When to Embrace Redundancy: Practical Guidance for Managing Digital Assets

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ABSTRACT

A key performance predictor for development organizations is how well they manage their digital assets. The intuitive goal is to eliminate redundancy and maintain the minimum assets that satisfy the portfolio needs. Taken to a logical extreme, this would mean that any need should be satisfied by only one solution. Organizations have succeeded in achieving extremely lean asset portfolios by embracing a culture of relentless sharing and employing technical solutions that enable variation without duplication. But even with the best culture, modular architectures, and advanced Product Line engineering (PLE) approaches there are still times when allowing redundancy may be a reasonable decision. However, allowing teams to self-justify redundancy will quickly undermine the digital asset management objectives.

This paper provides a set of parameters to determine the organizational value of redundant solutions in a portfolio from 1(one for all) to N(one for each). These organizational value metrics are applied to common governance decision points including initialization, new effort startup, sustainment, and merging existing products into the portfolio. Practical examples are provided using the Live Training Transformation (LT2) product line as a historical baseline. With over a decade of history managing a diverse product portfolio, LT2 allows us to assess these organizational value calculations using real events and witness long-term effects. This paper will discuss new data-based recommendations for decision making to effectively manage rapid modernization programs for live training and explain how decision criteria could be used to inform other organization management strategies.

This unique perspective on organizational value offers practical solutions for instituting decision-making guidelines for digital asset management. These findings will be of particular interest to organizations sustaining, evolving, and consolidating large portfolios who are looking to provide rigor and accountability into their decision-making processes.

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INTRODUCTION

Efficient use of resources is critical for any organization's success. For a development organization, efficiency is typically a key performance predictor of how well its digital assets are managed. The intuitive goal is to eliminate all redundancy such that any need can be satisfied by only one solution, requiring only a single solution to be developed and maintained. Total optimization is unachievable, and organizations maintain redundant solutions for any number of reasons. Consolidation efforts, when applied without clear guidance on cost-value trade-off decision making, can themselves produce significant waste. The goal should instead be to find a balance point where redundancy of value is warranted, and the organization is optimized in managing and using resources. This is achieved by empowering thoughtful resource consolidation decisions to occur at all levels within the organization. Success requires decision makers to be able to identify and avoid localized efficiencies that undermine the organizational objectives without creating burdensome processes that stifle innovation and long-term progress.

Managing Digital Assets

Organizations have succeeded in achieving extremely lean asset portfolios by embracing a culture of relentless sharing and employing technical solutions that enable digital assets to support varying needs without duplication. Two significant approaches to consolidating digital asset portfolios are critical for the understanding of the techniques identified in this paper: Modular Open Systems Approach (MOSA), and Feature-Based Product Line Engineering (FB PLE).

