Army Training Data Management using a Product Line Approach

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ABSTRACT

The Program Executive Office for Simulation, Training & Instrumentation (PEO STRI) Project Manager Integrated Training Environment (PM ITE) fields a wide variety of virtual, constructive, and gaming (VCG) simulations, that operate both in stand-alone and integrated modes. As with most simulations systems, these VCG simulations are largely data driven—both in data that is engineered into the capabilities when they are delivered (e.g., equipment characteristics), and data that is developed for use of these systems (e.g., terrain and scenarios). Although there is a great amount of overlap in the data these systems require and manage, each has its own data management capabilities (e.g., scenario generation). In addition to the stand-alone data management capabilities for these VCG simulations, there are separate capabilities for federations in which these VCG simulations are integrated.

PM ITE conducted an analysis of a subset of the current data management capabilities, specifically those integrated via the LVC Integrating Architecture (LVC-IA), and then developed a proposed architecture and transition strategy for how data management could be conducted in a more efficient and effective manner, with improved data quality. This paper describes the "as-is" analysis of the data management capabilities and identifies the common requirements and overlapping capabilities. It then presents the proposed "to-be" architecture. This "to-be" architecture aligns with the newly adopted ITE software product line methodology, in which shared assets are identified, managed, and incorporated into multiple products. In the case of data management, these shared assets are not only software, but encompass data exchange agreements, common requirements, common architecture design, and data interchange formats. Although the analysis described in this paper focused on a subset of the systems in the ITE, the analysis approach and many of the architectural recommendations are applicable to the full range of the ITE portfolio, and to other Army, Service, and even national capabilities for simulation data management.

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INTRODUCTION

Timely and accurate data are essential to the construction and execution of any simulation environment. When large-scale environments are constructed integrating multiple simulations and operational systems, consistency of data is essential. A prime example of such an environment is the Army's Live-Virtual-Constructive-Gaming (LVCG) environment, which encompasses multiple simulations that operate in both stand-alone mode and in federations that include interfaces to mission command (command and control) systems. Without proper data management practices and infrastructure, a range of undesirable effects can occur, include unrealistic simulation, negative training, fair fight issues between simulations, and technical interoperability problems.

To address data management within the Army's training community of interest, the Army's Program Executive Office, Simulation Training, and Instrumentation (PEO STRI) Program Manager Integrated Training Environment (PM ITE), conducted an analysis of the current data management practices within a subset of the PM ITE portfolio and formulated recommendations for improving the state of data management. The desired outcome of this analysis was to identify opportunities to:

- shorten timelines for conducting training using the LVCG capabilities within the portfolio;
- reduce costs for managing data within the portfolio;
- improved data quality and thus validity of simulation outcomes; and
- lower the time and cost to maintain the current portfolio and produce new products.

This paper will describe the approach used for that analysis, along with the results and recommendations. While the specific details of analyzing the PM ITE portfolio will be of interest to some readers, others will find both the methodology and guidelines used in this analysis can be applied to other environments. In addition, the findings and recommendations from this analysis are likely to be applicable to other large-scale LVCG environments.

Integrated Training Environment System of Systems

The analysis was bounded within the PM ITE portfolio to the virtual, constructing, and gaming components of the ITE System of Systems (SoS). For the purpose of this study, the ITE SoS is defined to be those simulations and interfaces integrated via LVC-IA, as shown in Figure 1. The ITE SoS encompasses a variety of simulation systems and interfaces to mission command systems used to conduct collective training at brigade and below levels at the Mission Training Complexes (MTC). A key mechanism that the ITE SoS uses to integrate these systems is the LVC Integrating Architecture (LVC-IA). LVC-IA is a network-centric linkage that collects, exchanges, and retrieves data among live instrumentation, virtual simulators, and constructive simulations as well as the simulation/stimulation of Army mission command systems. For this analysis, LVC-IA version 2 was taken as the "as-is" capability; improvements already under consideration for LVC-IA version 3 were considered in defining the desired "to-be" architecture. LVC-IA contains components that manage and prepare data products for use in simulation-based training and manage the data collected from training. The simulations integrated via LVC-IA were developed prior to LVC-IA, and thus have their own data management capabilities. In many cases, the data management tools and processes are different between stand-alone operation of these simulations and operation in the ITE SoS configuration.

