Component-Based Software Reuse Strategy For Army Live Training Ranges

Paul Dumanoir
Jorge Rivera
U.S. Army PEO STRI
Orlando, Florida
Paul.Dumanoir@peostri.army.mil, Jorge.Rivera2@peostri.army.com

Barry Clinger
Riptide Software, Inc.
Orlando, Florida
Barry.Clinger@Riptidesoftware.com

Keywords:
Product Line, Live Army Training, Software Reuse

ABSTRACT: *Realizing cost savings from systematic software reuse through component-based development strategies has traditionally been a challenging undertaking. Software component reuse will never occur automatically; it must be strongly supported by management, methodology, and process. Factors including technical, managerial, and economic have hastened the failure of many corporate reuse initiatives in the software development industry (Frankes and Fox 1996). For the U.S. Army Program Executive Office Simulation Training and Instrumentation (PEO STRI), Project Manager for Training Devices (PM TRADE), their software reuse initiative was further compounded by the complications of coordinating the development of a software product line among several different government contracting corporations who view themselves as competitors. The objective of the PM TRADE product line is to achieve a reduction of software development and maintenance cost by maximizing component reuse and to reduce product fielding times while enhancing training benefits to the Soldier. Through successful execution of the product line strategy, PM TRADE will deliver a set of common components that provide integrated and interoperable training solutions for live collective training across the Homestations, Combat Training Centers (CTCs), deployed, and joint training domains. This paper describes the innovative approach PM TRADE is using to manage, facilitate, and implement its product line, along with the successes and failures encountered during the implementation of this strategy. A web-enabled infrastructure was required to accommodate the delivered components and facilitation of the construction of new components for the product line. A series of analysis tasks were conducted to establish the reuse plan among all the products of the product line, and a set of processes were created to manage and maintain the product line. The paper concludes with lessons learned regarding the harmonization of multiple companies under separate contracts with different software development practices and management structures. It is the intent of this paper to capture the successes and failures while implementing this strategy to assist similar projects in the future.*

1. Introduction

Component-based software reuse is a fairly common practice implemented successfully throughout the commercial market by companies such as Microsoft and General Motors Corporation to name a few. In comparison, the DoD has less experience implementing component-based software reuse because of several unique technical, managerial, and economic reasons. This paper describes how the U.S. Army's Live Training Transformation (LT2) product line strategy is addressing these constraints to achieve a reduction of software development and maintenance cost by maximizing component reuse and to reduce product fielding times while enhancing training benefits to the Soldier. Through successful execution of the product line strategy, Program Executive Office Simulation, Training, and Instrumentation (PEO STRI) Project Manager (PM) Training Devices (TRADE) will deliver a set of common components that provide integrated and interoperable training solutions for live collective training across the Homestations, Combat Training Centers (CTCs), deployed, and joint training domains. This paper describes the innovative approach PM TRADE is using to manage, facilitate, and implement its product line, along with the successes and failures encountered during the implementation of this strategy. The paper concludes with lessons learned regarding the harmonization of multiple companies under separate contracts with different software development practices and management structures. It is the intent of this paper to capture the successes and failures while implementing this strategy to assist similar projects in the future.

2. Background

2.1 Live Collective Training

Live training range systems provide the means to plan, prepare, execute and provide training feedback for Force On Force (FOF) and Force On Target (FOT) training. Live collective training exercises at these ranges are characterized by the following:

- Actual soldier/vehicle activity on actual terrain under simulated combat conditions,
- FOF weapon engagement with instrumented targets via Tactical Engagement Simulation (TES) and FOT with actual targets and Live fire,
- Position and tracking of training audience done through Instrumentation System (IS),
- Training system allows analyst to link observations, events, and training reports to build Cause and Effect
- Alerts (training) and alarms (safety) can be triggered, for example, when soldiers/vehicles cross control measures; enter restricted areas
- Humans and IS implemented real and simulated visual and sound effects for battlefield events (e.g., vehicle kill indicators, smoke, pyro, barricaded bridges, etc.).

The remainder of this section describes how these Live collective training range exercises are being improved through the execution of the LT2 product line strategy.

2.2 Live Training Transformation (LT2)

LT2 is an Army initiative to develop a live training range product line that includes capabilities centered on a common architecture, known as the Common Training Instrumentation Architecture (CTIA), and common plug-and-train components called LT2 components (Dumanoir, Rivera 2005). The LT2 product line strategy is required to synergize training instrumentation, targets, and tactical engagement simulation systems to ensure the efficiency and effectiveness of training during peacetime, mobilization, mission rehearsal, and in-theatre during deployed military operations. LT2 products are composed using a "family of components" approach, which maximizes software reuse, provides common functionality, interfaces and standards. LT2 training systems will also provide interfaces to virtual and constructive training domain systems, the Army's Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) infrastructure systems, Future Combat System (FCS) platforms, and to components of the Joint National Training Capability (JNTC).