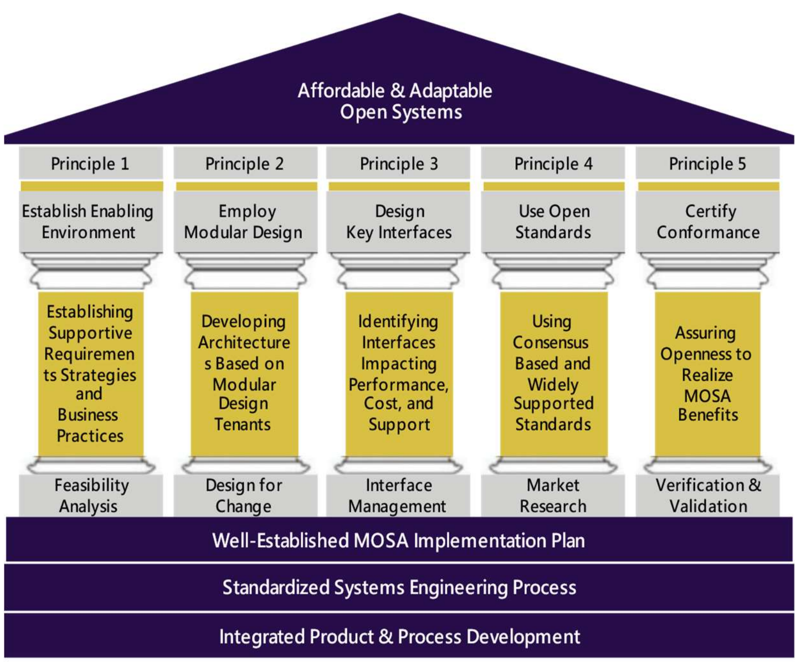

Figure 1. NAVAIR's Five Pillars of MOSA, the building blocks for affordable and adaptable open systems. (NAVAIR, 2023)

MOSA is a hybrid technical and business strategy for designing an affordable and adaptable system. It includes the technical approaches to ensure modularity and interoperability through standards and interfaces and the business approaches to protect Intellectual Property and data rights that enable continued industry participation as solutions grow. MOSA enforces open standards and interfaces to make systems extensible and maintainable using modularized components that can be switched out, upgraded, or replaced to meet evolving needs. Core to the MOSA approach is the open governance to establish and evolve the system over time. Governance drives the openness in MOSA so that a broad stakeholder community can participate and grow, and to enable increased adoption and usage of an established solution. By using what is already available and open, teams can focus on delivering the specific value their customers need without recreating solutions. Figure 1Figure 1 shows the five pillars for applying MOSA (NAVAIR, 2023).

Feature-Based Product Line Engineering (FB PLE) is an approach for managing assets as a single superset and allowing variation within the assets to support divergent use cases from a common baseline. Variation is governed by a well defined set of Features that describes how one instance of a system is different from another. This is defined in ISO 26580 standard “Methods And Tools For The Feature-Based Approach To Software And Systems Product Line Engineering” (ISO, 2021). The FB PLE approach is shown in Figure 2. In this diagram the bottom half vee models represent all the digital assets managed by the organization. On the lower left side is the superset of all assets, which is used to generate specific instances of products on the right side. The instance-specific assets are subsets tailored to the unique needs of the individual consumer. The new and unique value offered by FB PLE is in the top half of the diagram where the definition of features, what can vary, and the feature profiles that define feature selection for a unique instance are actively controlled by the organization. The center of the diagram shows this feature language feeding the automation to generate instances on demand from the superset. Digital Assets in the diagram are indicated by the System Engineering Vee model (Fairley & Forsberg, 2024) as a representation of everything you need to build and support a system inclusive of the environment that the system is crated within. FB PLE can also vary the digital engineering relationships (digital threads, DevSecOps, automation) shown by the yellow line, tailoring all aspects of the digital ecosystem. For digital asset management, PLE is a strategy that allows singular assets to support a significantly more diverse set of users without duplication. PLE enables dramatic reduction in the set of digital assets required to support a portfolio of products. This is done by allowing variation for unique product-specific needs to be inserted into a single superset baseline. Common examples of variation that FB PLE encapsulates are the ability to account for multiple fidelity levels, performance constraints, or compliance issues such as separation of information required for foreign export. Using variation within a digital asset means a singularly-managed asset can support an extremely diverse set of needs in the family of systems.

Through MOSA and FB PLE, many of the conventional objections to “one size fits all” are mitigated and asset management can more reasonably approach unity. The decision factors in this paper presume that MOSA and FB PLE are used to the maximum extent reasonable and provide decision makers the information they need to balance the development and long-term sustainment objectives of the overall organization with divergent needs of programs.

