Methodologies Applied on LT2 to Achieve a Long-Term Strategic Vision

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ABSTRACT

The U.S. Army Project Manager Soldier Training (PM ST) office has established a legacy of innovation based on the Product Line Engineering methodology to manage a complex System of Systems architecture for live training systems. PM ST has invested in long term initiatives to evolve the Live Training Transformation (LT2) enterprise to meet the future needs of warfighter training. These initiatives resulted in common training capabilities that can expedite the realization of the Synthetic Training Environment (STE) vision as we move from technology exploration efforts to an established foundation of continuously maturing capabilities. Key to this approach is LT2's community accessible approach to advance their core mission though shared capabilities which reduces the "not invented here" mentality. This enables funding to be applied to specifically high value needs instead of redundant solutions common to all training environments (e.g. performance data collection, training specific message exchanges, position location tracking, data retention, data security. Etc.) This methodology also allows adjacent programs to benefit from existing baseline and focus on their unique needs, LT2 has demonstrated this with the inclusion of the Integrated Live, Virtual, Constructive (LVC) Test Environment (ILTE) system. Most importantly by enabling teams to focus on new capabilities, PM ST established a culture focused on achieving long-term objectives. These concepts are evident in the current enterprise architecture that reaches down to the individual and cloud hosted micro-services for Live Training. In this paper, we will explain the methodologies that PM ST used to support continuous incremental improvement across multiple programs and how to apply them to other programs to achieve similar cost avoidance when executing multiple technology efforts towards a common strategic vision.

ABOUT THE AUTHORS

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BACKGROUND

This paper covers methodologies used to successfully achieve horizontal and technology integration on Live Training Transformations (LT2) that you can replicate on your program. The U.S. Army Project Manager Soldier Training (PM ST) office, formerly PM TRADE, has established a legacy of innovations to manage a complex System of Systems product line. Through its well-known Live Training Transformation (LT2) product line, PM ST has integrated several innovative methodologies to effectively execute its horizontal and technology integration mission. These practices are considered the prime instruments used to develop high quality and low cost live training enablers. The most visible of these live training ranges are the Combat Training Centers (CTCs) but extends to home stations and family of force on target ranges totaling over 200 locations worldwide. These systems achieved great savings using the LT2 methodologies discussed in this paper, which were applied to enhance the quality and quantity of training for soldiers.

INTRODUCTION

Since the early 2000s, PM ST has invested in long-term initiatives to evolve the LT2 enterprise to meet the future needs of warfighter training. One of the initiatives was the creation and continuous evolution of the Common Training Instrumentation Architecture (CTIA), Live Training Engagement Composition (LTEC), and Future Army System of Integrated Targets (FASIT) architectures. This continuous improvement pursuit includes both the LT2 products and the methodologies used to create them. Throughout this journey, LT2 has explored many different methodologies to manage the diverse portfolio of live training products, each one providing various benefits.

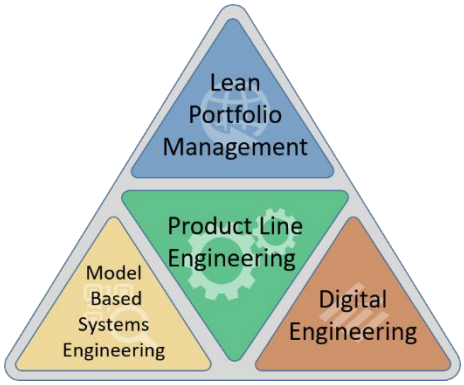

Figure 1 LT2 Key Methodologies

To continue this journey PM ST maintains an LT2 vision: *To be the vanguard provider of a **common interoperable product-line** through innovative and adaptable solutions for training devices.* PM ST has set Strategic Goals, as shown in Table 1, to focus teams as they field Live training systems using a common interoperable product-line approach.

Table 1 PM ST Business Goals

Focus	Goal
Managed Product Line	Foster product line culture of efficiency, stability, quality, automated production and delivery
Operationally Focused	Provide mission ready products to support operational needs and ensure a meaningful user experience
Cost Effective	Reduce development, quality assurance, procurement operations and sustainment costs
Relevant and Concurrent	Foster technology agility using industry best practices and technologies to enable rapid alignment with Army priorities

This paper explores the current evolution of the most impactful methodologies that have enabled LT2 to remain concurrent with continuously changing technologies to ensure the sustainability of live training ranges now and in the future.