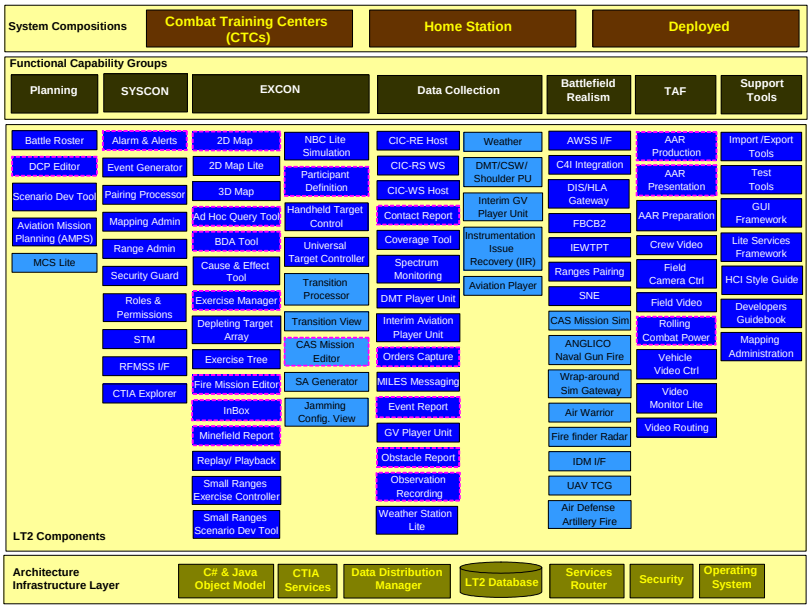

Figure 1. LT2 Component Product Line Framework

2.3 LT2 Family of Training Systems (FTS) Requirements Evolution

The Live Training Transformation Family of Training Systems (LT2-FTS) is the Army's family of interoperable Live training systems based on the LT2 product-line strategy. The LT2-FTS is based on requirements from eight existing live training Operational Requirements Documents (ORDs) and consolidates them into a single Family of Training Systems. These ORDs encompass requirements from the Combat Training Center Objective Instrumentation Systems (CTC-OIS), Integrated MOUT (Military Operations on Urbanized Terrain) Training System (IMTS), Homestation Instrumentation Training System (HITS) Instrumented Ranges (IR), One Tactical Engagement Simulation System (OneTESS), and Next Generation Army Target Systems (NGATS).

During 2000-2001 a domain requirements analysis of these 8 ORDS (LT2-FTS domain) was conducted and determined that 90% commonality existed across this set of live training systems requirements. Given the extent of similarities and manageable differences within the LT2 family of programs, PEO STRI and the Army Training Support Center (ATSC) elected to formalize the LT2 product line strategy acquisition.

2.4 LT2 Components and Software Reuse

Under the LT2 product-line strategy the CTIA provides the common IS standards, interfaces and protocols for Live ground maneuver training ranges within a JNTC environment (CTIA, 2006). A LT2 component is a plug and train architectural element of the LT2-FTS, and serves as a building block for any LT2 product. A LT2 component is defined as a software artifact, a hardware specification, an interface specification, or a combination thereof, that encapsulates functionality that has been identified as a candidate for potential reuse across multiple LT2 products, has a clearly defined interface, has an associated LT2 component agreement, and when completed, will reside in the LT2 Repository under configuration control with complete documentation. All components residing in the LT2 Repository are also called LT2 assets. An example of a LT2 asset is a 2D mapping tool.

All LT2 component capabilities are traced back to an ORD requirement. Each component has a defined set of product dependencies that are tracked to make sure the component will meet its expectations. All LT2 components are designed, developed, and tested by the LT2 product teams and are placed in the LT2 repository to facilitate re-use. LT2 components are expected to evolve as technology and requirements evolve.

Figure 1 provides a notional representation of the LT2 components from a Product Line Framework perspective. These LT2 Components are used to implement an instance of a LT2 system in conjunction with the Architecture Infrastructure layer. The Architecture Infrastructure layer in this figure represents the "core architecture components provided by the CTIA. The LT2 components are grouped into

Functional Capability Groups (FCGs) that focus on U.S. Army doctrine of plan, execute and assess (FM 7-0).

LT2 components are considered candidates for reuse within the LT2 product line under the following categories:

- **Systematic**: The component was originally intended and designed to be reused by more than one LT2 product. This approach assumes that the consolidated set of product component requirements were available and well understood prior to component development.

- **Opportunistic**: This category describes components that may be reused by other programs, but were not specifically identified for that reuse. This could be because the reusing program was not well-defined during the original component development, or simply a well-designed component was deemed suitable for use within another product.

- **Design re-use**: In design reuse category, the component itself is not reused, but the design of the component is used in the creation of a new component. This type of re-use is most commonly utilized when different software or hardware platforms are being used and the component is re-implemented in a different language or for another operating system.

There are also different manners in which a component can be reused:

- **Complete**: In this case, the reusing product uses the common component "as is" without modification. Use of this component requires no additional development effort by the using product.

- **Extended, New Version**: The common component is "extended" in some fashion to create a new extended version of the reused component. The extended version maintains backward compatibility with the reused component or replaces the reused component to become a new version of the reuse (or extended) component.