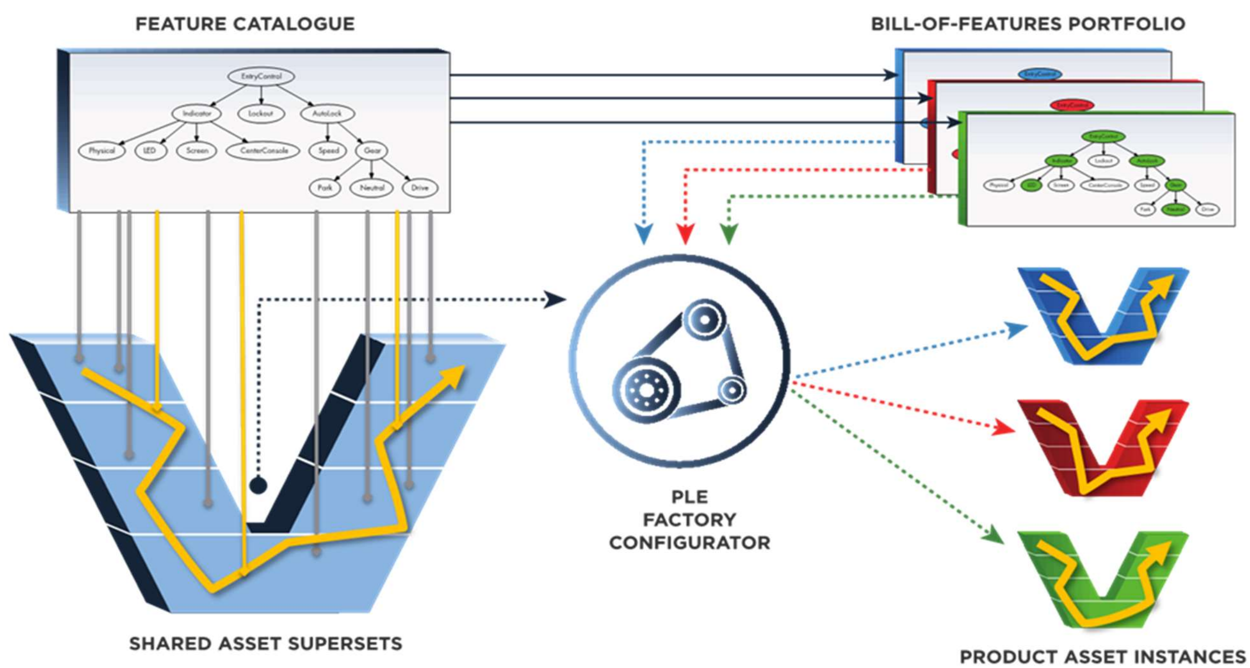

Figure 2. Feature-Based Approach to managing a complete family of systems portfolio of shared assets and their digital thread relationships.

Exploration of these sometimes obvious justifications will show that there are still times when allowing redundancy may be the most reasonable decision.

Managing Families of Systems

The examples in this paper are based on the extensive history of the Live Training Transformation (LT2) product line. LT2 has an open governance process with documented workflows that allows the LT2 experience to provide insight into the logic behind historical decisions concerning consolidation and the ability to examine how those decisions affected future value. LT2 currently manages over 400 source code Shared Assets and has accumulated over $1B in cost avoidance value for annual Post Deployment Software Support (PDSS) and new capability development. This billion-dollar cost avoidance (Yates, 2023) has been accumulated through PDSS for 22 live training products that have collaboratively evolved the shared assets, and through initial startup cost avoidance for new training systems. As shown in Figure 3 each product contributes to the shared development (blue line) and fields the value from the contributions of others (red line). Over the life of LT2, contributions are returned at about a 2.5 factor by other programs. The Governance processes where sharing decisions are made include considerations for many factors that influence this 2.5x effectivity for changes.