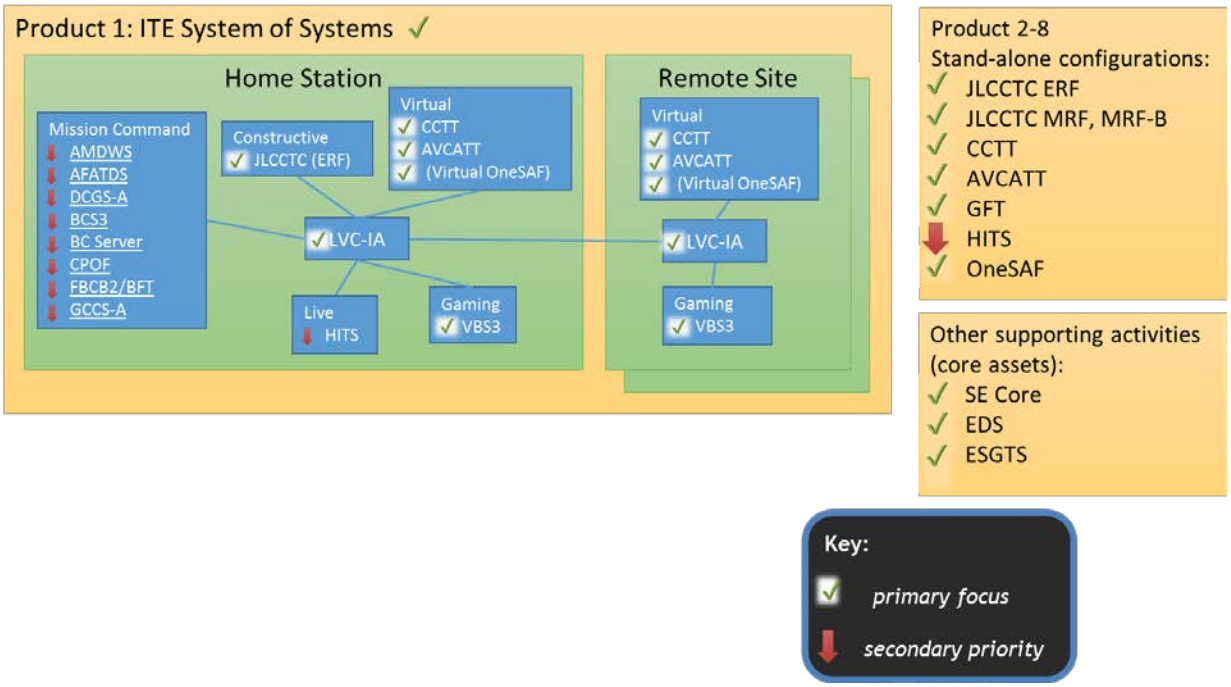

Figure 1. ITE System of Systems Product Configurations

The ITE SoS encompasses two virtual systems—Close Combat Tactical Trainer (CCTT) and Aviation Combined Arms Tactical Trainer (AVCATT)—the Virtual Battlespace 3 (VBS3) gaming system, and interfaces to live simulations via the Home Station Instrumentation Training System (HITS), interfaces to Mission Command systems, and multiple constructive simulations. A version of the constructive simulation OneSAF operates within CCTT and AVCATT to drive the computer-generated forces. The Joint Land Component Constructive Training Capability Entity Resolution Federation (JLCCTC-ERF) provides the other constructive simulations in the ITE SoS. JLCCTC-ERF is a federation of simulations with the current primary combat simulation being Joint Conflict and Tactical Simulation Enhancements (JCATS). JLCCTC-ERF has its own set of Mission Command system interfaces, which are used when this federation is employed without integration via LVC-IA. The analysis considered the stand-alone use of JLCCTC-ERF, as well as the JLCCTC Multi-resolution Federation (MRF) and MRF- Brigade, which uses WARSIM as the primary maneuver simulation.