- **Extended, New Component**: The common component is "extended" in some fashion to create a new component that has been based on the reused component. The new component then becomes an additional component that meets other set of requirements with new functionality and interfaces. This process can occur with varying amounts of reuse from the original component, but focuses on adding new functionality to the new component which warrants making it a separate "new" component.

3. LT2 Product Reuse Planning and Analysis

The LT2 product line is utilizing an evolutionary incremental acquisition and development approach which focuses on three main product groups: Combat Training Centers (CTCs), Homestation training ranges, and deployable training range capabilities. Figure 2 below shows the notional evolution of the LT2 products, within these three main product groups, as more components and architecture capabilities become available, and reusability and commonality increases. The Digital Multi-Purpose Range Complexes (DMPRCs), which are a type of Homestation product, in conjunction with the CTC-OIS programs have made the initial investment, and most crucial investment, in the product line, by beginning the development and maturing process of the CTIA and LT2 components. Follow-on programs such as the OneTESS (OneTESS, 2005) and Homestation Instrumentation Training System (HITS) are starting and will continue to reap the benefits of reusable components that have already been developed and hardened by the DMPRC (IR, 2005) and CTC-OIS (CTC-OIS, 2005) programs.

The foundation of this evolutionary development approach was a detailed LT2-FTS requirements domain analysis that was conducted by PEO STRI to ensure that there was enough requirements commonality to justify a product line strategy. Once 80-90% commonality was confirmed, a common architecture (e.g. CTIA) was designed to meet the requirements of all of the different programs described by the LT2 set of ORDs. These requirements are documented in a requirement traceability matrix database, called the Domain Object Model (DOM), and serve as the foundation for the allocation of requirements for the LT2 components. In addition to the aforementioned requirements analysis, a detailed bottom-up functional analysis was performed on each evolving LT2-FTS program so that a common solutions could be identified based on the LT2 product line strategy. Program analysis working groups, composed of representatives from PEO STRI, LT2 support staff, and the program itself were created to perform the analysis. This proved to be beneficial for all programs since existing separate, stove pipe efforts are now being aligned under the LT2 product line

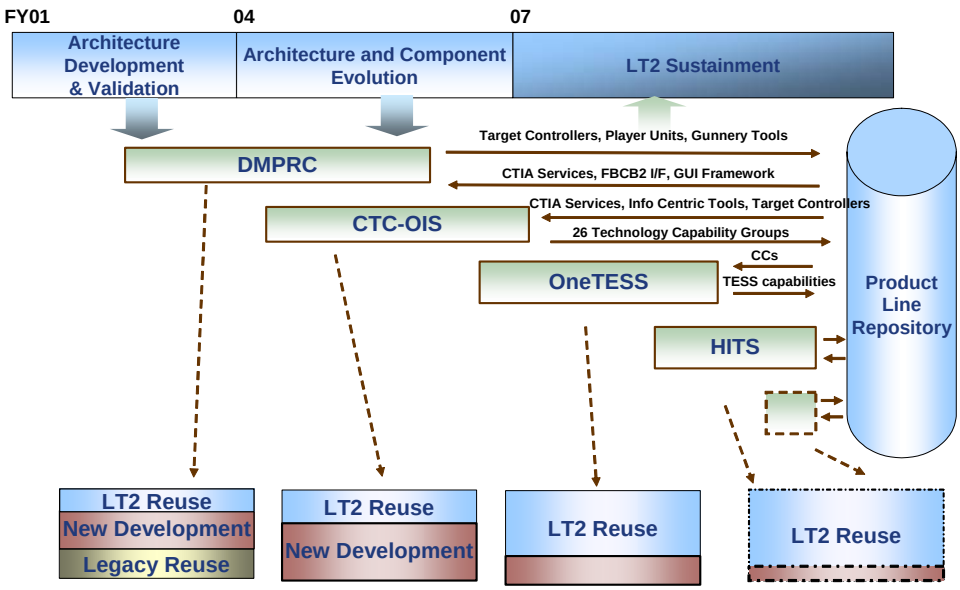

Figure 2. LT2 FTS Evolutionary Development

strategy, and are working together to provide common solutions that can be reused by other LT2-FTS programs.

The primary artifacts used for this analysis were the LT2 capabilities matrix and the LT2 components definition spreadsheet. The capabilities matrix defined the known set of generic capabilities being fulfilled by the LT2 programs on the left, and across the top each program had two columns, one for the program's current approach and one for the desired future approach. The matrix served as a starting point for discussion with the programs and was completed throughout the sessions. The second artifact, the components definition spreadsheet, was a working document that captured attributes data for each identified component, such as, functional classification, responsible organization for creating the component and timelines, organizations planning on reusing the component and implementation description, a description of the component, and any dependencies. The information contained within this spreadsheet later became the foundational metadata for each component in the LT2 repository and serves as search and filter criteria within the LT2 portal today.