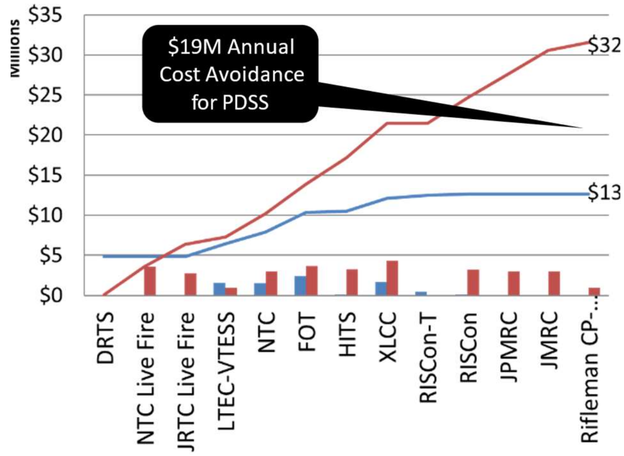

Figure 3. 2023 LT2 PDSS cost avoidance ($19M) gained by sharing digital assets across the live family of training systems.

Governance

Governance is an overused term and requires further definition in the context of asset management. Following MOSA, the governance is the execution of five pillars and for FB PLE, governance is about managing the allowable features in the superset. Because LT2 is a government-owned product line with stakeholders spanning multiple contracts, its governance prioritizes visibility for government decision making. Combined governance is providing the customer the complete picture of how changes support current program needs, consider long term objectives, including lifecycle cost, and how changes can be best executed to support the overall PM TRADE (Project Manager Training Devices) business goals.

LT2 has an open community-facing workflow for the top-level governance, where significant decisions can be publicly scrutinized. This open workflow collects impact assessments and peer reviews of shared asset development or enhancements to help guide decision making.

- Architecture teams provide feedback about adherence to design principals, best practices, and APIs.
- Standards working groups bring industry feedback to evolve standards.
- Adjacent development and PDSS teams feedback identifies sharing opportunities and advances collaborative objectives.
- Other industry stakeholders provide added scrutiny for decision making to ensure competitiveness.
- The LT2 Construct (a product line support organization for LT2) drives all members to actively participate and provide constructive inputs.

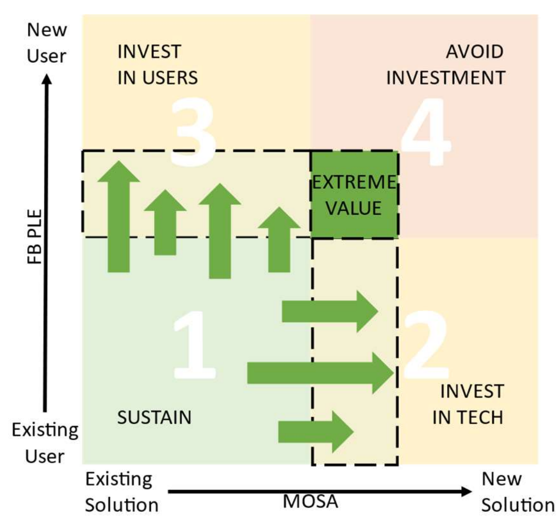

Figure 4. The "Extreme Value" region is where investment enables new capability development to support expended user growth without the risk of investing in the fourth quadrant of the Ansoff matrix.

Top level governance provides the visibility to make informed decisions for where to invest in the product line. When viewed as an Ansoff matrix (Figure 4) decision making can be shown as encouraging technology insertion into programs (right arrows) that can be adopted and used by other programs (up arrows). The green “extreme value” region represents the value of cost avoidance where new users get new solutions that they didn’t have to fund. This is a conceptual view of both the $1B cost avoidance and continuous re-invention of LT2 without incurring the risk of development in quadrant 4. Applying this context drives teams to use what is available and build solutions that support internal objectives under the influence of adjacent programs’ needs. With the feedback provided from key stakeholders, right arrow tech insertion may be permitted even when redundant to existing options. Up arrow new user adoption may mean fielding different redundant solutions across different ranges. Governance must force these necessary conversations to take place between subject matter experts (SMEs) to identify when investment in new technology is justified for one program vs adoption of an existing alternative. Having an open workflow creates a clear thread of decision making where dissent and conflict are provided in clear view for the government to make a final decision. Using the guidance and patterns that have evolved within the LT2 product line can help to drive these decisions to extreme value instead of the natural tendency to divergence.

