TOTAL LEARNING ARCHITECTURE

2019 Report

Prepared by
The ADL Initiative

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The DoD's Advanced Distributed Learning (ADL) Initiative is designing a framework of commercial standards, technical specifications, and business rules to enable plug and play interoperability of learning technologies. The Total Learning Architecture (TLA) framework will allow education and training products to interoperate with each other, with existing learning support systems, and with other DoD systems. The purpose of this report is to guide Command decisions toward a shared vision and end-state that benefits every warfighter individually and the entire DoD holistically.

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1.0 EXECUTIVE SUMMARY

Technology is changing the way we live and learn. Large-scale social networks, interactive content, and ubiquitous mobile access have emerged as driving factors in the evolution of education and training. Enterprise analytics now allows for new ways to assess the effectiveness of training content and instructional strategies for different learners, and to understand organizational trends through access to large volumes of education data.

Just as the increasing globalization of society underscores the importance of cross-cultural communication and understanding, the growth of technology enablers like cloud computing and the *Internet of Things* has increased the need for interoperability and cross-platform communication throughout the Department of Defense (DoD). The DoD's Advanced Distributed Learning (ADL) Initiative is designing a framework of commercial standards, technical specifications, and business rules to enable plug and play interoperability of learning technologies. The Total Learning Architecture (TLA) framework will allow education and training products to interoperate with each other, with existing learning support systems, and with other DoD systems.

The purpose of this report is to guide Command decisions toward a shared vision and end-state that benefits every warfighter individually and the entire DoD holistically. By necessity, the focus of DoD's education and training community will evolve from simple compliance to a game-changing approach centered on innovation. Thus, measures of effectiveness will shift from inputs to outcomes.

KEY TAKEAWAYS AND RECOMMENDATIONS

Data is a critical asset that enables effective decision making. The TLA data strategy provides a common set of goals and objectives across DoD's education and training community to ensure data are used effectively. This overarching strategy will ensure that all data resources are positioned in a way that they can be used, shared, and moved efficiently across the organization. This report describes the four pillars of the TLA data strategy. Each revolves around commercially available standards, and while they will continue to evolve, DoD education and training communities are urged to adopt and employ them now.

These commercial standards describe the data within the four pillars of the TLA data strategy**:**

- **IEEE P9274.1 Experience API (xAPI) 2.0** – Learning activity tracking uses the xAPI to capture learning activity streams. The xAPI standard also includes xAPI profiles such as cmi5 and the TLA's Master Object Model. xAPI 2.0 is targeted for approval in 2020.
- **IEEE 1484.12.1 Learner Object Metadata 2.0** – Descriptions of learning activities and their associated content are stored in the TLA's Experience Index and use a modified version of the Learning Resource Metadata Initiative standard. A draft standard is being submitted for finalization in early 2020.
- **IEEE 1484.20.1 Reusable Competency Definitions** - The definition of a competency, the relationship to other competencies, and the alignment of evidence to help measure proficiency of the competency, are included in this standard. This standard is expected for approval in 2020.
- **IEEE 1484.2 Interoperable Learning Records** or **IMS Global Comprehensive Learner Record** - Learner profile standards do not currently meet all TLA requirements. These new standards are actively being developed and modified based on input from numerous industry groups and associations.

2.0 INTRODUCTION

The TLA is a project by the ADL Initiative to develop a set of technical specifications, standards, and policy guidance that define a uniform approach for integrating current and emerging learning technologies into a *future learning ecosystem*.

Throughout their careers, DoD personnel are educated and trained by various organizations, each using their own IT systems and business processes. Typically, these systems are developed and implemented independently, without coordination, causing duplication in function and stovepiping of the data maintained. Many of these systems have site- or agency-specific models for capturing data, or their own proprietary data repositories. Additionally, data transport, control, management, governance, and ownership are not easily compatible or interoperable across network boundaries. Therefore, there is now large-scale duplication of data and a lack of interoperability, transparency, and effective management to ensure DoD-wide data quality, availability, integrity, security and usability.

The TLA vision recognizes that learning often occurs outside of formal education and training. In the current DoD environment, different tools, technologies, and platforms are used to track the *knowledge, skills, attitudes, and other capabilities* (KSAOs) acquired and certified through formal education and training. But the digital world around us creates even more opportunities to apply informal and non-workplace learning resources accessible from home, through social activities, and through alternative types of structured learning experiences. At the heart of the TLA concept is the learner and the associated policies, technical standards, and capabilities required to track all education and training experiences across the continuum of learning.