Length of the analysis sessions depended on the relative size of each program, ranging from three days to two weeks. In these analysis meetings it was critical to employ the correct team makeup, and establish the appropriate context. Through some trial and error, we have found the following crucial to program analysis success:

- Program participants must be assured that the analysis is not being conducted to determine how to replace their role or contract. For the analysis to be successful, an open exchange of information is required, and having defensive or uncooperative team participants severely hinders the process.

- Program participants must be adequately informed of the product line reuse approach and provided with required context. We found that making the effort up front to disseminate information to the team participants about the goals and entire process of the LT2 product line eliminated many participant concerns and made for more cooperative teamwork.

- A moderator role provided the ability to keep the meetings on track, stay out of the technical details, when it could be avoided, and kept the group focused and moving toward daily goals. This moderator role was satisfied by LT2 support staff or a PEO STRI participant.

- The team must possess adequate resources with sufficient technical knowledge. This applies to the program itself, and to the product line components. Ultimately the conversations gravitated to the technical attributes of either the existing program's system, or to the product line's component offerings. It is critical to have individuals on the team who can competently discuss these details. On many occasions our analysis teams scheduled sessions with varying individuals depending on the agenda topics for that session.

- The final results of the analysis need to be reviewed by all participants and any conflicts resolved, before making them really final.

4. LT2 Product-line Infrastructure

A critical key to product line success is the establishment of an infrastructure to support the product line activities. Due to the varying goals and motivations of the LT2 stakeholders, the infrastructure required has to be flexible, easy to use and understand, and satisfy several different categories of users. LT2 infrastructure products take the form of documents, a software developer framework, a web-enabled portal, processes, assignments, and working groups. Key products of the LT2 infrastructure are described below.

4.1 LT2 Component Agreement

To facilitate communication among the different programs and vendors developing LT2 components, a standard document is used to describe component details. The component agreement serves as an agreement between the component developer, the users, and PEO STRI. The component agreement includes:

- CTIA compliance levels define the level (1-4) a component could be reused by other LT2 products. Level 1 equals least level of reuse.

- Component requirements (e.g. functional, quality, physical, and interface) Specification (e.g. Software Requirements Specifications (SRS), Interface Control Definition (ICD), etc),

- Design (e.g. Unified Modeling Language (UML) and/or DOD Architecture Framework (DODAF) artifacts),

- Test documentation used for verification and validation of components during asset handover (e.g. test conditions, procedures, build / install procedures, etc) , and

- Component dependencies that may include other components, data stores, and Commercial Off The Shelf (COTS) /Government Off The Shelf (GOTS) equipment.

4.2 LT2 Developer's Guide

This is a set of guidelines written from a software developer's perspective that provides the background, procedures, and required reference material to successfully create software using the existing assets of the LT2 Product Line and to submit potential assets for future LT2 Product Line inclusion (Version 4, PEO STRI 2006).

4.3 LT2 Human- Computer Interface (HCI) Style Guide

This style guide leads application developers in the design and implementation of LT2 compliant applications, displays, controls and visual components (Version 2.1, PEO STRI 2006). Many of the items covered in the guide are domain-specific to the US Army, such as coordinate display and input, map-based casualty assessments and area weapon effect display. However, a large portion of the document is dedicated to the specification of industry standard user metaphors aimed at reducing the user's error rate and education time required to master the application.

4.4 LT2 Product Line Management Concept of Operations (PLM CONOPS)

The purpose of the LT2 PLM CONOPS (Version 3, PEO STRI 2006) is to delineate the implementation and management processes necessary to define, develop, and sustain the LT2 Product Line. This CONOPS also describes the processes, methods, roles and responsibilities, and tools required to manage the product line. The CONOPS includes three high level process groups used to acquire LT2 products and compliment normal acquisition processes. These LT2 processes are described based on who is responsible for the particular action, rather than in a sequential timeline. The CONOPS shows the process flow across and between the three responsibility areas. These three high level process groups are:

- Government Acquisition. These are the processes the Government LT2 Implementation and Product Teams conduct when a new requirement is provided and a component or product must be acquired. A Description of these processes is provided in the LT2 Acquisition Guide (PEO STRI 2005).

- Contractor Development. These are the processes the contractors follow to develop LT2 components and products according to the LT2 strategy and CONOPS. A description of these LT2 processes is provided in the LT2 Developers Guide (PEO STRI 2005).

- Government Product Deployment and Supportability Management. These are the processes conducted by the Government to deploy and sustain the LT2 product. A description of these LT2 processes is provided in the LT2 Supportability Strategy (PEO STRI 2005).

4.5 LT2 Metrics Plan

A key to determining success of the product line is to establish, maintain, and track a set of metrics that produce accurate, reliable, and meaningful information. This plan describes the LT2 metric methodology, determines the means of measurement, collection, storage, and analysis of the metrics (Version 0.4, PEO STRI 2006).

4.6 LT2 Configuration Management (CM) Plan

The LT2 CM plan is a standard document describing the management and life cycle of the LT2 assets that are under configuration control within the LT2 repository (Version 0.3, PEO STRI 2006).

