Manager–Live (TCM-L) for targetry acquisition under the Army Targetry Systems II (ATS-II) contract. FASIT-based systems have been fielded to over 120 ranges worldwide.

Army Tactical Engagement Simulation System (ATESS)

The Army will use Army-Tactical Engagement Simulation System (A-TESS) to conduct live force-on-force training from Brigade Combat Teams (BCTs) to individuals beginning in Fiscal Year 2015. Incrementally, A-TESS will provide new and improved capabilities for direct and indirect fires devices and is being developed under a standards-based open community/ open architectural framework to ensure interoperability and compatibility with existing and future training systems. The framework will enable PMs to develop and integrate A-TESS components into their systems (embedded or appended) with maximum reuse and interoperability of components.

Just like FASIT, A-TESS standard-based architecture that ensures that equipment manufactured by a vendor and delivered to the range will be interoperable with any other A-TESS equipment delivered by any other vendor. A-TESS will provide the physical characteristics of the equipment, the power specifications, and all other specifications down to the physical connector. It is anticipated that significant cost avoidance will be realized by the implementation of the A-TESS architecture and acquisition of A-TESS compliant solution. [7]

Standard Interfaces

Aside from establishing common architecture frameworks, LT2 has established common interfaces to enforce interoperability among products and external interfaces. The following standard common interfaces were established under LT2 and are managed under CPM:

- **LT2 GUI Framework** – A developer toolkit that provides a consistent look and feel across all LT2 products' user interfaces. This standard toolkit provides adherence to standard display items such as artillery effects, and casualty status, it also frees the developer from having to implement common LT2 user interface capabilities.
- **Common Player Unit Standard** – Specifies the protocol and messages to transmit live instrumented player events to a LT2 Product Exercise Control (EXCON). This standard eliminated the proliferation of vendor proprietary gateway interfaces, and also solved a critical information assurance issue that required a re-assessment when swapping instrumentation vendors on an accredited system. This standard is widely accepted and supports over two dozen vendor instrumentation systems.
- **LT2 Video SOA** – A web service definition created to providing a standard video abstraction of

camera control, live stream management, video query, and stream collection. This standard abstracts the camera and video-related devices vendor-specific interfaces from the LT2 products allowing any LT2 product to interface with any video-related device adhering to the standard. Interfaces have been implemented for all major industry standard video protocols.

- **Common Battle Roster Import** – A common standard XML interface established to import organizational battle structures into LT2 products. This common interface is used for bulk loading large organization structures as well as for single roster entry additions or swaps.

Common Components and Common Services

Shared software is the result of a successful product line. It is also where ROI is most easily quantified though it is by no means the sum total of the ROI gained. *Figure 3* shows shared software reuse between projects using TL2 including their contributions and usage of the CTIA architecture.

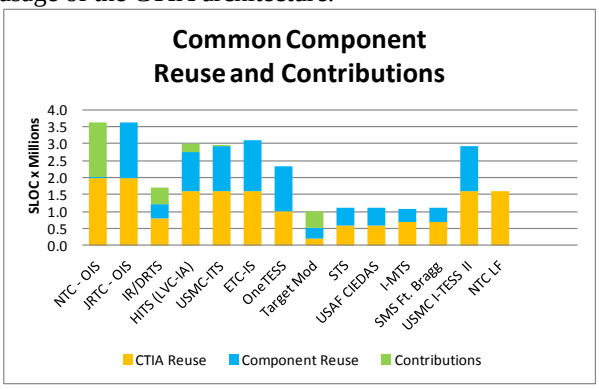

Figure 3 - Common Components Reuse

It does not, for instance, include the reduction in procurement due to standard interfaces to devices or reduction in user training and logistics, but it does enumerate a portion of the gains made by establishing governance of all core assets. The LT2 product line consists of approximately 120 individual software components. LT2 components are used in conjunction with the CTIA to implement an instance of an LT2 product. Each component maintains a Component Agreement which includes requirements, design, test procedures, and user manuals. Each component is managed to the same standards, implemented using the same GUI framework and style guide, and results in easily reusable production artifacts that can be made variant with the same feature variations that are implemented in the source code for the component.

LT2 component reuse is prevalent, as you can see from the chart in (*Figure 4* below, LT2 has been able to field entire products composed entirely of reused code with little to no new development on the part of the fielding project.