- Product Line Engineering (PLE)
- Digital Engineering
- Model Based Systems Engineering (MBSE)
- Lean Portfolio Management

For each of these impactful methodologies, this paper will explain the approach in the context of PM ST's use cases, demonstrate how the methodology contributed to the PM ST vision as part of the long-term strategy and provide recommended guidance for teams that wish to implement these methodologies within their own environments. It is important to recognize that although these are presented as individual methodologies, is only by combining them effectively that PM ST has been able to overcome the challenges of managing it's diverse and continuously evolving portfolio.

METHODOLOGIES

Product Line Engineering

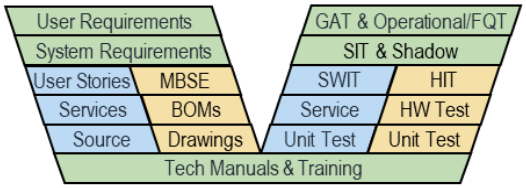

Figure 2 Systems Engineering V Diagram

Feature-Based PLE continues the work pioneered in second generation PLE[1,2] as an evolution of traditional reuse-based portfolio development. The Feature Based incarnation of PLE has an increased focused on the Business and Technical Organizational Management required for the technology to be effective. This methodology allows all stakeholders to clearly understand their relationship to programs in the portfolio and makes is possible for programs to immediately accept any enhancements and fixes in the shared baseline.

The tangible assets that teams already use are shown in the systems engineering V-Diagram (Figure 2 above). When using PLE these assets are consolidated into a single shared domain superset and product instances are created from the superset as needed. To control and automatically orchestrate this content generation, Feature-Based PLE introduces an abstraction layer for the superset, called a Feature Catalog. In this approach, a "Feature" is a distinguishing characteristic of a product that makes it different from another product in the portfolio. With a feature-based approach, new products are composed through the creation of a bill-of-features describing the product. New capabilities are added to the product line as features for inclusion in all or some of the products as updates to the bill-of-features.

An example of a feature, or difference, in the LT2 product line is a training system with a need for event based video monitoring versus another training system with no video requirement. To express this feature, teams implement variation logic within the shared digital engineering asset supersets. This abstraction and flow is shown in Figure 3. With a PLE tool, the feature selections in the Bill-of-Features product portfolios are used to automatically configure source code, systems configurations, bill of materials, tests and all other Digital Engineering Assets shown in the Superset Systems Engineering Vee. The result is a complete set of Product Digital Asset Instances needed to build and field a training system with, or without, event based video monitoring. The cost to maintain the shared baseline and coordinate efforts across products are quickly offset as products avoid significant duplication of sustainment effort by working from the single baseline were a single fix or enhancement often benefits 3 other products in the portfolio.

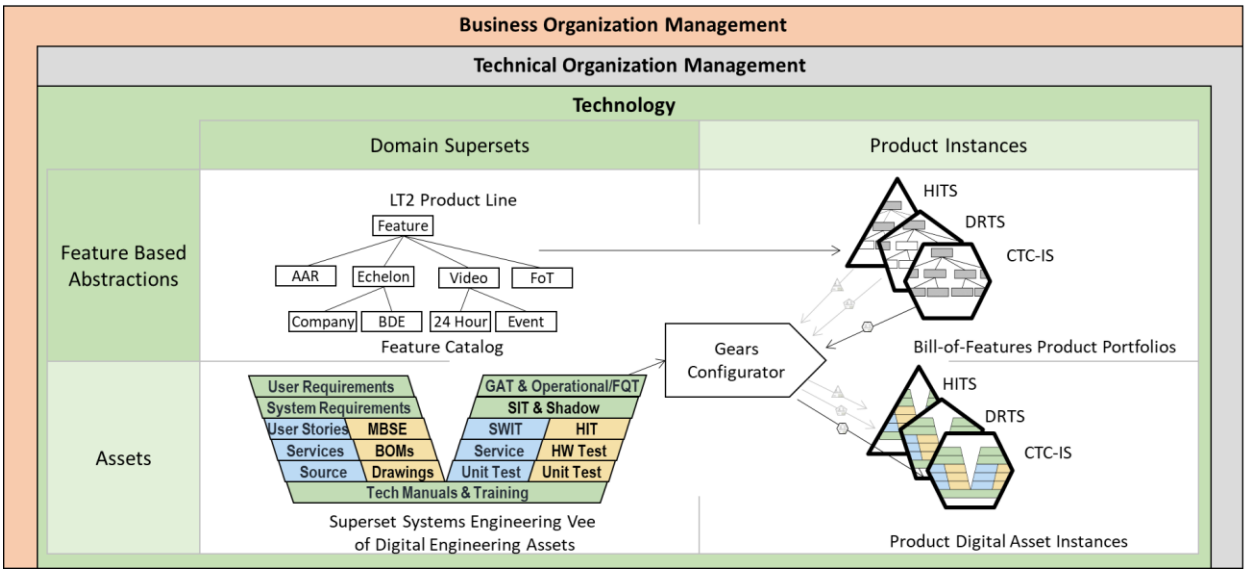

Figure 3 Feature Based Product Line Engineering Technology and Business Processes

