Modernizing the U.S. Army's Live Training Product Line using a Cloud Migration Strategy: Early Experiences, Current Challenges and Future Roadmap

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Abstract: The integration of different networks, databases, standards, and interfaces in support of U.S. Army soldier training is an ever-evolving challenge. This challenge results in U.S. Army organizations repeatedly spending time and money to design and implement irreproducible architectures to accomplish common tasks. In response to this challenge, the U.S. Army has made significant improvements on its Live Training Transformation (LT2) product line to support the needs of live training simulations. Despite the progress with LT2 the Army continues to struggle to support the dynamic needs of the training units. These improvements have been inadequate due to growing technical complexities of interoperating legacy systems with emergent systems arising from advances in technology that suit the users' ever-changing needs. To better address and support the needs of the end-user, a cloud-based modernization strategy was crafted and deployed on the existing Common Training Instrumentation Architecture (CTIA). CTIA is the foundation architecture that provides software infrastructure and services to LT2 product applications. This paper describes some of the U.S. Army's initial experiences and challenges while crafting a cloud-based migration strategy to modernize its LT2 product line and underlining CTIA. It starts by providing some background and rationale and then it discusses the current state of this modernization effort followed by future directions including the U.S. Army's 2025 vision of its LT2 product line. The overall vision entails an evolution plan from today's standalone products to a modernized cloud-based TaaS (Training as a Service) approach. The Army's ultimate goal is to reduce complexity as well as operational and maintenance costs, while providing enhanced training for the Warfighter at the point of need, anytime, anywhere. Finally, this paper discusses some of the current challenges including the exploration of appropriate testing methodologies and related security issues for the SOA-based LT2 architecture and its services.

1 BACKGROUND

For over twenty years, the U.S. Army has addressed interoperability requirements between training systems through the creation and management of several system architectures. These systems are continually advancing in technology and growing in operational use in order to support the evolving needs of the U.S. Army's training communities. The Army has made significant strides in improving their current architectures, but these improvements have been inadequate to meet the growing training and system integration demands of users arising from technology advancement. Thus, it quickly became apparent that the need for a new architectural approach should be either developed or adapted in order to support the U.S. Army's live training environment.

1.1 Live Training

The U.S. Army uses many types of training simulations categorized as Live, Virtual, and Constructive (LVC). The focus of this paper is the architecture in support of the live simulation and training domain. Live simulation and training, defined by AR 350-1, is "real people operating real equipment" and is used to train and develop Soldiers' war-fighting skills (U.S. Army, 2011).

From an operations and training perspective, the surge in simulation and training technology and use was plagued by fragmentation and limited coordination between the U.S. Army branches due to

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divergent operational demands, and the inability of technology to provide a "one size fits all" solution to the various needs of the operations and training community. This led to the consensus that limited interoperability was the highest level of integration possible at the time, which in turn led to the development of "stove-pipe" or "silo" systems across the Army's war-fighting functions: movement and maneuver, command and control, sustainment, protection, intelligence, and fires (M. G. Geruti, 2003)). The stove-piped systems were "able to send data to other applications within the same domain but not across boundaries" (R. L. Hobbs, 2003)). The impact of these stove-piped systems in live training ranges and instrumentation restricts their reusability, increases the cost to upgrade, and causes significant amount of range downtime to modify. In addition, the incompatibility between these disparate training systems results in the replacement of expensive components or requires the addition of adapters, which increases both cost and development time (M. Gomez, T. Kehr, 2011). The "stove-piped systems were built with different suites of sensors, networks, protocols, hardware, and software" (R. J. Noseworthy, 2010). The challenge and risk of linking stove-piped systems was identified in the 2006 Net-Centric Services Strategy that stated, "Patching stove-pipes together is a temporary solution; however, this leads to a fragile environment, which will eventually crumble under the high demands and unpredictable needs of the users" (DoD, 2006).