The analysis reported in this paper focused on virtual, constructive, and gaming (VCG) elements of ITE SoS, and did not delve in to live and Mission Command system interfaces. The biggest opportunities for data management improvement are expected within and across the VCG elements. Where there is data commonality with the Mission Command interfaces and VCG elements, those were addressed.

The simulations with the ITE SoS are employed at the MTCs using LVC-IA, but they are also used individually at the MTCs and at other sites. In the analysis, we considered these usage configurations as distinct PM ITE products. As seen in Figure 1, the LVC-IA integrated federation constitutes one product. Each of the simulations (or federations) used in stand-alone mode are distinct products, e.g., JLCCTC ERF executing on its own is considered as product 2.

In addition to the simulations' data management capabilities, the analysis considered other data management capabilities that are key enablers for the ITE portfolio or provide relevant data management points of reference:

- the Synthetic Environment Core (SE Core) capability used to produce synthetic terrain for the ITE SoS and stand-alone systems using a standard terrain database generation process;
- the Enterprise Data Services (EDS) capability (Gupton, et., al, 2014), which provides data discovery and accessibility across a variety of data sources; and
- the Enterprise Scenario Generation Tool Suite (ESGTS) research performed by PM ITE which examined the potential for utilizing the Exercise Design Tool (EDT) in conjunction with the Web Military Scenario

Development Environment (WebMSDE) to provide a sharable exercise planning and scenario generation capability.

Data Management Use Cases

The analysis focused on a range of data management capabilities that included the extraction of data from authoritative data sources, the integration and transformation of data to a form usable by ITE systems, and the loading of data into ITE systems. Three specific data management use cases were examined:

- Conduct Training – When employing the ITE products to conduct training, the training units and Mission Training Complexes' staff must properly configure and initialize the systems with data that is authoritative, fit for purpose, sufficient in content, and accessible in the appropriate format(s). Similarly, the training exercises produce data during and after execution. Thus, solutions for managing the full data lifecycle of M&S execution by users are critical.
- Develop the ITE SoS – When developing models and simulations, product developers must manage the interface specifications (application programming interfaces and data format specifications) among the system components to ensure the intended interoperability and the desired forward/backward compatibility among products and with external data services.
- Manage ITE capabilities – Similarly during development, simulation products must be managed in terms of the entity types (platforms, weapons, sensors, munitions) and capabilities (mobility, detectability, lethality, communication) these models and simulations can represent. Core data management encompasses assets such as behavior models, 2D/3D models, characteristics/performance data, mission command interfaces, etc.

Scope of Training Data

One of the first key tasks in the analysis was to define the scope of data for which data management is conducted. Consistent with use cases described, this includes the data that is obtained and prepared for training with the ITE SoS (shown in the Figure 2 as "Conduct Training" data), as well as the data that is used in the engineering of the ITE SoS. This latter set of data is shown in Figure 2 as "ITE Engineering" data. The ITE engineering data contains the entity-type enumerations and the mappings between enumerations sets necessary to allow translations across systems. ITE engineering data also includes characteristics and performance (C&P) data—data to characterize interactions between entities (e.g., probability of hit (Ph)), as well as the models that govern the observability of entities across the electromagnet spectrum (e.g., probability of detection and identification). Engineering data also includes the common data-related system requirements and the collection of issue and bug reports pertaining to the products.