4.7 LT2 Graphical User Interface (GUI) Framework

A software developer framework was created as a sister product of the LT2 HCI style guide. The purpose of the framework is to assist the software developer in creating LT2 compliant graphical user interfaces as part of LT2 products. The framework reduces development costs by providing a set of fully tested, user approved software "widgets" that are compliant with the LT2 HCI style guide. Use of these widgets in multiple LT2 products further reduces the cost of training the user community as the same common "look & feel" for applications becomes prevalent across LT2. The GUI Framework was the first LT2 common component created, and also the first collaboratively developed component. The experiences captured from this effort helped spearhead many of the later LT2 processes.

4.8 LT2 Web-Enabled Portal

The intent of the portal is to create a web-enabled interface to facilitate development, support, and management of the product line. As depicted in Figure 3, the portal has been designed to accommodate varying types of end users with disparate objectives: program managers requiring status on schedule, risks, and metrics; software developers charged with constructing software applications that reuse common components; end users requiring support and training on deployed LT2 products; and organizations new to the LT2 concept requiring information and guidance.

The portal provides a virtual "gathering place" for the LT2 community. Program managers come to the portal to review schedule, identify risks, review metrics, and produce reports. All the LT2 component schedules are tracked and updated on a weekly basis. Program managers are provided easy to understand dashboards as their home page with customizable content that, at a glance, quickly summarizes their area of concerns. Graphs and the data behind them can be downloaded for insertion in presentations and further analysis. Pre-canned searches and filters are used to determine the dependencies a program manager may have on other products and the items he or she is responsible for providing. On-line calendars track important milestones and provide easy import into a user's Microsoft outlook calendar.

Software developers use the portal to download the most recent versions of the architectures and components for use in their product development. They can review ICDs, hardware specs and make comments on future revisions of these documents. Software developers have access to libraries of documentation on the architecture, on the components themselves, and on the LT2 development practices. Forums are available to allow the developers to interact with each other in an informal fashion across product and corporate boundaries exchanging lessons learned and practical tips. On-line tutorials and training material exist within the portal to assist new developers in becoming proficient in LT2. Collaboration areas allow LT2 stakeholders to facilitate working groups by providing common file storage, action item maintenance, calendars, email distribution list, virtual meeting capability with desktop sharing, common configuration managed area for storing source code, forum for idea exchange, and other items all under tightly controlled roles and permissions.

LT2 product users have access to FAQs, user discussion forums, training and reference material, and the LT2 help desk. Through the LT2 help desk the user can review the currently known issues list for their product, submit trouble tickets, check the status of active trouble tickets, and request supplementary support. The FAQs help prevent duplicate or superfluous trouble ticket submittal. The monitored discussion forums can help ascertain user concerns and usability issues that can be addressed in subsequent versions of the product.