Technical and Business Organizational Management principles are used in the development of the technical solution to ensure that all stakeholders adhere to well established governance and best practices for the product line. Feature-Based PLE provides the language of features and variations that allows teams to have actionable conversations about sharing without letting differences become a justification for divergence. The language of products, features, and variations is key to enable the teams working within the product line to identify opportunities for sharing without divergence. This is critical in early stages of PLE when product line teams are working to combine disparate products into a single product line.

How The Methodology Contributed To The Vision

Feature-Based PLE is the primary methodology used to achieve the PM ST Business goal of being cost effective. Through the use of PLE, PM ST consistently achieves more than 2.5x impact on every dollar spent on software development, resulting in more training capabilities delivered to the Operating Force, and contributing significantly to the Army readiness. This is further improved by the extreme sharing of follow on artifacts such as tech and training manuals where in many instances over 50% of content is common. Once PLE becomes part of the workforce culture, conversations change from justifications for differences to tailoring existing solutions, which allows all funding to focus on the most impactful change. Building on others' success is essential to advance with industry and accelerate innovation.

Effort avoidance is measured as the quantity of shared assets that the program did not expend resources to develop. Shared assets are the content that is shared between products: e.g. requirements definition, software lines of code, or technical data. For example, if a capability was improved with funding from program A and deployed in program B, then program B is able to avoid the effort of A. The total effort avoidance is the value of the shared assets deployed on program B minus the cost of participation in the product line.

The LT2 product line provides a diverse set of capabilities common to DoD training domains as well as those with similar capability needs such as the Test community. In addition to PM ST, LT2 capabilities are used directly by PM CT2 Integrated Live, Virtual-Constructive Test Environment (ILTE) and USMC PM TRASYS programs. There is significant interest by other DoD organizations to instantiate their own product lines; especially with the ongoing major modernization efforts.

How Can Others Adopt The Methodology

Table 2 PLE Key Considerations

Key Considerations
Identify commonality
Model feature variation
Shared don't reuse
Get a coach
Maintain the culture

PLE can and should be adopted incrementally by first focusing on a few high-value efforts and then using the gained efficiencies and newfound capacity to justify expansion of the approach to new products. Defining the initial shared baseline (a.k.a asset superset) is performed by either consolidating divergent baselines, as was the case with LT2, or by using the latest of the most representative baseline and creating feature based variation to support new products. A clear startup adoption plan and vision is critical to ensuring that all stakeholders embrace the technical and business processes and not allow divergence because "they are different". In a PLE approach, commonality justifies consolidation, and differences increase value to the end users. However, this increase in value can only occur if it does not include the sustainment burden of divergent baseline maintenance.

It is important to remember that Feature-Based PLE relies on a clear definition of differences between products. The products themselves are not the reason for variation and should not be enumerated in the feature catalog. By following this rule, the feature catalog and bill-of-features will approach stability as they reflect the variances in product performance specifications. This stability and clarity allows PM ST to identify opportunities where capability improvements can benefit more than a single product. This allow for the consolidation of efforts across program of records that is required to leapfrog to new technologies at a small fraction of the cost. This cost would have been incurred by multiple programs implementing divergent capabilities to achieve similar results.

A key phrase when adopting PLE is "sharing over reuse". The goal is to avoid the natural tendency for individual programs to "clone and own" separate copies of the baseline, which increases cost to each program and reduces benefits when changes on one product are not available to others. The word "reuse" is often implies an event in which divergence occurs, you can for example reuse a file by making a copy and changing the name. To avoid this, instead use "share" which is valid now and in the future.

For organizations new to PLE, we strongly recommend getting a "PLE coach" subject matter expert to help with the initial adoption and continue to advise the organization periodically until the PLE culture is fully embraced by the organization. LT2 gained significantly by partnering with an industry PLE vendor and consultant to implement an effective product line approach and overcome failure modes common to new PLE implementers in industry.

As the PLE culture is adopted, another best practice is to establish a group of internal PLE coaches within the organization to ensure new team members are trained and the PLE practices and benefits are not lost over time. Internal coaches can help the organization track PLE benefits through standard metrics (see Effort Avoidance above) and avoid local product optimizations that result in negative cost impacts elsewhere in the product line (e.g. "clone and own").