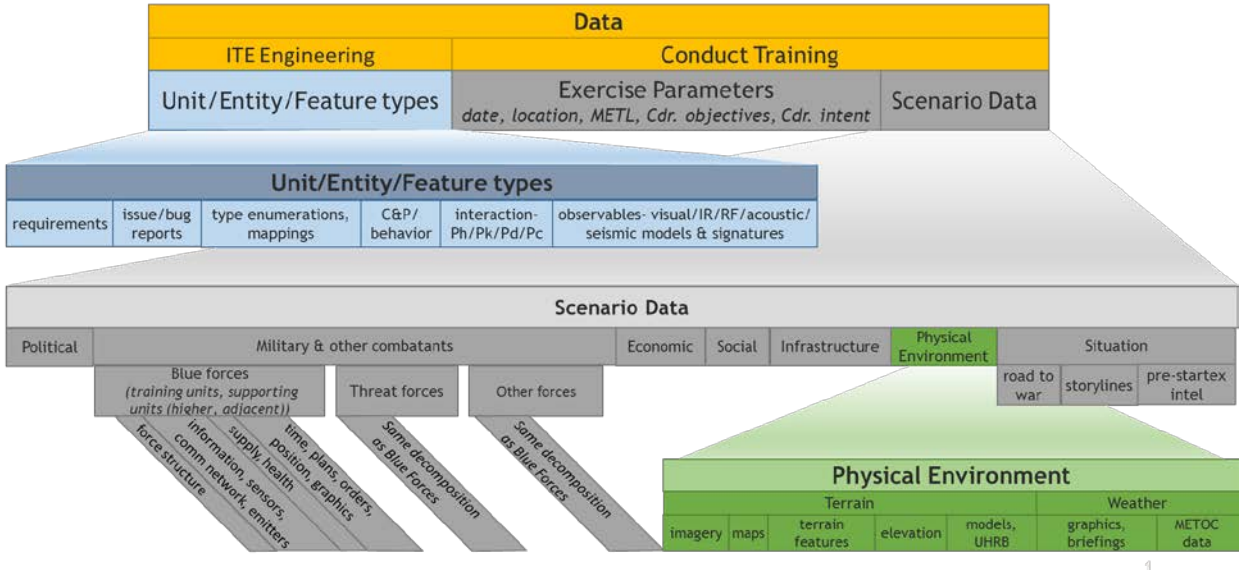

Figure 2. Data in the ITE SoS

The data needed to conduct training consists of the parameters that define the scope of an exercise such as event location, Mission Essential Task Lists, commander's intent and objectives, and the event scenario. The scenario contains a description of the military and non-military units (threat, friendly, and others) and the operational environment to include the political, economic, social, infrastructure, and information environment descriptions. It also contains the situational understanding at the start of the exercise and the physical environment to include terrain and weather. By volume, terrain data is the largest component, which constrains how this data may be processed and distributed in the as-is and to-be architectures.

ITE Product Line

Based on the prior success and efficiencies that PEO STRI has achieved in the Live Training Transformation (LT2) product line[1], PM ITE is establishing a Synthetic Simulation Transformation (S2T) product line[2]. A software product line establishes a management focus that identifies and manages shared assets and then utilizes those shared assets to create a line of products (Clements and Northrop, 2001). Shared assets are not just the software, but can also include other systems, software, and data engineering assets such as data standards, a common requirements baseline, interface specifications, and data sharing agreements with external data sources. Externally-sourced components such as VBS3 (commercial product), HITS (from PM TRADE), the Mission Command systems (from PM Mission Command) may also constitute shared assets, especially as license, end-use, and support agreements are negotiated on behalf of the product line. The core systems within ITE SoS are "products" within the S2T product line, and consequently, the data management capabilities central to this analysis are anticipated to become shared assets is this product line. Figure 3 depicts where different categories of data management shared assets interact with the "Conduct Training" and "Develop the ITE SoS" use cases. Several of those shared assets categories—such as external data sources and entity type management—relate to both use cases.