CONSOLIDATING DIGITAL ASSETS

With the tools of MOSA and FB PLE available, and governance in place to provide visibility into decision making for the product family, we can now look at specific use cases to illustrate how prior decisions impacted long term value. The following examples were taken from the archives of LT2 because they show clear consequences from specific decisions.

The Database Dilemma

Databases are a fundamental component of system architectures with a high degree of user impact during operation. Integrity and performance are key design constraints when selecting a database. In live training the database is an integral part of data sharing between services and is used for many purposes including optimized replay of exercise events, maintaining a common operational picture for assessing interactions between players in the field, and managing information necessary for after action reviews. Another important function of the database is the ability to archive exercise data for future analysis, sometimes weeks and months after a rotation has concluded.

In early LT2 the Common Training Instrumentation Architecture (CTIA) was built upon an Oracle Relational Database with support for SQL for all products and to meet the reliability and extreme demands of the Combat Training Centers. Oracle offered solutions for redundancy through Oracle Real Application Clusters (RAC). Even though SQL support is standardized across the industry, each database vendor has extensions and customizations that make it very sticky within a system. Once a database solution is chosen for an enterprise architecture, a significant investment is usually made in software interface and database deployment configuration development to maximize performance features provided by the vendor. This was the case for CTIA and deployment of the Oracle capability after database selection.

The LT2 Product teams leveraged the architecture investment and fielded Oracle. Only the Combat Training Center (CTC) sites required the additional license costs to use the Oracle RAC component for failover redundancy requirements, but all teams were able to leverage the investment. However, as teams reevaluated the full lifecycle costs it became evident that Oracle did not provide significant enough value to teams deploying to smaller sites that did not share the performance needs required by the CTCs. The Home station Instrumentation Training System (HITS) team initiated the MOSA governance workflow to support an open-source alternative.

The HITS team received significant feedback from the LT2 community including from the CTIA architecture team and other government stakeholders. The HITS team used this to modify their evaluation criteria and increased the lifecycle cost estimation for the “free” PostgreSQL open-source alternative. The HITS team gained deeper understanding of the costs to their program and decided to proceed with the implementation of the alternative database, the government customer was able to assess the cost impacts to the overall portfolio and the decision was made to support multiple databases. PLE Features were defined to encapsulate changes necessary to support both PostgreSQL and Oracle database implementations and all shared assets including code, configurations, documentation, tests, cyber patch/STIG configurations, were updated. Though the alternative database capability became redundant with in the product line all other assets remained singular.

Long term effects of this decision though ultimately having a small negative effect on the reuse-driven cost avoidance shared between teams resulted with exceptional value generation in the product line. Modernization initiatives such as the migration to CTIA 4 Service-Oriented Architecture (SOA) were able to leverage the investment of HITS and start from an established and deployed solution greatly reducing risk for CTIA 4. Adjacent teams like Digital Range Training Systems (DRTS) later adopted the PostgreSQL solution. DRTS had to expend effort to migrate the small number of additional DRTS services that were not used by HITS, but this was significantly smaller than adopting the full system and allowed license cost reductions lowering the DRTS total ownership costs.

Many decisions seem obvious with hindsight but in the moment, it was not clear that other teams would justify the cost of changing to align with the HITS solution, or that the efficiencies lost by leaving a common solution with such high operator involvement would recover savings in license costs. Allowing HITS to implement technology investment and mature the solution reduced the risk to other programs that were able to field mature capabilities with minimal additional effort.

Geo-referenced Battlefield Map Viewers

Visualizing instrumented battlefield players and activities in a geo-referenced view with the backdrop of map or satellite imagery data is an essential component for any battlefield situational awareness capability. For LT2 this capability is simply referred to as the “Map” or “Maps” and is essential for monitoring and assessing live training events. Significant attention is paid to the Map as technology is constantly evolving in industry and visual representations are something all users have strong opinions about. Map components are constantly scrutinized, and they are frequently the target of modernization initiatives. Maps are also highly customized to support live training unique needs and these needs vary greatly across the portfolio. At many times in the history of LT2 there have been multiple 2D and 3D map solutions often with several in use at the same time.