In the attempt to break down the barriers created by the stove-piped systems, the U.S. Army's Program Executive Office for Simulation, Training and Instrumentation (PEO STRI) developed the Live Training Transformation (LT2) product line to support the needs of live training. The first goal of the LT2 product line was to maximize commonality and systematic component reuse and to ensure interoperability across the live training community. The second goal was to reduce fielding time and acquisition cost and to provide "total ownership cost reductions across the live training domain" (J.T. Lanman et al, 2012). The LT2 product line supports home-station training, deployed training, Military Operations on Urban Terrain (MOUT) training, Maneuver Combat Training Center (MCTC) training and instrumented live-fire range training. Figure 1 depicts the initial three use cases for the live training architectural migration. The first use case entails the use of smart phones during combat training to capture soldier situational awareness and/or other related data and broadcast them to the command post data center for strategic decision making. The second use case presents various Army combat vehicles and soldiers transmitting training instrumentation data through defense or commercial satellite and network gateways back to the command post data center. Finally a future use case shows sharing and sending of information using special sensor devices connected via Bluetooth or other commercially available standards to various edge devices (e.g. tablet or smart phone) back to the command post data center for analysis.

1.2 Current Architectural Approach

The architecture that supports live training today is the Common Training Instrumentation Architecture (CTIA). CTIA is the foundation architecture of the LT2 product line that was developed by PEO STRI to specifically support live training. The benefits of CTIA have been seen in the reduction of development costs, sustainment costs, maintenance costs, and fielding time of live training ranges (J. T. Lanman et al, 2012). CTIA consists of architecture services, software components, standards and protocols that are Information Assurance (IA) certified to operate at the secret level (U.S. Army, 2013).

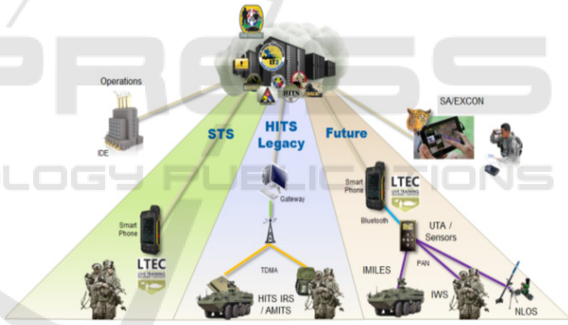

Figure 1: Initial use cases for live training.

Although CTIA has enabled units to conduct training through the benefits discussed in the previous section, CTIA technology is reaching its limitations to support the LT2 product line and ultimately the needs of the training community. This inability to evolve with user requirements has left a gap in supporting web interfaces and wireless mobile devices. This gap in support can be linked back to a lack of LT2 architectural vision that ties standards together resulting in live training components being highly dependent on the CTIA versions and limited backwards compatibility (J. T. Lanman et al, 2012). Additional challenges with CTIA include compatibility with other military systems, supporting distributed training center support, and scalability of footprint across LT2 product line. To address these