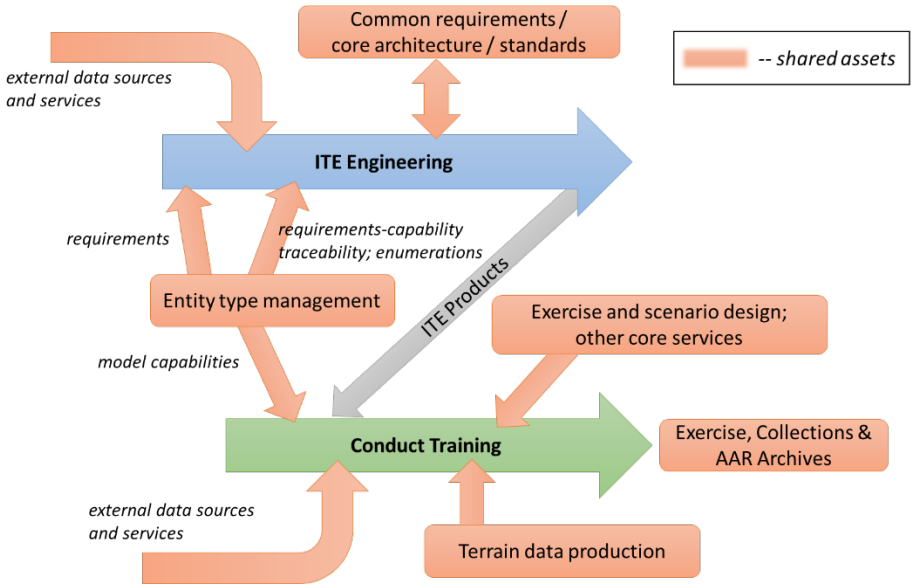

Figure 3. Shared Data Management Assets

ANALYSIS OF CURRENT DATA MANAGEMENT CAPABILITIES

The first phase of the analysis was the documentation of the current state, or "as-is", data management architecture for the ITE SoS. This process began with surveying and collecting architecture documentation, data and interface specifications, requirements, and process information from each of the ITE product teams. The analysis also incorporated products from prior analyses conducted under the EDS project. The LVC-IA documentation was extensive, and the most useful were Capability Production Document (PEO STRI, 2012) and System/Subsystem

[1] https://www.lt2portal.mil/
[2] https://www.s2tportal.mil/

Description Document (PEO STRI, 2015). These documents also served as the source of Games for Training (GFT) documentation. For JLCCTC, the JLCCTC Capability Production Document, Database Overview, and Scenario Generation (SGEN) Workflow were the primary sources. For JLCCTC, AVCATT, and CCTT, the product teams completed a detailed questionnaire, which described the data management components, data sources, data management processes. For EDS, site visit reports and build plans for the integration of ITE-required data sources were referenced. The SE Core process documentation was provided in a collection of documents that describe their Standard Terrain Database Generation Capability. These process documents were augmented by a series or SE Core architecture views. Documentation on the Enterprise Scenario Generation Tool came from yearly analysis reports, and the WebMSDE documentation came from their User's Manual. The complex and diverse documentation for each product was collected and organized into a set of DoD Architecture Framework (DoDAF) architecture (DoD CIO, 2017) viewpoints, which allowed comparison across the ITE SoS. Many of these viewpoints were directly extracted from the aforementioned documentation, thus the drafting of new viewpoints was minimal. The key viewpoints that were developed for the ITE SoS were:

- Organizational Relationships Charts (OV-4) depicting the organizational structures and interactions within PM ITE and with external organizations.
- Project Portfolio Relationships (PV-1) describing the dependency relationships between the organizations and projects, linking the PM ITE organization structure to the portfolio of projects it manages.
- Project Timelines (PV-2) timelines, denoting key milestones and interdependencies among project phases.
- Conceptual Data Models (DIV-1) depicting high-level data concepts and their relationships.
- Standards Profiles (StdV-1) listing standards that apply to the "as-is" ITE solutions.
- Systems Viewpoints
    - Services Context Description (SvcV-1) identifying the services, service items, and interconnections. The SvcV-1 views were primarily used to depict a decomposition of each ITE system into components.
    - Services Resource Flow Description (SvcV-2) describing the resource (data) flows exchanged between services. The data flows include machine-to-machine interfaces, user-machine interfaces, and person-to-person interactions.
    - Services Functionality Description (SvcV-4) identifying functions performed by services and the data flows among service functions/activities.
    - Services Evolution Description (SvcV-8) depicting the planned incremental steps for evolving a current system to a future implementation. Several of the ITE product teams provided architecture descriptions for future versions of their systems. The future version architectures were taken into account when drafting future data management plans and developing a transition strategy.

FINDINGS FROM THE "AS-IS" ANALYSIS

An examination of data management capabilities in the current ITE product architectures validated previous assumptions that there are significant potential benefits in transitioning to a software product line. Multiple opportunities exist for both consolidating existing overlapping capabilities as shared assets and better integrating the data management flow across the ITE enterprise.