Digital Engineering

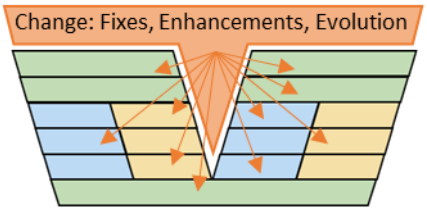

Figure 4 Change in interconnected assets

Digital engineering is a logical extension of agile processes to systems engineering. In a digital engineering environment all artifacts are interconnected allowing for change to occur at any point within the system development lifecycle instead of a linear flow of changes building on layers of systems engineering artifacts see Figure 4. This allows all products in the PM ST portfolio to simultaneously benefit from change regardless of their lifecycle progression.

To enable this, PM ST provides a centralized Integrated Development Environment (IDE) as a government-owned, community-accessible environment for hosting a shared digital capabilities and content. This connected digital environment see Figure 5 is called the LT2 Information Enterprise. The connected repositories for complete content of systems under development provide the authoritative source necessary to facilitate an enduring common understanding between programs. Connectivity between the development repositories as well as external data sources spanning the product lifecycle from development to maintenance allow all contractors and stakeholders to gain deep understanding of all aspects of the portfolio and to easily use and contribute to the shared PLE product baseline. A

representative example of this connected digital environment is an update to a systems description that incorporates new capability. The systems artifacts, technical manuals, and training content are simultaneously updated as they link to the same content in the digital environment.

How The Methodology Contributed To The Vision

Through the creation of the LT2 Information Enterprise, PM ST has been able to significantly reduce the barrier to entry for new contractors to participate in the product line. PM ST now maintains configuration management control of all acquisition domains, not just systems engineering. As shown in the Figure 5, the connected digital environment has narrowed the gap between the development environment and the operational environment of deployed products allowing the government owned DevSecOps approach for CTIA to synchronize cyber security engineering with systems engineering efforts. This significantly reduces the time between capability acquisition and deployment to the training ranges.

PM ST has recently expanded the Digital Engineering toolset to extend configuration knowledge to the sustainment phase of the acquisition lifecycle. Digital Twins collect changes to products from multiple sources to provide an accurate, current, picture throughout development, fielding, and sustainment. This allow for real time impact assessments that would never be possible with traditional Technical Data Package based CDRL deliverables.
This connected digital environment allows for workflow integration spanning all systems assets that link from a government approved change through each individual change across all functional domains. This ensures that complete systems solutions are delivered at the completion of development efforts and that improvements to the shared baseline are immediately available for use by all programs and follow on efforts.

How Can Others Adopt The Methodology

Table 3 Digital Engineering Key Considerations

Key Considerations
Adopt Incrementally
Keep a total systems view
Lean portfolio management

Like PLE, digital engineering can be adopted incrementally. Software-driven programs can realize benefits quickly by adopting a central code repository to store common software baseline and defining common tools and build processes so that all product teams can immediately benefit from shared assets improvements without the cost to maintain separate "clone and own" baseline copies. Hardware-driven programs may start with a central tool to share hardware design information across products. Over time, the product line management team can grow the shared repository and tools to cover the entire systems engineering Vee and enable continuous delivery of multiple systems artifacts including Technical Manuals, Training content, logistics reports, and portfolio wide Continuous Integration / Continuous Deployment of products.