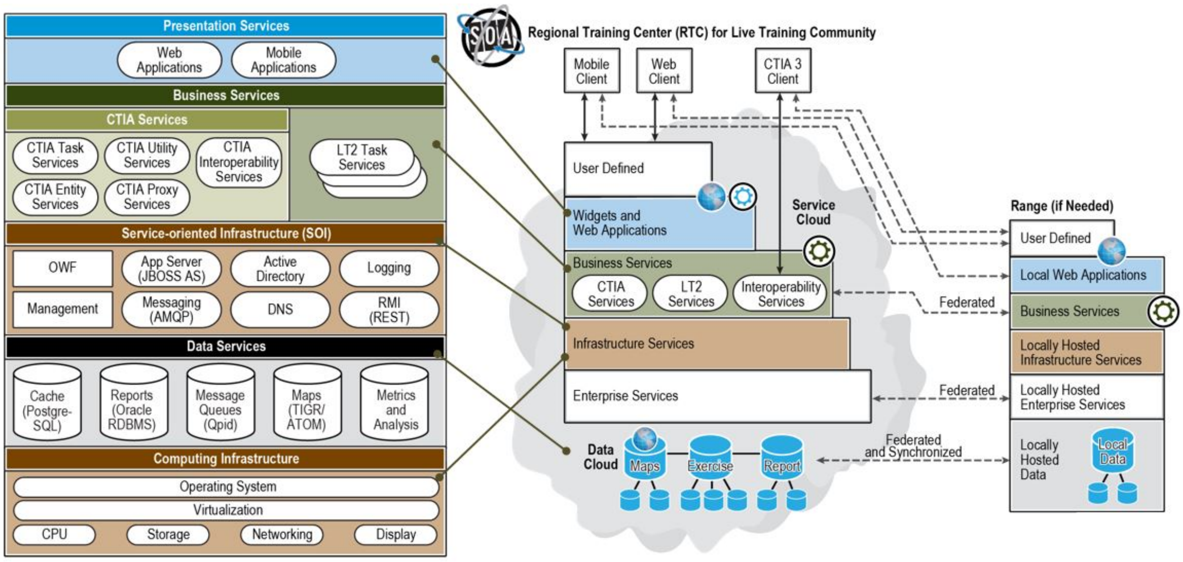

Figure 2: Conceptual view of a SOA-based cloud migration strategy for CTIA.

challenges, the architecture team and PEO STRI have adopted a Service-Oriented Architecture (SOA) migration strategy (J.T. Lanman et al, 2011). Figure 2 depicts a conceptual view of such strategy including a list of architectural layers and corresponding services provided. The architectural layers are mapped to the service layers of a conceptual Regional Training Center (RTC), a cloud-based data center that hosts services and data for training capabilities at various Army installations and ranges. If an Army range does not have a communications network, then a private mini RTC can be deployed at the range and later federated back to the main RTC data center.

1.3 Training as a Service

The term "Training as a Service" (TaaS) is used by the U.S. Army in order to refer to an "on-demand training environment" delivery model in which training software and its associated data are hosted in a cloud and are accessed by users using a thin client, normally using a web browser over the Internet.

The U.S. Army has deployed a TaaS strategy in order to develop simulation and training services (i.e. Web services) and the supporting infrastructure (i.e. networks, communications, sensors and computing hardware). Moreover, such TaaS strategy aims at building functional components and the supporting intermediate infrastructure according to modern cloud engineering principles and practices. It decomposes the system into components and layers. To obtain maximum flexibility and the greatest opportunity for reuse, each component exposes its capability through services available to the end-user and to other applications on the Army's Enterprise Network (AEN). By designing software around a set of services rather than a set of applications, TaaS aligns with the DoD migration to net-centricity and architectural patterns used in industry (DoD, 2012). Moreover, the architecture segregates the software that exposes persistent information (data services) from functional (or business logic) and presentation services. Both TaaS and the CTIA SOA and cloud infrastructure are built upon layered architecture frameworks. TaaS and CTIA SOA embraces consistent SOA and cloud-based concepts and architectural tenets, but differs in the sense that CTIA SOA is focused on defining architectural patterns that, while consistent with the TaaS objective architecture, focus on the unique issues of the instrumentation training environment rather than the holistic enterprise environment.

TaaS is now evolving while building common Army training apps and software services for Web browsers, desktop computers and mobile devices in the cloud environment. Army units and individual soldiers can access software applications such as a GPS tracking app for land navigation and exercise-control monitoring, tactical engagement simulation apps for laser and simulated fire engagements, and instrumented range apps for fixed live-fire targets. TaaS will eventually support up to brigade and battalion level force-on-force instrumentation and home station training with constructive simulation data feeds and battle damage assessment. TaaS is cloud-based with a deployable software service infrastructure to support the full live training domain. Figure 3 illustrates the LT2 based CTIA domains (home station, force-on-force, force-on-target) supported by TaaS.

It is expected that CTIA will eventually support fully the mobile computing world. One of the goals here is to enable trainers to use mobile devices to capture training observations and evidence just like one might use an app to post a photograph to a social networking site. Finally, a more detailed description of how the Training as a Service (TaaS) delivery model is deployed by the U.S. Army can be found in (J. T. Lanman, P. Linos, 2013).

1.4 LT2 Vision

Figure 4 below summarizes the steps currently taken to fulfill the US Army's 2025 modernization vision of its LT2 product line and related CTIA. As depicted in Figure 4, the CTIA is migrated to a cloud-based architecture and all related products are converted to SOA services. This effort enables a transition from the standalone model to a target cloud-ready model, which will eventually reduce costs.