Multiple data management issues were identified that related to exercise planning and scenario generation to include employment and sustainment of multiple overlapping scenario generation capabilities within the ITE portfolio. These include the Joint Remote Client and Exercise Development and Integration Tool as part of the LVC-IA product, Joint Training Data Services Order of Battle Service as part of JLCCTC ERF, SGEN as part of the JLCCTC MRF, and WebMSDE as part of the OneSAF product. Multiple cases were identified where unit order of battle and electronic order of battle data are manually entered and reentered across these tools when operating in the ITE SoS configuration. A significant gap for an exercise planning capability (beyond mere scenario database production) was identified. Although the potential for scenario reuse was evident, there was no institutionalized data discovery and distribution capability.

Affecting the engineering and sustainment of the ITE SoS, multiple additional issues were identified. These include the fact that many sets of overlapping enumerations are used and maintaining consistency across them is a time-intensive process susceptible to errors. SE Core has established a Master Enumeration List of entity type enumerations

and mappings, of which LVC-IA has adopted a subset. The individual ITE SoS simulations have their own enumerations, which are mapped to this list via manual processes. Characteristics and performance data (e.g, platform speed) and entity interaction outcome data (e.g., probability of kill), within the virtual simulators, has not been kept current. A lengthy process for data validation was found, namely the "parking lot tests" where each entity type is methodically displayed to verify that the visual model database is complete and accurate. Overall, there was a lack of a data distribution management and configuration management capability that could be used to track what version of data had been distributed to each training site. Likewise, there is no ability to track and assess what ITE SoS capability configurations are being utilized for training and with what data sets. There is no overall data discovery and access capability, but rather ad hoc and duplicative engagement between ITE product teams and external data sources to establish data access agreements and service interfaces.

From this analysis, a range of potential shared assets—some existing, and some that could result from consolidation or integration of existing capabilities—were identified:

- Common scenario generation tools, where the shared asset is mined from the existing tools identified above
- Exercise design tool, where the capability developed by TRADOC G27 appears to be the best starting candidate
- Data source agreements and interfaces for existing data providers:
    - US Army Force Management Support Agency (USAFMSA) for Army force structure data
    - US Army Training and Doctrine Command (TRADOC) G222 and G27 for non-US force structure and PMESII data
    - US Army Materiel Systems Analysis Activity (AMSAA) for characteristics and performance data
    - US Army Program Executive Office Command, Control, and Communications-Tactical (PEO C3T) for network configuration data
- Enterprise Data Services for data discovery, data retrieval, data delivery, and entity type enumeration management services

"TO-BE" ITE SoS DATA MANAGEMENT ARCHITECTURE

The next phase of the analysis was to create a recommended ("to-be") data management architecture for the ITE SoS. While a full expression of that architecture and all of its service, data flows, and data products embodies more detail than can be provided in this paper, Figure 4 depicts the high-level service groupings and their relationships.

Training Environment Lifecycle Manager – the core of the architecture, providing the stand-alone and ITE SoS simulation environments, as well as the user interfaces for configuring and managing execution of the training environment. While these are not data management capabilities, they are key consumers of information from the other data management services.

Exercise Lifecycle Manager – provides the capability for creating and editing exercise designs (in the form of Training Support Packages) and scenarios, as well as the After Action Review (AAR) services.

Training Management Services - implemented separately from the ITE SoS, these services support training management, readiness tracking, as well as training facility and resource planning. The Army vision is to provide these under the Army Training Information System (ATIS) program.

ITE Data Services – the planned implementation of the EDS capabilities. It provides the common services for data search, notification, retrieval, and distribution. These data services also provide a semantic knowledge base (KB) for managing entity type enumerations, mappings, linking to authoritative references, entity models, and entity software libraries. Finally, ITE Data Services provides an External Data Manager that interfaces to data sources, implementing the system-specific interfaces to each source.

SE Core data production services – remains relatively unchanged in scope within this architecture as the provider of environmental data to the ITE products.