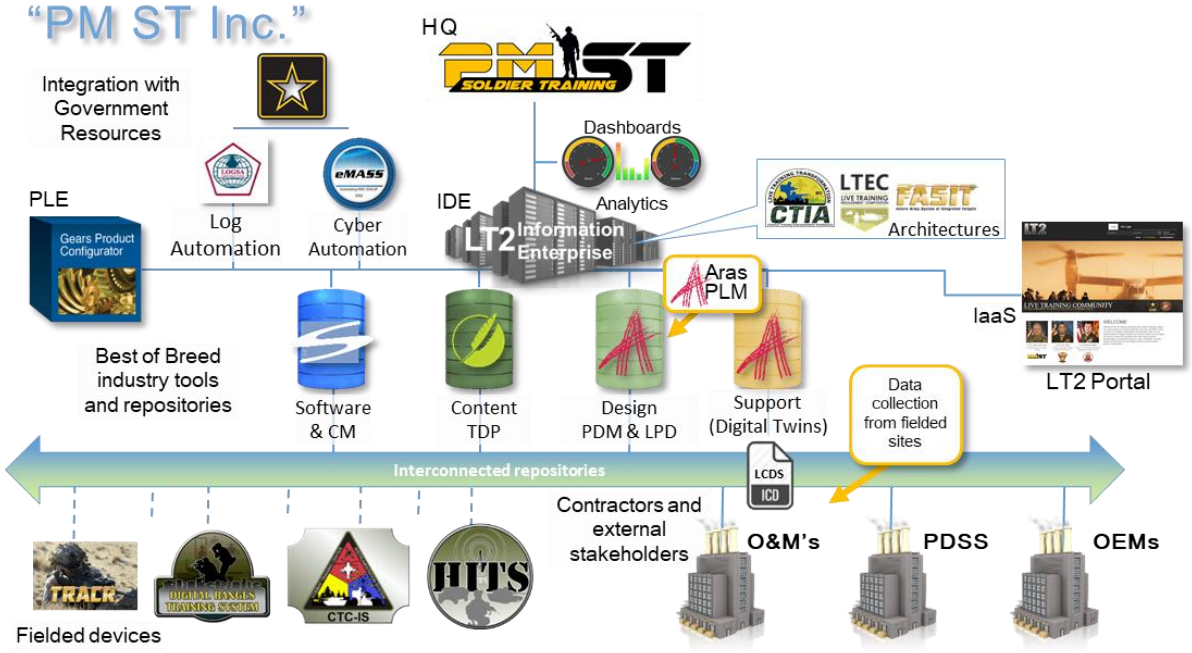

Figure 5 LT2 Digital Engineering Ecosystem

LT2 finds that the commercial and DoD shared development platform offerings such as GitHub and Digital Intelligence Information Enterprise (DI2E) support software development very well. However, they do not support the complete systems engineering needs for a complex systems of systems environments required in the live training domain. This led the LT2 program to expand their collaboration environment tailored to their unique needs. Digital Engineering environments can be provided by prime contractors. One limitation of a contractor owned digital environment is that it is usually not available to their competitors for collaboration, which could indirectly impact the Government acquisition strategy.

Development environments are continuously evolving. Effective governance and change management of the environment is necessary to ensure all stakeholders are aware of, and can accept, changes without significant impacts to their deployment schedules. Establishing a lean portfolio management group that coordinates efforts effecting multiple products is central to governance of the product line.

Model Based Systems Engineering

Model Based Systems Engineering (MBSE) is the application of systems models to assist in making informed engineering decisions as well as communicating these decisions to a broader audience. In the LT2 Digital Engineering Environment, MBSE has emerged as a major enabler for ensuring new capability development meets its intended objectives. In the LT2 environment, with significant legacy content, a complete and up to date systems model is not a viable option, this however does not mean that MBSE cannot provide a significant value proposition. MBSE is consistently used within LT2 programs to identify and coordinate implementation of CTIA- Force on Force (FoF) , CTIA-Force on Target (FoT), and LTEC capabilities. MBSE allows all product line stakeholders to provide accurate impact assessments for the government to understand consequences of program changes including how common capability changes benefit others in the portfolio. This impact analysis also provides a mechanism for avoiding re-architecture by varying the MBSE models using feature based PLE to account for emergent differences without corrupting other products. As shown in Figure 6, MBSE solution connects program of record requirements to the final implementation. In the case of PM ST, all artifacts including models are government owned in the LT2 Information Enterprise and managed by contractors as work is performed.