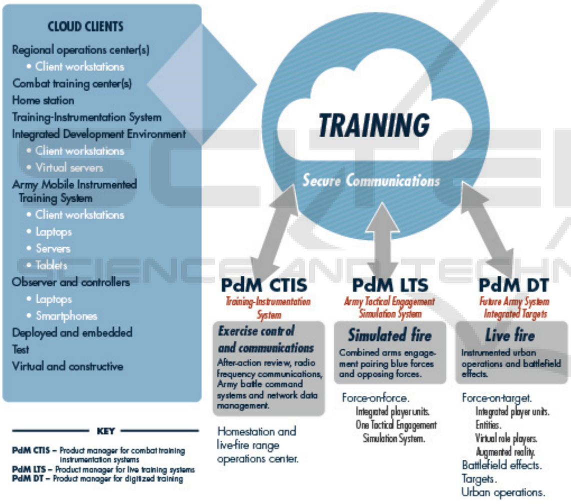

Figure 3: Training as a Service (TaaS) supporting the LT2 based CTIA domains.

In addition, all proprietary instrumentation systems are moved to a robust family of standards based sensor components. Also, the complete enterprise is modernized to a stand-up persistent, cloud-based LT2 enterprise of training services. Finally, the overall user experience is now moved from an operator-driven approach to a self-serve web or mobile apps tactic.

As part of meeting the LT2 vision objectives, Lanman and Linos discuss how decisions to change a product must be driven by the goals and objectives of the customer and other key stakeholders if they are to be successful (J. T. Lanman, P. Linos, 2012). Just as

Thrust	Description	Benefit(s)
Core SW	Move CTIA and Products to SOA services	• Reduce Costs (80% SLOC reduction) • Enable the Cloud model
Products	Move from standalone model to Cloud-ready	• Eliminate HW dependencies • Enable RTC concept
Instrumentation	Move from proprietary systems to a robust family of standards based sensor components	• Commoditize Instrumentation • Control evolution of capabilities • Leverage COTS
Enterprise	Stand-up persistent, Cloud-based LT2 Enterprise of Training Services	• Reduce Costs • Simplify Operations • Centralize SW, IA, Support
User Experience	Move from Operator-driven to Self-Serve Web / Mobile Apps	• Simplify Operations • Enhance Training • Capability Agile

Figure 4: A plan included in the U.S. Army's 2015 vision to modernize its LT2 product line.

the decision to adopt a product line approach for LT2 involves recognition of avoidable duplication, the decision to migrate to a cloud-based platform involves recognition of deficiencies in meeting upcoming fielding needs for CTIA based training systems. To ensure that the adoption of a cloud-based migration strategy addresses the true needs of the LT2 community, the architecture team, comprising key stakeholders based on influence and interest, have carefully defined and prioritized the strategic business goals and objectives for the LT2 architecture. CTIA provides the foundation for this architecture; however, business goals and objectives were extended to the LT2 community at large to ensure that the CTIA architecture aligns with community needs. These goals were then used to determine the priorities for the technology insertion effort.

1.5 Migration Roadmap

The migration roadmap of the current CTIA, to a modernized state, entails six Transition Architecture (TA) path-points (i.e. TA1 through TA6) as shown in Figure 5. Each such TA is based on a specific use case for tracking soldiers in both individual and small units training. Services allocated to each TA instantiation enable progressive levels of product team adoption. In addition, product teams are able to orchestrate the architecture services to meet their intended training use case, and develop user level application interfaces. Finally, each such transition architecture supports integration with first generation CTIA to the extent of the services provided. It is worth mentioning that TA6 was added to the migration plan later due to a funding opportunity with an LT2 product. That opportunity allowed the SOA to mature more quickly with additional services; however, it pushed the migration of other services out one year. The derived benefit was a faster deployment of a critical training capability at a major Army installation.