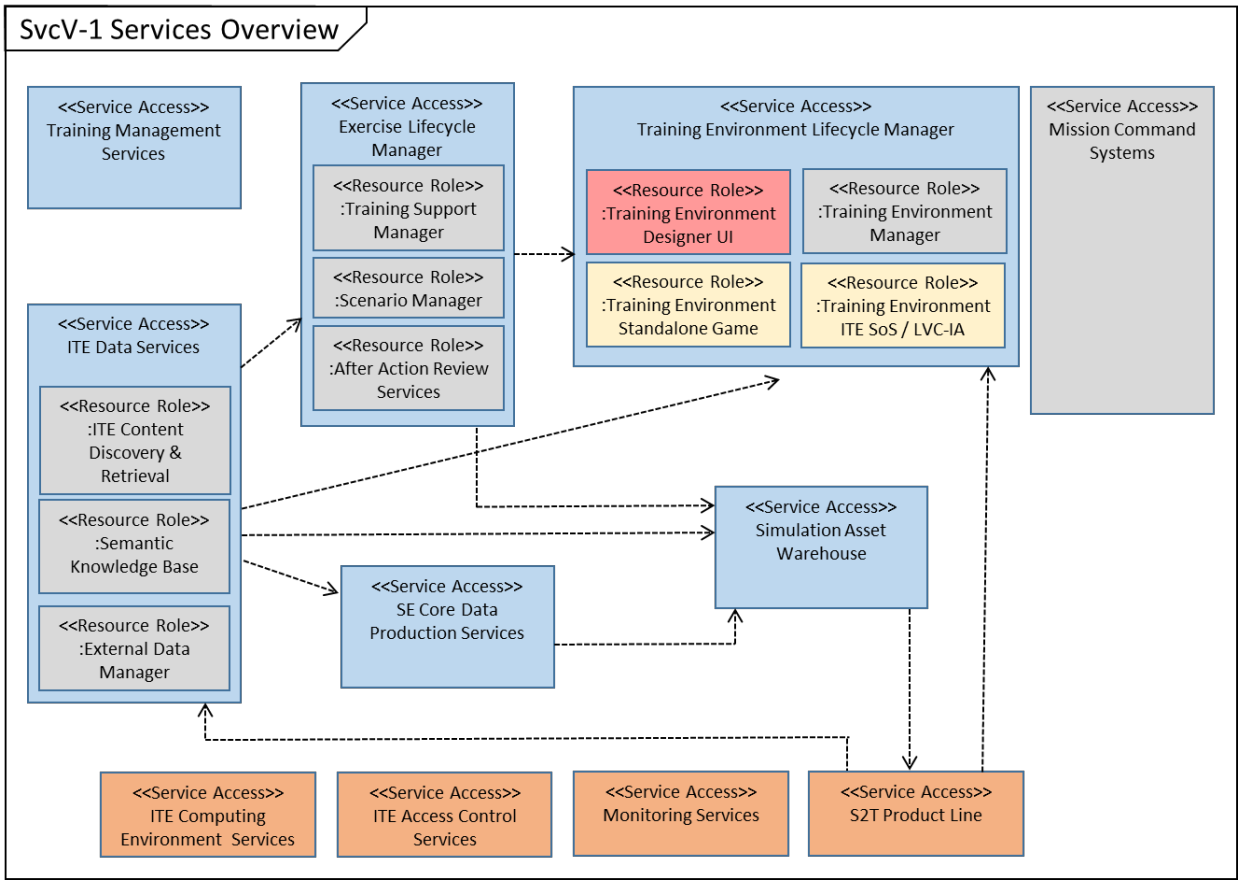

Figure 4. "To-Be" Data Management

Simulation Asset Warehouse – a managed repository of the various lifeform, platform, scene object, and terrain implementations that are validated, verified, and tested. These services are central to engineering, testing, and exercise setup and intended to eliminate stove-piped implementation of entity states and behaviors within the live, virtual, constructive, and gaming systems.

Infrastructure services – shown across the bottom of Figure 4, the services include the Computing Environment, Access Control, Service Monitoring capabilities, as well as the infrastructure to support the implementation and employment of the S2T product line. The infrastructure services are fundamental to the hosting of data management and non-data focused services.