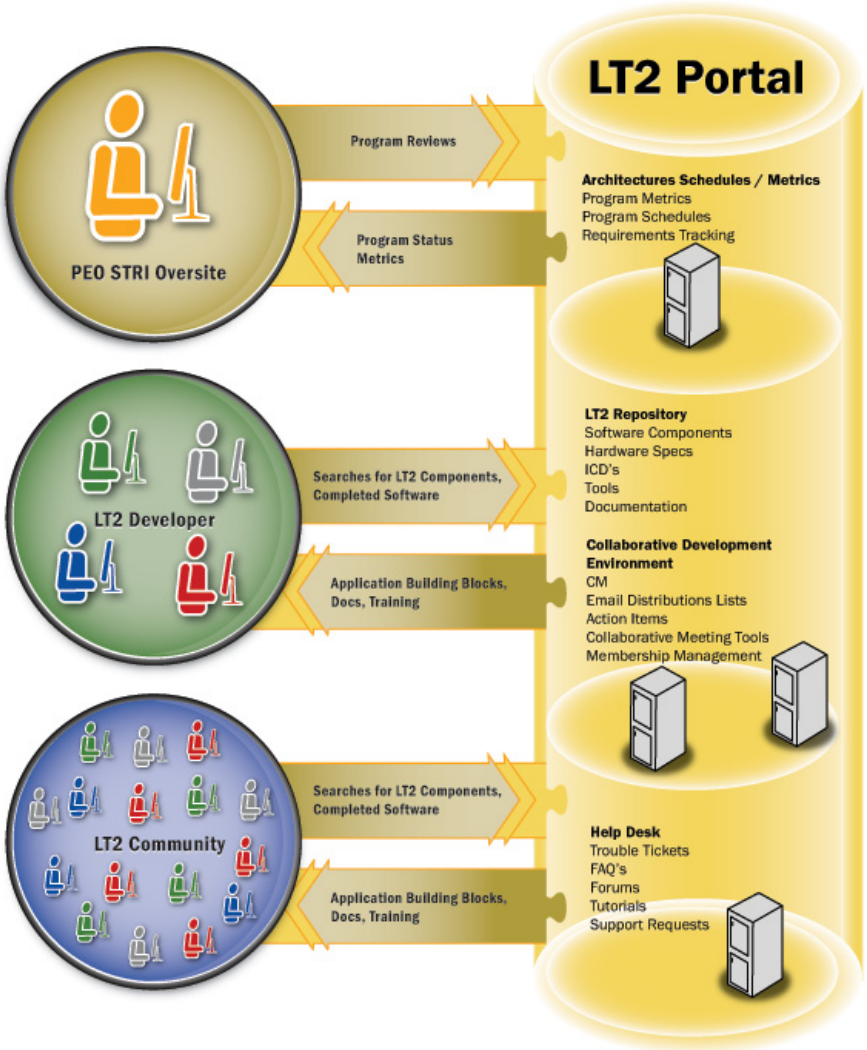

Figure 3. LT2 Portal

The portal is also used to provide information about upcoming programs to the contractor community. The portal is separated into a public and a user account / password protected side. On the public side, general information about the LT2 product line and future opportunities are described. On the user account side, the capabilities of the portal are restricted by role and permissions. A security disclaimer must be signed and approved to obtain a user account on the LT2 portal.

4.9 LT2 Processes, Assignments, and Working Groups

Another key element of the infrastructure are processes specific assignments, and working groups that can be easily understood and implemented so that all LT2 stakeholders are aligned and efficiently support one LT2 strategy.

- LT2 component assignment – Development tasks for systematic reuse of LT2 components are clearly assigned to the responsible organizations, as well as the planned reuse. Assignments are tracked on the portal so that there is no confusion over who is responsible for developing the component, and furthermore, who is intending to reuse that developed component. A specific component handover process is also defined, which allows the developed component to go through a verification process before it's admitted into the LT2 Portal. LT2 community involvement in the component development process is also defined. The LT2 community is defined as all product line stakeholders; in particular, those that will want to re-use the LT2 artifacts that are being developed. The LT2 component development processes prescribe how and when those stakeholders should be involved in component development via peer reviews.

- Collaborative development process – From a LT2 perspective, collaborative development is defined as two or more LT2 organizations or programs working cooperatively to develop a LT2 component. A process was created solely for the purpose of describing the roles and interactions of the respective development teams. The process provides guidance in identifying a facilitator and organization chart, the implementation of the software lifecycle for the component, configuration management for the software and associated documentation of the component, and a description of the roles and responsibilities required for LT2 collaborative development. The LT2 portal provides support for collaboration groups that helps facilitate the process and solves many of the ownership issues associated with jointly developing a software product among competitive contractors. The outlined LT2 collaborative process is intended to be tailored, much like a Capability Maturity Model Integration (CMMI) process, so that it can be suited for the specific collaborative effort.

  Difficulties encountered in earlier collaborative efforts which we attempted to resolve by the implementation of the LT2 collaborative development process include:
  - Overall component responsibility
  - Ownership of the software configuration management
  - Status & progress reporting
  - Work share distribution
  - Conflict resolution

- Advisory and working groups – Several working groups have been established, with a specific scope and finite duration, to support the LT2 product-line strategy. These groups can be categorized into Working Groups (WGs) and advisory groups. WGs are composed of Government and contractor teams who focus specifically on how to improve specific LT2 components or the CTIA, for the benefit of the product line. The advisory groups are mainly comprised of Government teams that make recommendations and or decisions on the technical and management aspects of the product line. These WGs and advisory groups are governed by processes, roles and responsibilities described in the LT2 PLM CONOPS.

5.0 Management Considerations & Lessons Learned

This section discusses management issues that that have been encountered by PM TRADE during the execution of the LT2 product-line. It also proposes a set of management guidelines that should be considered when executing a product-line, based on LT2 experiences.

- **Stakeholder expectation management**- Different stakeholders have their own needs from the product line. Therefore, their expectations and priorities are not the same and sometimes are in competition. An approved and recognized management structure, that resolves problems and priorities, is vital for the success of a product line approach. The tendency is to deviate from the product-line goals to address each new crisis, since most of the time it offers an easier way to "patch" something together when you are not restricted with the standardization and re-usability overhead. Although it's important for stakeholders to begin harvesting the benefits of reusability as soon as possible, stakeholders need to understand the need to first build the infrastructure, populate the repository and allow maturation before it becomes effective and an acceptable solution. We believe we are getting close to that point, but have not completely gained the necessary expectation from all stakeholders. It is crucial to show the benefits to management and the specific products/systems teams so that the initial investment can be defended and executed. Most of the time in the DoD or commercial world, but especially in the DoD environment, the need is now and project managers cannot afford the investment in time and dollars for something that will provide dividends years later. The product line management structure, defined in our LT2 PLM CONOPS, constantly evaluates these conflicting needs and determines, objectively, the best course of action from the Army and customer perspective while balancing the need to achieve the product line goals. To successfully manage these constant conflicting objectives, an experienced product line manager, with good leadership skills, is required to maintain the product line vision, establish realistic goals, sustain morale, and solicit feedback to continuously improve the process.