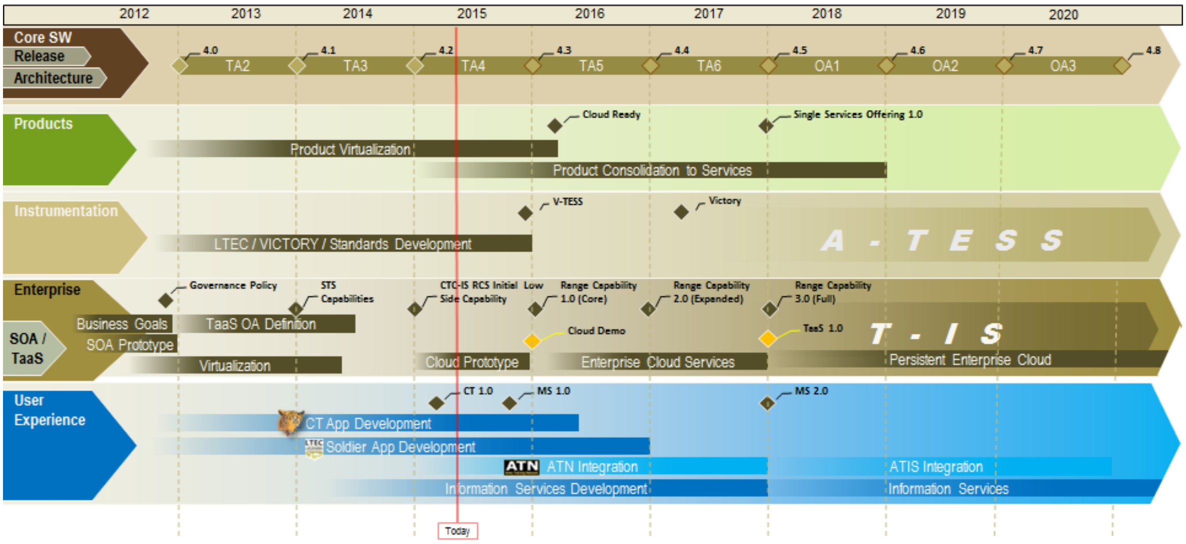

Figure 5: A roadmap depicting the evolution of Transition Architectures with related timeline.

The adopted migration roadmap entails modern cloud computing and virtualization technologies, which ensure effective interoperability among the Live, Virtual and Constructive (LVC) training systems and related applications. In addition, typical cloud engineering principles have been utilized while developing and orchestrating reusable, highly cohesive and loosely coupled software services at various granularity levels. Figure 5 also depicts the timeline and evolution of transition architectures TA1 through TA6 and their impact on core software, products, instrumentation, enterprise, and user experience.

As of today, transition architectures TA1, TA2 and TA3 have been already released with reasonable success. The future architectures will be evolving over the next ten years into a series of the remaining transition architectures (i.e. TA4 through TA6). More specifically, TA4 will provide services to support basic force-on-force instrumentation for brigade level home station training with constructive data feeds and battle damage assessment. Services will include asset tracking and exercise replay. Finally, TA5 and TA6 will be the last instantiation of the migration effort. Afterwards, the architecture transitions into production and sustainment for objective architectures OA1, OA2 and OA3. The target solution architecture (a.k.a. Objective Architecture) will be fully cloud-based with a deployable Service-oriented Infrastructure (SOI) supporting the full live training domain. Training will include up to battalion level force-on-force exercises integrating with mission command systems and entail full wrap-around live, virtual, and constructive interoperability capability.

2 CHALLENGES

2.1 Current Testing Issues

Changing to a cloud business methodology to support military requirements is unique because it changes the paradigm of traditional testing methodologies. This paradigm shift brings a new challenge of testing the architecture prior to implementation.

The current testing practice lacks the necessary metrics to validate the LT2's transition to a service-oriented capability. The current method is to "implement once ready" without putting the new or modified application through the rigors of a comprehensive testing framework. The current testing must expand from a solely integration focus to examining the effects of any new or modified application, such as interoperability and composability. Ignoring these effects may result in an open architecture without boundaries creating a governance nightmare.

In addition, the length of the potential migration amplifies this challenge. Currently, the new LT2 CTIA Objective Architecture Vision is a multi-year plan requiring that the SOA evaluation framework to be highly reusable and flexible. These characteristics allow the framework to adapt as end-user requirements naturally evolve over time as technology advances. With the long-term goal of developing testing criteria for the on-going evaluation of the LT2 architecture components, a thorough literature review is being conducted identifying potential applicable and validated SOA testing models that could support the LT2 cloud migration.

2.2 Observations on Cloud-based Testing Methods

Any reusable testing framework, including those utilized outside of the immediate LT2 architectural focus, must support the testing, data collection, and effective evaluation of the dependability and quality of services produced in a cloud-based services environment. Our literature review so far reveals various approaches and techniques for testing cloud-based applications at different test levels. Although these approaches and techniques seem promising, they lack the maturity of a validated and repeatable testing framework required to adequately assess the LT2 SOA-based implementation.