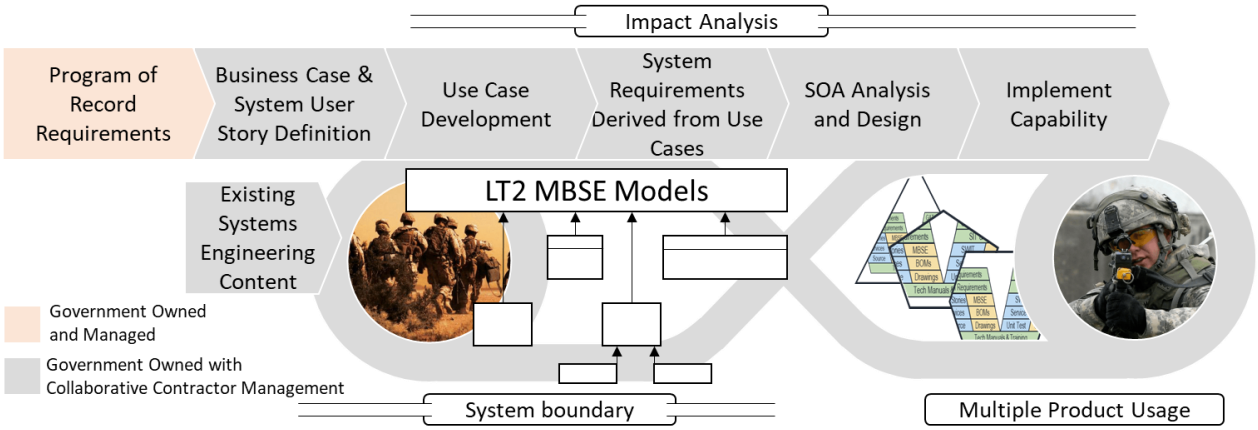

Figure 6 LT2 Model Based Systems Engineering Process

How The Methodology Contributed To The Vision

By applying MBSE, PM ST now has a deeper understanding of the product line impacts to change introduced by products. Implementations are often adjusted to meet broader demand with no additional cost or schedule impacts. MBSE is also used to define public interfaces in the LT2 Information Enterprise and publish Interface Control Documents between sub-systems. As LT2 has migrated to new architectures, the MBSE models have significantly reduced development costs and improved quality by generating infrastructure code for interoperability between services and by clearly defining external system interfaces. MBSE also provides the crucial linkage that synchronizes the hardware design with software implementation.

The majority of a product's cost is incurred during sustainment. The system design has an overwhelming impact on those future costs. Product sustainment costs can be significantly reduced by gaining a broader understanding of the impacts of change and how it can be applied across multiple programs. Sustainment costs for new capabilities can now be weighed against the implementation cost. The most important aspect of MBSE in the LT2 environment is that it allows teams to focus on the areas of highest value in achieving the PM ST Business goals.

How Can Others Adopt The Methodology

Table 4 MBSE Key Considerations

Key Considerations
Accessibility
Minimum Viable Product
Appropriate scope
Well defined work products

MBSE artifacts must be hosted in an environment accessible to all stakeholders. Experience shows that approaches based on importing content fail to foster collaboration across the development factory (see Digital Engineering above). Once a common MBSE system is available, teams should focus first on meeting the immediate needs of the end user by defining the Minimum Viable Product (MVP) informed by product line impact assessments. By focusing on immediate needs without distraction from the multitude of future unknowns, teams can maximize the positive benefits of the initially fielded solutions and justify follow on work through positive user demand.

Implementations should follow Modular Open System Acquisition (MOSA) principals to build modular and scalable architectures using industry best practices, while being aware that it is impossible to account for every unknown. A combination of PLE and MBSE allows established designs to vary in support of emergent products requirements without the need to re-architect existing solutions. In other words, the combination of these two methods allow PM ST to insert leading edge technologies to support new requirements without the need to revamp entire system/software architecture. Within the governance workflows, MBSE activities must be clearly defined and enumerate which modeling artifacts are needed for critical reviews. These milestone activities provide the necessary clarity to teams so that all MBSE activities are planned and funded before work starts.

Lean Portfolio Management

Balancing the competing interests of product development and product line efficiency is a persistent challenge for LT2. Initially teams were structured around products with workers encouraged to patriciate in the factory. This was referred to as the "bring the workers to the factory" model. Because product teams owned their own staff, experts on specific LT2 capabilities were often inaccessible to the enterprise teams, causing developers with generalized knowledge to learn specific information. Though this benefits the diversification of knowledge in the workforce it is also inefficient for execution and often led to implementations that didn't account for the broader product line needs. To overcome this challenge, LT2 adopted a Lean Portfolio Management approach based on the Scaled Agile Framework (SAFe)® [3] shown in Figure 7. This model aligns well with the product line approach where scrum teams with specific expertise can be allocated work individually from programs. LT2 has structured its scrum team into two categories. The first category is the product aligned teams with responsibility to executing program specific tasks such as delivering products to sites. The second category is capability aligned teams with the responsibility of development of shared enterprise solutions used by the product teams. LT2 uses Lean Portfolio Management to provide clear definitions of how these teams interact and receive direction from products to execute in alignment with the product line roadmap.