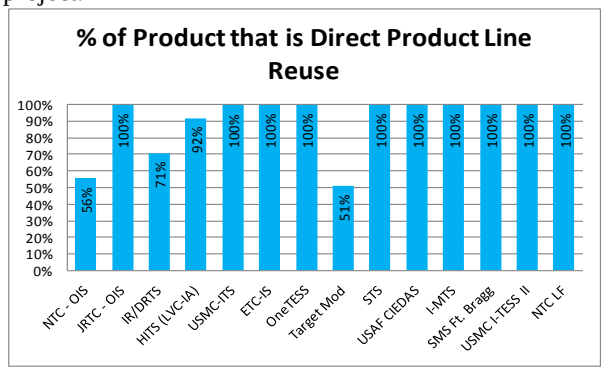

Figure 4 - Product Reuse

Integration and Development Environment (IDE)

The Integration and Development Environment (IDE) is a government run development facility providing an integrated lab for LT2 P/L development and sustainment. Programs either have resident labs in the IDE facility or leverage its capabilities remotely. As a badgeless facility that accommodates multiple contractors, the IDE provides improved collaboration, software P/L management, a co-located workforce, and significant cost reductions due to shared lab space, shared licenses, IT equipment, reduced facilities overhead, and resource sharing.

For contractors that use the IDE facility. the government saves ~25% through off-site rates. For 44 Full Time Equivalents (FTE) per year that's ~1.5M dollars saved which more than offsets the facility's operational costs. Additional savings come from consolidated CM, IT management, backup strategies, decreased configuration time for builds and testing, and reusable lab spaces. Products leveraging the capabilities of the IDE remotely are able to gain savings for CM, some IT management, backups, and even builds and testing, albeit to a lesser degree than those projects that are run exclusively from the IDE. Migration to tools that specifically support remote development like SVN, CQ2SVN and greater use of the LT2 portal are essential for remote development to be successful. These tools are all hosted and administered by the IDE and its staff.

Adoption of the IDE by more projects has caused some contention for space. In order to gain a greater ROI, the footprint of the current projects will have to shrink. This is being done through the use of virtualization and more efficient use of lab space through technologies such as virtual desktops and virtual labs. These allow more efficient sharing of lab space while allowing non-resident developers to participate in critical activities which generally required co-located staff.

Centralized staffing is not required for a product line but constant communication between teams is and the IDE fosters a sense of community though shared office space and labs as well as shared meeting spaces for face-to-face collaboration such as Core Asset Working Group and LT2 Product Review Board (PRB) meetings. This coordination between resident teams causes a "collaborative ethos" which extends beyond the physical IDE and touches remote development teams as well.

Governance/Common process ("Factory")

During the transition from the first-generation product line to the second-generation product line, the LT2 philosophy shifted from managing a common set of components and products to focusing on the development of those products using a "factory" approach which imposed specific governance and process guidelines on the development teams. In a commercial product line, this factory would typically consist of a core team whose singular focus is to maintain the core assets based on feedback from the development teams.

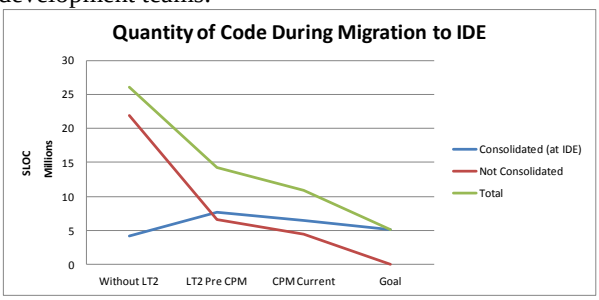

Figure 5 - Reduction of Base Source Code

In a DoD environment where funding follows projects, governance and processes were put in place to ensure that development teams participating in the product line meet the expectations of the community and not only their singular product focus.

There are two primary documents which guide this philosophy. The *CPM Operations Guide* is a document, published on the LT2 portal which defines the roles and high level objectives of the product line. The *CM Operational Procedures Guide* is the "how to" guide for developing in the LT2 product line.

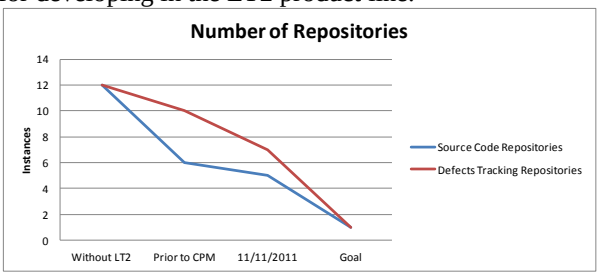

Figure 6 - Reduction of Source Code Repositories

Common policies and governance also mean that team members can easily transition between projects without having long spin-up times. This enables efficient surge support and load balancing of staffing between project startups. Factory governance and processes have enabled a total reduction in Source lines of code maintained by LT2 from 26 million lines of code to 10 million lines of code. Further consolidation will drive to a unity value of 5 million lines of code, *Figure 5*. The driving factor to reducing the maintained lines of code is to consolidate repositories to store it. Total number of maintained repositories to manage code and requirements has likewise been reduced, *Figure 6*.