- **Funding** – Institutionalization of a product line is a long term effort that requires years to achieve and a well defined and stable funding flow. The current DoD funding process does not provide the funding structure required to effectively achieve the goals of a product line approach. Current funding process is focused on delivering systems that support the Soldier now, as it should, and balancing with latest DoD needs, in addition to constantly facing budget cuts. That is a hard fact, which is the nature of DoD, especially in war time. This is the reason that funding

for product-line such as the LT2-FTS, which is dependent on system specific funding, is even more vulnerable than the system/program themselves. This uncertainty complicates the already challenging environment in making a product line a reality, because it affects specific product line dependencies and delivery schedules on a yearly basis. Therefore, clearly communicating the need and the dependencies of each product line component against each of the products/systems is critical in defending funding cuts since resources are normally associated with a system/product and not with pieces/components that will be shared and reused by many. We have found the LT2 management infrastructure very useful to oversee the overall funding availability, resolve funding issues, and provide recommendations on how to quickly adapt the plan to execute the product line.

- **PLM CONOPS** - A CONOPS is essential and should clearly define the infrastructure and management structure to oversee efforts, processes and responsibilities. It should be a living document and start at a sufficient level to gain consensus and program buy-in. As the program progresses and processes evolve, the CONOPS should be revised and refined to provide more details that reflect the product line maturity. All stakeholders should be involved in the CONOPS development and revision process if team consensus is to be achieved.

- **Communications & Essential Personnel** - To stay viable and relevant within an organization you need to keep the stakeholders aware of issues, progress, and all other topics of interest to them. To successfully execute the product line you need resources (personnel) dedicated to oversee its progress and guide its efforts to include dependencies and effort tracking. The dedicated personnel executing these tasks will act as the honest brokers and should be empowered to guard the integrity of the product line and the adherence to the standards and plans established by the product line management structure.

  It is essential to market the product line throughout program lifecycle and keep all relevant stakeholders informed at all times. This especially important since stakeholders will change over time and existing stakeholders need reaffirmation. Communication between product teams and ensuring all product line teams are following common processes is another key to success for the product line.

- **Getting competitive contractors working together** - A clear definition of the goals, the architecture/framework, and each component, to include requirements, security, documentation, testing, design, etc is a key so that information can be placed on contract. Product Line training on all the aspects of the product line is also is essential. A clear and consistent use of terminology is also important. Once you have this basic set of information, you can share consistently with all the contractors that are interested in the development of the product line. A challenge for DoD PMs is to motivate contractors to buy into a product line approach since it seems to contradict the "bottom-line is profit" objective. That paradigm is not easy to change, but in this age of continuous and inevitable budget cuts, contractors are starting to realize there are not many other options. Once they recognize and understand that the Government management is serious about the product line approach, they realize there are profits to be made if they buy into this approach, by focusing on their strengths. In other words, they can develop components that only they (or very few others) have the expertise to develop. The Government has a need to keep their industry base interest on the product line strategy. This needs to be done by constantly demonstrating the product line benefit, not only to the Army but to industry as well, so that they support the concept and influence their own internal research and development investment toward the product line.

- **Metrics** – Since software reuse and product line engineering is relatively new within the DoD, there is not much quantitative data available to capture trends and case studies. Although the cost of collecting metrics could be high, it's necessary to begin collecting quantitative and qualitative data associated with a product line, so we can mature the product line processes within the DoD. 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 users)

  Although the LT2 metrics strategy is still evolving, the plan focuses on providing a wide variety of well defined metrics that can be applied for different purposes, but enforce only a minimum set of product line metrics, and allow each program to define a complementary set of metrics depending on program acquisition phase and risk areas for that specific program. To facilitate product line risk management,

the metrics should include not only technical measurements but a full spectrum that can measure cost, schedule, and performance. There is no perfect set of metrics; instead the metrics need to be tailored on a case by case basis very carefully to make them useful and to avoid investing money on metric with no real added value.

- **Success criteria** – Product line success should be measured in small pieces. An effective product line strategy should aim to incrementally develop tangible products that meet the stakeholder's needs and advance the product line objectives. In the case of LT2, we had too many disruptions and increases in domain scope to be able to define incremental success, much less manage it. After the product line domain scope stabilized, by defining the LT2-FTS, we are now trying to define specific success increments in the form of CTIA software versions that will be part of a mature baseline and LT2 components that will be available for reuse and support a specific system fielding.

  The product line execution plan should be incremental to allow for early fielding of some of the capabilities. This will allow for not only the maturation of the product, but also keep the interest of the community and stakeholders/investors. It will show progress and viability of the final goal. If not, viewgraphs get hard to justify after a short while, especially with competing requirements and the continued changing climate of the environment. You need to prove and be ready to justify the relevancy of your final goal. Show the final goal and your status against it.

  Define achievable, realistic goals for the near term, but always keep in mind to define your overall goals. Don't lose sight of the finish line. Be ready to show small successes throughout the product line development so that you can get long term investment commitment for the future.

- **Teaming** – Partnerships are a key factor to a successful product-line implementation. This includes all sides and layers within and outside the Government. It includes teams of contractors developing product line components. It includes Government program teams, within the product line domain, working together to develop product line assets. It includes Government and contractors working together as a team toward a common goal, were the Government is sensitive to the contractor profit objective, and the contractor is sensitive to Government's funding constraints.