This LT2 use case looks at the Map capability’s evolution from FalconView, an aging thick off-the-shelf application for Windows with a LT2 2D Map Custom plug-in that had grown from a single use case to support the entire training portfolio following the same over-arching path as the CTIA architecture. The Map capability needed to become a web-based solution as CTIA evolved to SOA based services with web-based application interfaces for the user. The transition from FalconView affected almost all the LT2 product teams. FalconView was a blend of third-party and proprietary code bases—a system with a well-established user base, including implied requirements from the third-party tool's capabilities, and contained PLE feature variation to support the variant needs across the product portfolio.

After thorough studies comparing potential new map tools, defining interfaces, and a decisive make-or-buy analysis, the planned replacement was to leverage a very mature and extensible tactical map solution (TIGR). Despite significant feedback and MOSA based APIs and modularization the solution did not become the preferred choice for many of the products in the portfolio. Intricacies in managing the diverse needs and unique nature of training systems drove design complexity that led to a digital asset decomposition effort. This decomposition defined an abstraction layer that enabled separation and composition of much smaller shared assets that could meet individual product needs and allowed for increased modularization of the underlaying technologies. During this time other teams looked for cheaper Minimum Viable Product (MVP) alternatives that would allow initial capabilities with minimal effort. One of these was the LT2 Canvas for small ranges. Having multiple solutions allowed teams to execute parallel development on the shared assets they needed most, eventually leading to a set of composable assets that met the complete needs of the product line using the same back-end map engine. An overly simplified summary of this sequence of events is shown in Figure 5 with explanations of the transitional maps.

- FalconView full featured thick application.
- Tactical Ground Reporting (TIGR) System brings familiar tactical maps to training, met the complete product line requirements but was too complex for small training ranges.
- LT2 custom Canvas for urban and small ranges, incredibly simple situational awareness viewer providing only what was necessary for training.
- NASA Web World Wind web-based 2D/3D SA (Situational Awareness) viewer that allowed embedding within web-based applications.
- TCE (Tactical Computing Environment) Android application for observer controllers in the field, innovative UI (User Interface) for mobile users but not aligned to the EXCON views.
- Mobile Observer Controller App (MOCA) for observer controllers in the field, innovative designs but not aligned to the EXCON views.
- GUI (Graphical User Interface) Framework separated presentation layers from the map architecture allowing development of custom composable GUI interfaces.
- GUI overlays built on top of the GUI Framework are individually managed composable shared assets built to meet specific training needs.

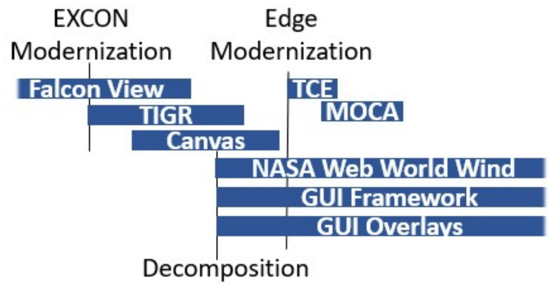

Figure 5. Map evolution and overlap of multiple solutions applied to fit unique product line needs.

Adjacent modernization efforts at the edge provided off the shelf map capabilities to observer controllers in the field. These were technology insertions initiated to fill emerging needs, but they increased the number of heavyweight managed shared assets, increasing the sustainability footprint. User feedback and shared asset evolution made these redundant solutions unnecessary as the common web-based apps provided the same views to all users, greatly improving communication and collaboration. The lessons learned from these edge-based map solutions further advanced and streamlined the Graphical User Interface (GUI) Framework and increased services usability for the Exercise Control (EXCON) users. In these instances, the injection of external new ideas continued to advance the product line. Although the solutions were "redundant" and only temporarily part of the systems there was significant value in their presence. Tech insertion applied modernization pressure within the product line which was likely more efficient and effective than development of custom extensions against new requirements.