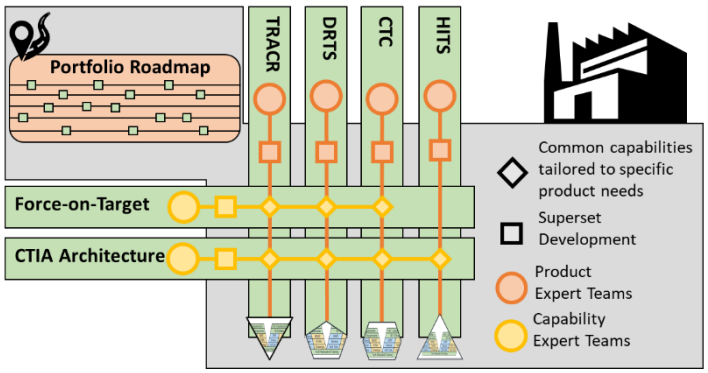

Figure 7 LT2 Capabilities Based Organization Built on SAFe Agile

How The Methodology Contributed To The Vision

Our agile alignment within the product line mimics commercial industries where teams are focused on overall organizational interests in addition to their specific deliverables. The effect of the workforce re-alignment is that procurement models have changed to better support PM ST's acquisition needs. Initially the contracts were constructed to align with products/programs. The product line portfolio makes it easier to construct contracts/delivery orders based on specific capabilities that benefit multiple products while maintaining the linkage and dependencies between products. In addition, synchronization of interdependencies are more easily tracked to ensure the final complete system operates as desired. A perfect example of a new procurement model is the CPM Next 'Force on Target' delivery order. This acquisition involves development and fielding of the latest CTIA capabilities to multiple FoT products and ranges.

How Can Others Adopt The Methodology

Table 5 Lean Portfolio Management Key Considerations

Key Considerations
Balance Products vs. Capabilities
Published Roadmap
Dependency Tracking
No Shortcuts

When establishing the Lean Portfolio Management methodology, focus on achieving balance when aligning teams to core product line vs product needs. This balance must push to advance core technologies while also keeping a firm focus on product ownership measured by quality on time deliverables to end users. Neither the product or the product line enterprise can dominate this decision making process and all decisions that cause a compromise on either side must be adjudicated through a well-defined governance process so that these conversations are happening with visibility of all stakeholders. There are often times when a single product need necessitates a product specific solution or product line divergence. The process should allow for this to happen without putting future work at risk with unknowns embedded in dependencies.

A core philosophy of agile development is the discovery of user needs and iterating as needed, but when managing a large product line it is also important to have a well-defined architectural runway and well managed backlog. By defining the vision of the product line in a published roadmap, the product teams align to a common understanding. In a world of potentially infinite equal alternatives, teams must implement a selection from the subset that aligns to the organizations long-term vision.

A common challenge in a product line environment is maintaining a long-term roadmap that spans multiple programs and tracking cross program dependencies. The Lean Portfolio Management approach uses rolling-wave planning consisting of Epics, Capabilities, Agile Features, and Stories to support this. Epics and Capabilities describe the long-term Portfolio roadmap which includes future work and they are broken into Features and Stories as contracts are planned. Part of the backlog grooming is to ensure that all work has a clear scope and definition of done. Because multiple programs can contribute to a single capability but not all efforts execute simultaneously, a clear understanding of what is in and out of scope, and dependencies necessary to complete a given effort must be documented. This occurs by linking Features to programs and by demarcating the Feature boundaries in the MBSE models that describe the capabilities.

The last takeaway is that although tailoring of the approach is always necessary, don't take shortcuts to gain local efficiencies at the expense of team understanding of the high-level product line objectives (e.g. skip on planning, skipping retrospectives, fewer people participate in planning activities).

LESSONS LEARNED

Table 6 Lessons Learned Key Considerations

Key Considerations
Strong leadership
Clear governance
Cultural acceptance
Full systems view

The use of catch phrases such as sharing, data driven, model based, agile as well as others often obfuscate the underlying details and leave the audience to fill in the gaps themselves, using mental reference models which may be incompatible with a broader adoption vision. Often times organization attempt to adopt only a single methodology to "start small". For LT2 these methodologies are interconnected and all are required to overcome the challenges of individual implementation. For example: an MBSE model that is not connected to the rest of the digital engineering environment ceases to provide value when changes to derived artifacts require "extra cost" to keep the model up to date. Agile teams focused on a single product compete instead of collaborate when PLE doesn't provide an obvious method for sharing similar but different solutions. For LT2 all of these methodologies have been present in a form sufficient enough to counteract these second order effects.

The most important aspect of these methodologies is that they do not focus on an individual technologies and are well defined in governance and engrained within the culture of the workforce. This allows them to mature and adapt to new technology and complementary engineering approaches. LT2 has been successful in part because of a continuous pursuit of expanded perspective and not letting teams, or leadership, focus only on a single approach. No single technology or methodology will solve all the problems an organization has, and everyone has second order effects that must be mitigated. To help adopt these together, we have collected lessons learned that span all the methodologies addressed in this paper. Each of these deserves special mention to help teams overcome the obstacles of managing a large portfolio of systems-of-systems solutions.