RECOMMENDED NEAR-TERM ACTIONS

Four major lines of effort were identified as candidates for immediate attention. Some of the necessary changes to implement these efforts are already underway and are elaborated in the descriptions that follow. There are dependencies among some of the tasks within these efforts, although any or all of the major lines of effort can be pursued simultaneously.

1. **Scenario generation capabilities** – Currently a variety of scenario generation tools are used in conjunction with the ITE SoS. A selection of one tool should be made, or at most two tools if the needs for different resolution federations dictate. The best candidates appear to be WebMSDE and SGEN. Specific tasks that will be necessary are:

   a. Build a capability to access the USFMSA-operated Army Organization Server (AOS). This work has already started under the ITE Data Services effort.
   b. Analyze WebMSDE and SGEN features, and compare them with documented requirements. Review functionalities, data formats, and interfaces for consistency in S2T.
   c. Select WebMSDE or SGEN, or make the decision to continue with both
   d. Modify WebMSDE and/or SGEN to incorporate USAFMSA AOS data (including DATE threat force data). The work for SGEN has already begun.
   e. Establish the Authority to Operate for WebMSDE and/or SGEN for the Non-Secure Internet Protocol Router Network (NIPRNET).

2. **Exercise design capabilities** – Exercise design is not currently performed in a consistent manner across sites that employ the ITE SoS, nor is there reuse of the training support packages produced via the process. Specific tasks that will be necessary are:
   a. Create reference databases (e.g., country code lists) needed by Exercise Design Tool (EDT), SGEN, and other tools and establish processes for keeping the data current for users.
   b. Bring the current TRADOC G27 EDT into the ITE portfolio, including validation and user support for fielding to trainers.
   c. As part of tasks [2a] and [2b], host the EDT in the Defense Information Services Agency (DISA) MilCloud environment (or other ITE hosting solution).
   d. Once task [1b] has been completed, integrate EDT with the selected WebMSDE and/or SGEN.
3. **Common simulation asset warehouse** – Common assets (e.g., entity models and their supporting data) are not currently managed holistically across the ITE portfolio.
   a. Build access to AMSAA unclassified characteristics and performance (C&P) data into the ITE Data Services
   b. After [3a], incorporate this C&P into the JLCCTC and Virtual simulations (specifically into the version of OneSAF used in CCTT and AVCATT)
   c. Integrate the MilGaming repository of models with the ITE Data Services. This work is underway.
   d. Integrate the Army Model Exchange repository of models with the ITE Data Services. This work is partially complete.
   e. After [3b], [3c], and [3d] are complete, establish the S2T entity engineering process. Establish the engineering lifecycle for entity/feature models across ITE, to include requirements, realism criteria, acquiring performance data, and building visual models, developing behaviors, and verification and validation of the models in across all simulations and games.
   f. Create Entity Type Enumeration Catalog in the ITE Data Services. This work is partially complete.
   g. After [3f], build an Entity Editor that supports the creation, editing, and composition of entities and developing their behaviors.

4. **Establish authoritative reference data** – Although not a separate set of activities, task [1e], [2a], [3b], and [3e] (and their precursor tasks) all result in a capability where common, authoritative reference data is managed as shared assets across the ITE SoS products via the S2T product line.

CONCLUSION

As was expected at the onset of this analysis, many opportunities exist for improving the state of data management in the ITE SoS. There are currently many excellent data management capabilities from which shared assets can be harvested. PM ITE plans to begin executing the recommended near-term actions to improve data management of the ITE SoS. Implementing a product-line approach to data management within the ITE SoS will not require extensive new development, but rather integration of shared assets across the ITE products. As shown in the list of near-term solutions, many of the key efforts to provide timeline access to authoritative data are already in place or in development as part of the evolution of EDS into the ITE Data Services.

Although in its early stages, the PM ITE S2T product line, established for synthetic simulation assets, is a key business process that addresses organizational business objectives at the PEO STRI enterprise level. This approach will provide an efficient method to eliminate duplicate costs and reduce time to satisfy common data requirements. This PEO-level commitment to a product-line approach is a key factor that will result in effective management of shared data

management assets. In addition to serving the Army training community of interest, the potential exists for the S2T product line to increase M&S Community collaboration across the Services.

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