According to research conducted by Petrova-Antonova, et al., in support of their work to propose a possible SOA testing framework, there are several isolated testing tools and highly complex frameworks used in proprietary fashion for web service composition testing, however an available, proven, complete solution to both test and validate a SOA approach is still missing (D. Petrova et al, 2012).

Much of the challenge in developing a highly useful and repeatable testing framework is that cloud-based evaluation can be a highly complex computing issue. Services are dispersed over different deployment configurations; they must be highly adaptive as new services are added without requiring high levels of regression analysis. They may also be highly complex services with specific functionality offering differing operational tasks making on-going automation testing highly difficult (Y. Basili, 2012).

Youssef Bassil offers, as a part of his SOA-based framework development research, an overview of the five levels of evaluation that should be considered in any application of a SOA testing framework (Y. Bassil, 2012). They are as follows: *Unit Testing* (evaluating the individual service as an isolated element), *Integration Testing* (evaluating the SOA as a working group of co-joined services), *Regression Testing* (re-evaluating any recent updates to individual services across the working group of services), *Functional Testing* (evaluating that a service performs its intended purpose), *Non-Functional Testing* (evaluating properties such as availability and security vulnerabilities within the service).

In addition, Papastergiou and Polemi suggest that a proper testing framework used to evaluate a SOA approach to overcome interoperability challenges must include the following elements in order to confront recognized weaknesses in many of the currently available testing frameworks (S. Papastegiou, D. Polemi, 2010): *Clarified* (framework requires that testing apparatuses and necessary information are clearly defined as is the component being evaluated), *Adaptable & Extensible* (framework requires that new testing tools and methods, as well as new services, are easily integrated), *Flexible* (framework requires elements to be able to be adopted as needed for specific test cases, *Structured* (framework follows a concrete set of evaluation steps), *Interdependent & Scalable* (framework provides value independent of any given testing technology or number of services under test).

Although we identified several framework suggestions for testing a SOA-based implementation, there is clearly not a one-size-fits-all methodology to measuring the success of an implementation. Each evaluation framework must be informed by an understanding of the individual system needs and capabilities. The Army's live training systems, in all of their architectural complexity, particularly emphasize this need to take a customized approach of designing any intended evaluation framework with the LT2 goals and metrics of success top-of-mind. Therefore, we are still looking for experiences and recommendations on how to properly validate a SOA implementation (especially in the cloud) to be highly diverse. We will continue our literature review of related publications such as the one in (S. Tilley, T. Parveen, 2012).

3 LESSONS LEARNED

This section discusses lessons learned to date based on the on-going cloud-based modernization activities for the LT2 product line.

3.1 Leveraging Reuse

A lesson that we learned quickly during the cloud migration process is that common architecture frameworks succeed by providing a uniform and highly reusable feature-rich environment that allows developers to focus on their primary objective of implementing business-level use cases and not on repetitive implementation details. The Army's success with CTIA can be realized by the fact that it forms an average of 50% of the code base for all live training systems deployed since 2006. More specifically, the Army's LT2 products typically use about 57% of an approximate two million lines of code in the CTIA framework (J. T. Lanman et al, 2012). Another realization is that due to the large investment of the current architecture and the multitude of component dependencies it is unreasonable to expect that the new architecture can be developed in an isolated environment and deployed to replace completely the existing architecture. Therefore, it became apparent that backwards compatibility must be maintained with legacy software components through the existing CTIA framework interfaces. For more information on the historical evolution of CTIA we refer the reader to (J. T. Lanman, P. Linos).

3.2 Mapping Business Processes

In the live training domain the technical problem does not directly map to the IT business process for producing goods and services which SOA is typically modeled upon. As we know, the standard SOA business process is an orchestration of multiple business functions each of which rely on the results of the previous function to accomplish a discrete task. For instance, consider the archetypal example where a business process entails: booking an order => updating inventory => shipping => billing. In the case of a live training environment, business units are providers of content and context to artifacts generated within the system. The system collects artifacts and then consumers generate review content from the artifacts. The path through artifact generation, manipulation and presentation is not dictated by a predefined orchestration but by an ad hoc manner, depending on the fidelity of the training environment. A combat training center for example has multiple organizations dedicated to providing context and content for discrete aspects of the training exercise such as fires, upper echelon support, or aerial support, whereas a home station training range instantiation is typically an individual assessing the time on target, or efficiency in meeting the training objectives for a single unit. As a result, the lesson here is that the U.S. Army could not directly adopt a traditional IT business process, but customized such process to allow for scalability of multiple or simultaneous training assets to accomplish discrete tasks in a traditional SOA implementation.