First, a strong leadership commitment to the methodologies is essential in ensuring that teams are able to overcome the challenges during adoption. As steadfast focus on a well-defined shared vision for the organization allows the team to achieve incremental success and builds trust between stakeholders. This also reduces the churn incurred due to change and results in shared ownership for successes.

Governance must be clear. Any lack of clarity in the way that teams are to participate in the methodologies leads to the potential for incompatible and divergent approaches that result in artifacts that cannot be used by others, ultimately undermining the initiative. LT2 publishes the Operations Guide as a reference for governance processes that define the rules of engagement and detailed workflows for each asset type to participate as a member of the superset. This is supported at a lower level by community collaboration tools that provide how-to and best practices for individual to see in context references for clarity. The LT2 Operations guide is provided as a reference in Request for Proposal (RFP) packages to ensure all contracts are well aligned and can benefit from each other's efforts.

Cultural acceptance of the methodologies must be fostered and encouraged by organization leaders and coaches embedded within teams. Everyone has a different opinion about the "best way" to approach problems. By focusing on the cultural identity of the organization and agreeing on the high-level goals, this desire for improvement can be directed to overall organizational improvements instead of localized efficiencies that could undermine the overall methodology. This requires a continued dedication by all levels of leadership to focus on demonstrating incremental success and long term value. Each time a team benefits form the work of others is an opportunity to communicate the value to the organization and provide positive recognition further enforcing the culture.

Ensure all team members can see and focus on the complete system. Whenever system boundaries have been put in place, either explicitly by architectural boundaries or implicitly by team structures and funding sources, the scope of the decision makers often shrinks at the expense of "external" considerations that are "someone else's problem". There are many forces that will push teams towards local product optimizations, so it's important to balance them with forces that highlight the value of product-line optimization. For LT2, is done by addressing live training requirements from a common system-of-system architecture and by having a dedicated team focused on product line governance and coordinating product line efforts across teams.

The Methodologies in this paper cover the key enablers to support overall product-line success. Every product line is different so they will require tailoring. When considering changes, select methodologies that support the organization requirement for a product line. The key is to ensure participants to think globally and act locally so that teams don't inadvertently sacrifice the overall objectives in pursuit of localized efficiencies.

CONCLUSION

PM ST Strategic Goals and Future Vision for LT2

This paper explained the key methodologies that have allowed PM ST to make continuous incremental improvement across multiple programs and the remarkable results achieved through this approach. Additionally, it provides context and guidance for applying these methodologies within environments similar to LT2. The most important take away from this paper is a recognition that LT2 is more similar to other programs in the DoD and that the issues LT2 has overcome are echoed in recent recommendations for Design and Acquisition of Software for Defense Systems[4], in the DoD Digital Engineering Strategy which promotes the use of model based engineering [5], and in the new DoD software acquisition pathway [6].

The methodologies described in this paper are the main instruments utilized by PM ST to meet its business goals summarized in well managed product line that is Operationally Focused, Cost Effective, Relevant and Concurrent. In addition to the cost avoidance captured on a yearly basis, the LT2 product line has continued its journey of evolving its processes by adopting best DoD and industry practices for software architecture modernization, digital engineering ecosystem instantiation, product line engineering and task management. These initiatives have not only improved quality of the product line, they have also established a direct pipeline to enable rapid fielding of capabilities to meet the current operational needs and also postured PM ST for the future Live Training Environment enabled by STE. Specifically, the desired outcome of this paper is to provide a reference for expediting the realization of the STE vision as PEO STRI moves from technology exploration efforts to an established foundation of continuously maturing capabilities.

REFERENCES

[1] Lanman, J., Kemper, B.,Rivera, J., Krueger, C., Clements, P., "Second Generation Product Line Engineering at the U.S. Army", 27 February 2012 http://www.lt2portal.org

[2] Feature-based Systems and Software Product Line Engineering: A Primer https://incose.org INCOSE-TP-2019-002-03-0404

[3] Scaled Agile, Inc. Scaled Agile Framework (SAFe) https://www.scaledagileframework.com/safe-5-0-white-paper/ SAFe and Scaled Agile Framework are registered trademarks of Scaled Agile, Inc.

[4] DoD Defense Science Board (Feb 2018). Final Report of the Defense Science Board (DSB) Task Force on the Design and Acquisition of Software for Defense Systems.

[5] Office of the Deputy Assistant Secretary of Defense for Systems Engineering (June 2018). Digital Engineering Strategy.

[6] Undersecretary of Defense for Acquisition and Sustainment (Jan 2020). Memorandum on Software Acquisition Pathway Interim Policy and Procedures.