The transition of the maps highlighted numerous key takeaways. It became evident that the map had grown substantially larger over its life and should no longer be managed as a single shared asset. This necessitated a strategic decomposition into smaller more manageable shared assets. This decomposition facilitated parallel development efforts across teams, allowing for more efficient progress. Additionally, by adopting a modular approach, it was possible to establish transition architectures that included MVPs specifically adapted to meet the diverse requirements of different programs. These MVPs varied across programs, reflecting the unique needs of each group. Importantly, the implementation of a composable GUI Framework, along with the modularization of the technology foundation, ultimately led to greater overall convergence, creating extreme value through multiple tech insertion efforts adopted little bits at a time by adjacent users.

Alerts, Notifications, and Logs

The LT2 product line has developed a variety of tools and capabilities that all capture and deliver a list of human readable text-based time-tagged events. While each focuses on a different context, dataset, and target use case, each provides a means for understanding what happened, in chronological order, and presents information in a simple and timely manner. The solution overlap was not fully understood during development, but governance discussions eventually led to insights that helped converge on new and better solutions that catered to more stakeholder needs across the product line in the form of event logging, alerts and/or notifications.

Some of these components were developed based on specific capability requirements for system operators. The Alerts and Alarms Component would allow the user to register for audible and visual feedback when a safety event occurred in the training area and added the event to a list. The tool also provided the ability for a user to be notified and the event added to a list when a user specific alert criteria was met, such as units arriving within a planned boundary. Other logging components were developed to provide general situational awareness to assist operators. The Event Logger could record player unit state and engagement events and was filterable to focus on specific training objectives like damage state changes for a specified player unit. Database querying tools were also developed with a similar need to collect historical event data, such as collecting a list of the most recent tracking events or state changes.

Most services and user applications provided a mechanism to capture debug and trace information in human readable log files for troubleshooting issues. For example, the original Area Weapons Effect Service (AWES) and the user Fire Support Tool (FST) both wrote data to logfiles during operation that were useful for troubleshooting suspected issues with indirect fire missions and the effectiveness of AWES to adjudicate and deliver damage state changes to live player units. Developers created their own tool to assist in development and testing CTIA commands & events, named the CTIA Administrative Tool (CAT). The CAT tool was intended for developer only use but quickly proved to be a staple for onsite rotation support staff.

CTC users later requested the ability to collect all situation awareness events in a single event logging tool and the LT2 Alerts Window (LAW) Tool, was developed to replace the Event Logger. The LAW tool's primary purpose was to combine the simplicity of the original Event Logger with an expanded set of events, filtering detail collected to provide a rich text-based situational awareness companion to the 2D Map, along with automatic file logging and the ability to include content into presentations for AAR package development. The LAW tool was widely accepted and utilized, and additional enhancements were developed at user request to include events and detailed data for fire mission, associated battle damage assessment calculations and resulting assessment data providing better visibility into FST and AWES operation that ultimately led to improved trust in AWES capability performance.

During governance discussions for planning and development of the LAW tool, the overlap of logging, alerts and/or notifications became clear. This helped to inform the need for a common distributed enterprise level capability to be implemented during CTIA's evolution to web-based services. The resulting implementation is the Rules and Notification Service & Notification Manager UI, a feature-rich event logger with filter options to meet specific user needs. The new web service collected the best features from all the redundant alert, alarm, rules, notification and event log components and the UI was inspired by a legacy capability originally developed for a single program. Since implementation multiple programs have contributed to the shared capability with enhanced features for new event types, categorization, badges, support for use during 2D Map replay and for operational test data collectors.