- **CM and requirements baselines** – Configuration management is critical to any product line, especially as it evolves. Architectures, interfaces, and dependencies must be controlled to allow for an accurate reusability assessment. We are implementing a consolidated approach to allow for maximum leverage of the contractor development assets and are utilizing a centralized repository to exchange components. A well thought out and controlled process to accept information is critical to maintain the integrity of the product line and to protect the integrity of contractor "proprietary" data. Keeping interfaces and standards open is also required to allow for reusability.

  The sooner you can define and baseline a set of product line requirements (components and architecture) the better. If not, you will find yourself constantly negotiating, re-evaluating and managing conflicts with respect to evolving requirements. This creates inefficiencies and duplication of efforts which could waste your resources and deviate stakeholders from the strategy.

  Also, need to control requirements creep so that you can reach your goal. New players tend to bring new ideas. Listen to these new ideas, but be careful on modifications to your goals. Is better to get there first with an 80% solution and then improve upon that. Don't be trapped into always shooting for the 100% solution, if you do you will always be stuck in the 95% answer. Prioritize your requirements. If you address the top (most important) 20% of your requirements first it will most likely give you 80% of what you really need.

- **Cost Avoidance Data** – In the Government, it's called "cost avoidance" instead of "return on investment". It's important to have analysis data that captures cost avoidance for programs using the product line approach upfront, prior to committing resources. Need to be able to convince the stakeholders that product line efforts usually require investment from at least 2 programs, within the domain (LT2-FTS), to break even and start reaping the benefit of savings for rest of product line from a development perspective. The maintenance (supportability) cost savings aspect should be another cost avoidance data set that should be readily available to manage stakeholder's expectations. This cost avoidance data needs to be objective and convincing data not just ambiguous words.

6. Acknowledgements

The authors wish to thank COL James Ralph, Project Manager Training Devices (PM TRADE) and COL Whitehead, Training and Doctrine Command (TRADOC) Program and Integration Office (TPIO) – Live, and the PM TRADE and Live Engineering staff at, PEO STRI for their vision, contributions and assistance in the evolution of the LT2 product-line.

7. References

Combat Training Center-Objective Instrumentation System (CTC-OIS) web site. Retrieved 2005 from http://www.peostri.army.mil/PRODUCTS/CMTC-OIS/

Common Training Instrumentation Architecture (CTIA) web site. Retrieved 2006 from https://ssl.peostri.army.mil/CTIAPortal/index.jsp

Dumanoir, P., Rivera, J. (2005). *LT2- A Strategy for Future Army and Joint Live Training*. 2005 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), Orlando Florida.

FM 7-0 Training the Force (2002). Washington DC: Headquarters Department of the Army. http://www.army.mil/features/FM7/FM%207-0.PDF

Instrumented Ranges (IR) web site. Retrieved 2005 from *http://www.peostri.army.mil/PM-TRADE/dmprc.jsp*

Live Training Transformation (LT2) Developers Guide, Version 4, (2006). Orlando FL: U.S. Army PEO-STRI.

Live Training Transformation (LT2) DRAFT Configuration Management (CM) Plan, V0.3, (2006). Orlando FL: U.S. Army PEO-STRI.

Live Training Transformation (LT2) DRAFT Metric Plan, V0.4, (2006). Orlando FL: U.S. Army PEO-STRI.

Live Training Transformation (LT2) HCI Style Guide Version 2.1 (2004). Orlando FL: U.S. Army PEO-STRI.

Live Training Transformation (LT2) Product Line Management Concept Of Operations, Version 4, (2006). Orlando FL: U.S. Army PEO-STRI.

One Tactical Engagement Simulation System (OneTESS) web site. Retrieved 2005 from http://www.peostri.army.mil/PRODUCTS/ONETESS/

Author Biographies

PAUL DUMANOIR is the LT2 chief engineer at U.S. Army PEO STRI with extensive experience in system and software engineering. His current interests include product-line engineering, embedded training and mission rehearsal applications. He has 19 years experience working in DoD simulation and training programs. He earned his B.S. in Electrical Engineering from the University of South Alabama in 1987 and his M.S. in Computer Systems from the University of Central Florida in 1991.

BARRY CLINGER is the Chief Technical Officer for Riptide Software, Inc. and for NetPads Inc. He is an experienced software solutions expert who specializes in the design and architecture of large-scale distributed systems. Barry has over 16 years of commercial, DoD, and NASA software development experience. He earned his B.S. in Computer Science from Eckerd College in 1988 and his M.S. in Business from Kennedy Western University in 2003. He holds multiple software design and architecture certifications from Sun and Microsoft.

JORGE RIVERA is the Assistant Project Manager (APM) for LT2 at PEO STRI. His experience includes a strong software engineering and program management background in the Instrumentation System, Instrumented Ranges, and Urban Operations arenas. He has 21 years experience working in DoD acquisition both from a technical and program management perspective. He earned his B.S. in Electrical Engineering from the University of Puerto Rico in 1983 and his M.S. in Electrical Engineering from Fairleigh Dickinson University, NJ in 1987.