Defined Metrics

A set of metrics that produce accurate, reliable and meaningful information are critical for measuring progress and reporting status to stakeholders. LT2 has derived a set of metrics using the Goal-Question-Metric (GQM) method. GQM is used to define measurement in such a way that:

- Resulting metrics are tailored to the LT2 organization and its goals
- Resulting measurement data play a constructive and instructive role within the LT2 Product Line
- Metrics and their interpretation reflect the values and the viewpoints of the different groups affected (e.g., PM TRADE management, developers and TRADOC Capability Manager - Live TCM-L)

Rollup metrics for the entire LT2 product line are published though the LT2 Portal and clearly depict the status of core assets and product teams in a consistent and actionable way. A clear benefit of the product line is immediate inclusion of fixes between product teams. Roll up metrics allow for teams to measure their effectiveness based on the work they plan and complete and also see the quality of their baseline by aggregating the work done by all teams in the product line. This effectively allows teams to manage themselves and product line managers to manage the product line effectively. Because all teams are looking at the same metrics, there is a clear understanding of who is accomplishing and collaborating to ensure that critical trends are monitored and corrected when necessary.

Collaboration Environment - LT2 Portal

The web-based LT2 Portal (*www.lt2portal.org*) provides access to LT2 P/L assets, components, products, architectures, and developmental and sustainment support features that allow easy use of LT2 P/L assets across the Army, DoD, and industry partners.

The LT2 portal features content and tools which provide on-line support and information to the full spectrum of LT2 stakeholders to include: developers, program teams, support teams, combat developers, and end users and helps promote industry competiveness and participation.

The LT2 Portal is the primary source for obtaining LT2 Family of Training Systems information for users, developers and management. The LT2 Portal is a secure, web-enabled interface to the assets of the LT2 product line and is used in the following ways:

- Product Deliverables
- LT2 Core Assets
- Collaborative Development
- Help Desk
- CPM Working Group Requests
- Establishing Standards

RETURN ON INVESTMENT (ROI)

Pillars are not mutually exclusive. The ROI, cost avoidances and efficiency gains attained and enumerated for each of the pillars discussed above could not have been attained with that pillar alone. The total product line savings are abstract and hard to quantify. Calculating individual ROIs for each pillar is challenging. The ROI of the LT2 Product Line is most indicative as a factor of its artifacts. This number is developed using industry standards and evaluated based on code counts of the LT2 repository.

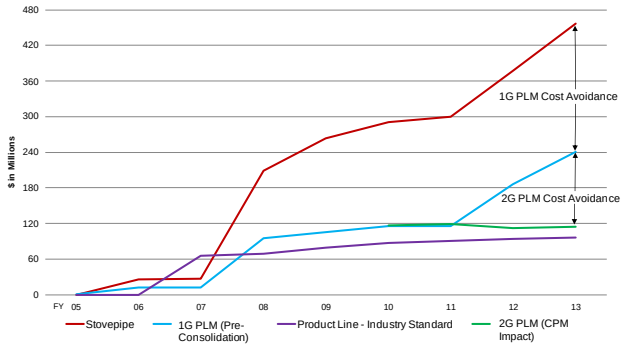

Figure 7 Benefits of LT2

The LT2 Product Line strategy generated a significant return on investment (Figure 7) to date within PM TRADE's live training system acquisition portfolio. The 1GPLE approach generated over three hundred million dollars in cost avoidance across the development of live training systems to include Combat Training Centers Instrumentation Systems, Home Station Instrumentation Systems, Instrumented Ranges, and Targetry. The CPM approach is projected to save another two hundred million dollars over the next two to five years. [8]

ACKNOWLEDGEMENTS

The authors wish to thank COL Mike Flanagan, Project Manager Training Devices (PM TRADE); Mr. Brian Kemper, Deputy Director Engineering Live; and Mr. Thomas Coffman, Assistant PM TRADE, for their vision, contributions, and continued support in pursuing the methodologies and technologies described in this paper.

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