3.3 Improving Deployment Time

In an archetypal cloud-based deployment the SOA system is ubiquitous and accessible from multiple disparate organizations. In addition, the system is always available with no defined end state. In the case of the U.S. Army's live training systems however, as they are deployed currently, installations exist as isolated standalone systems. Also, training exercises have specific training objectives and they access data that are not shared between concurrent exercises at different ranges. Moreover, service composition is a function of the training audience and range, from combat training centers with dedicated rack servers down to individual ranges consisting of a single workstation operated directly by an individual from the training unit. These systems are accessed and maintained onsite and their state is dependent on the phase of the training rotation. Although the target migration architecture (a.k.a. Objective Architecture) will be a ubiquitous solution overall, the cloud-based implementation of CTIA must account for the different phases of training where different subsets of services are available depending on the training rotation state. As a result, we have learned so far that additional architectural layers and specialized federation services are needed in the Objective Architecture in order to account for the various asynchronous training phases.

3.4 Assuring Security

Any changes to the CTIA and LT2 architectures and their components must consider the security and accreditation impact in order to comply with the Information Assurance (IA) policies and the DoD's Risk Management Framework (RMF) process. We need also to consider that as the U.S. Army evolves and in order to implement cloud computing and virtualization, that the security and IA requirements are also likely to evolve and introduce new requirements. Therefore, the lesson that we derived from this is to engage with security experts early in the cloud services design process and build in security constructs in the design, which allows for easier IA certification and a more secure and cost effective solution.

3.5 Pending Technical Concerns

We found that cloud-based migration challenges mostly concentrate around bandwidth, scalability, and technical issues based on SOA related implementation details such as limitations of proprietary Enterprise Service Bus (ESB) capabilities. Historical CTIA development has resulted in a set of metrics that ensure that all development activities comply with the required Technical Performance Measures (TPMs), which are internally defined by the U.S. Army. Continuous integration and testing ensures that any time these metric values are exceeded the development team takes immediate action. Also, existing test harnesses and training scenarios provide a baseline for validation testing. It is worth mentioning that the current system's performance exceeds the performance of the previous generation of CTIA. The first transition architectures focus on the most reused and also the most performance-sensitive elements within the system, ensuring that these issues are addressed early and often. The CTIA SOA is early in its development and we are still collecting metrics on performance and testing. However, since these technical concerns are an on-going investigation, we will continue to identify and address them as needed. We plan to include those findings and related data in future reports.

4 CONCLUSIONS

In this paper, we briefly described the U.S. Army's overall effort, experiences and lessons learned while modernizing its Live Training Transformation (LT2) product line. To this end, the U.S. Army decided to leverage the industry-wide knowledge and success of cloud computing using SOA, and it has identified this business approach as the new migration to its LT2 product line. Based on work accomplished so far from such an effort, the U.S. Army believes that this transition is already increasing the interoperability of its different networks, databases, and interfaces that support live training. At the same time, the U.S. Army also acknowledges the fact that this paradigm shift poses various new challenges. For instance, just as there is not an "out of box" cloud-based strategy, there is not a "one size fits all" testing framework. Based on such an observation we have found and discussed above some existing cloud-based testing techniques and approaches that could be used for the LT2 transition. However, we understand that further investigation is needed here before any decisions are made.

We have also made an attempt in this paper to explain how the U.S. Army's PEO STRI has incorporated the concept of TaaS (Training as a Service) in order to successfully migrate and modernize its simulation and training legacy software for the live training domain. Based on early observations, it appears that the TaaS strategy addresses the need to reduce costs and leverage technology developments in order to better support the soldiers' training needs. However, as we have described in our lessons learned section above, there exist some challenges. For example, SOA and cloud adoption related caveats are typically centered on network bandwidth, latency, software scalability and other technical issues. Furthermore, any changes to architectures and software services must consider the security and accreditation impacts that might affect information assurance.

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