Logging redundancy was the result of different capabilities developed by individual programs to meet specific needs that did not initially appear to have any overlap with others in the portfolio. This example shows the value in allowing different users to deploy overlapping and redundant capabilities. When solutions work for their specific use cases, users gain confidence. Visibility into alternatives in use by others opens opportunities for continuous improvement and collaborative development. New investment from multiple teams allowed technology insertion to provide each user the value they were accustomed to, and introduced new best of breed solutions with minimal risk.

GOVERNANCE DECISION CRITERIA

Decision criteria when managing digital assets is more than a lifecycle cost discussion. Cost often plays a minor role when viewed in the context of overall value assessment to the organization. Cost avoidance can only be assessed when teams make use of shared assets, and future or potential reuse projections are often severely overestimated by developers of new capabilities. Introducing new solutions to new users is the most risky development strategy, sticky solutions that are beloved by users will not be replaced by a "better" solution without significant additional justification. This perspective is essential as it underscores the importance of a holistic approach to decision making. Allowing "redundant" solutions can be a way to embrace innovative thinking. These new solutions could become the next shared asset that everyone adopts, or they could be short-lived solutions that push existing assets to meet evolving objectives. All scenarios, while difficult to estimate or measure, demonstrated clear value to the organization. Keeping teams close through continuous governance discussion maximizes the opportunity to gain extreme value by teams using proven solutions wherever possible.

Shared assets grow over time, and the more they are shared, the bigger they get. Replacing entrenched assets is not a straightforward task. Rather than seeking direct replacements, a strategy that decomposes assets and leverages all available resources is key to accelerating new shared asset development. It is essential to allow for some degree of divergence and redundancy within this process. Allowing teams to implement their own MVPs can be a viable approach, so long as development cycles are followed by periodic evaluations to align assets and share concepts across teams. Such an approach fosters community cohesion during development, promotes collaboration across teams, and results in convergence of new technologies and capabilities evolved from the most optimal set of shared assets. This cycle of product evolution in a product line environment will continue to further generate cost avoidance that keeps systems sustainable.

Effective governance is how these decisions are adjudicated. Governance must be sufficient but not greater than necessary, embracing genuinely open MOSA approaches and guaranteeing visibility to all stakeholders. Embrace FB PLE to allow teams variation in capability use and deployment for solutions optimal to their needs. Cultural buy-in to a shared vision can only be achieved when all stakeholders have visibility and know that they are being heard. SMEs must know their voices are heard even if their suggestions do not always lead to action. Watching out for commonly used trigger words for divergence justification can help prevent minor efforts from becoming major maintenance burdens. When "small" or "user-specific" solutions are fielded they can stick around and even gain sustainment tails that can drive up cost. While all decisions inevitably involve compromise, with a transparent governance process capturing these considerations, teams can more effectively manage their technical backlogs. Through collaboration, they can identify common solutions that mitigate technical debt by capitalizing on collective efforts.

CONCLUSION

The examples provided here show that having redundant digital assets in a portfolio, where more than one digital asset provides the same capabilities, can be the best way to achieve overall organizational value. These organizational value metrics are more than financial calculations evaluated at a decision point. Value can be realized in the advancement achieved through technology injection or by allowing different teams to conduct parallel development on different but overlapping MVPs. The key is to use the experience gained through MOSA governance decisions to converge on a solution that is most likely to be adopted by other users so that both the product and the organization can maximize the investment value. These practical examples are provided using the Live Training Transformation (LT2) product line as a historical baseline. With over a decade of history managing a diverse product portfolio, LT2 provides the big picture context for value decisions using real events and evaluating long-term effects. This guidance should influence decisions where rapid modernization programs are looking for big gains. The recommendation from this experience is that decision makers should follow the guidance for ‘governance decision criteria’ when making asset management decisions. It’s only with complete visibility and participation from SMEs that organizations can balance the effort of maintaining commonality against the effort spent towards achieving their primary goals and objectives. While both consolidation and innovation are noble efforts the most efficient organization is the one that can balance needs and deliver extreme value to consumers. It is also recommended that members of other product families collaborate to see how the guidance can be evolved to more standardized rules for evaluation across product lines.

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