The TLA project started in 2016 with the strategic vision of establishing a common data strategy across the education and training industry that enables lifelong learning. This goal required a multi-faceted understanding of the tools, technologies, modalities, and learning science used to support education and training within different communities of practice. The 2019 research refined and hardened the architecture, defined a standards-based data strategy, and established a 24/7 Reference Implementation as a shared resource to support test and evaluation of other DoD modernization efforts

This report describes and summarizes the research performed by the ADL Initiative in 2019 within the TLA research portfolio. It includes four appendices that detail the TLA's latest functional requirements, recommended draft standards, an initial architecture that conforms to the DoD Architectural Framework (DoDAF), and a Software System Design Document built around the 2019 TLA Reference Implementation. The target audience includes senior DoD leaders, educational institutions, and program managers of DoD training systems. The ADL Initiative invites review and feedback by technical personnel, subject matter experts, developers, academia, and other organizations interested in the interoperability of data related to lifelong learning.

2.1 Problem Statement

In the early years of Distributed Learning (DL), instructional content was constrained to online courses managed by a Learning Management System (LMS). The LMS controlled all aspects of the online course including the sequencing and delivery of content, tracking learner progress, managing learner records, and reporting. The Shareable Content Object Reference Model (SCORM) was created in the early 2000s to standardize the packaging, launch, and performance tracking of digital learning content so that it was reusable across different LMS platforms. SCORM helped revolutionize the way education and training is delivered, but it is limited in its ability to meet the needs of next generation learning content.

Today we understand that learning takes place both inside and outside the classroom. The digital world around us creates a web of learning resources that are accessible in the workplace, from home, through social circles, and on a growing variety of media and devices. The exponential growth of data generated by these systems has the potential to enable better insights while reducing costs through continuous process improvement across all education and training activities. Because work experiences are a significant part of learning, capturing and managing these learning experiences provides better insight into what an individual knows and what more they need to learn to support their current job.

The technology available is constantly changing and the next generation of learning activities cannot be defined within the context of a single LMS. In today's world, an individual's lifelong learning continuum is distributed across numerous technology platforms that use different instructional methodologies and learning activities. The future learning ecosystem will be defined by personalized and *competency-based* learning environments that rely on the availability and accessibility of learner data across organizational and institutional boundaries throughout an individual's life.

To address these trends, many DoD components are undergoing their own modernization efforts, with direct support from the ADL Initiative. This is exemplified in the work being performed with the Office of the Undersecretary of Defense for Intelligence (OUSD(I)) on their Talent Development Toolkit[1] (TDT) project. Among other things, this project addresses the limitations faced by the Intelligence Community in exchanging learner-related data among 17 different organizations.

Table 1 shows the high-level challenges such organizations face with the current factory model of education that is prevalent across DoD. The table summarizes how these problems manifest in the status quo and describes how TLA-enabled solutions can move DoD toward a desired end-state.

Table 1. Learning Modernization Challenges.

Status Quo	Desired End-State
STOVEPIPED: Most learning experiences are disconnected from one another; events lack cohesion and treat learners as "blank slates."	**INTEGRATED:** Learning experiences are integrated into a cohesive, career-long learning continuum by exchanging learning data across systems.
INEFFICIENT: Most education and training is "one-size-fits-all," which means top students waste time and bottom students fail to master all content.	**PERSONALIZED:** Learning is optimized by delivering the right education, training, and developmental experiences, at the right time, and in the right ways.
WEAK DATA: Education, training, and personnel management systems rely on spotty data, which are often locked in unreachable data silos.	**DATA-DRIVEN:** Richer data enable talent management and readiness analyses—more effectively managing the larger system via evidence-based methods.
CONVOLUTED: Operational goals and outcomes generally lack direct connections to education and training offerings, reducing agility and traceability.	**RESPONSIVE:** More traceable (automated and data-driven) connections with operations make education and training more responsive and accountable.
MONOLITHIC: Stovepiped systems have limited capacity for interoperability and require staff and new physical infrastructure to operate at larger scale.	**DECENTRALIZED:** Interconnected, hardware-agnostic capabilities that don't require major investments in new servers and other physical infrastructure.
INCOMPLETE: Current systems only document formal education and training experiences available through academic institutions and in the workplace.	**COMPREHENSIVE:** Captures data from informal and unstructured learning resources and content, available from a growing variety of devices and providers.

[1] *Talent Development Toolkit Requirements and Architecture Study - https://www.adlnet.gov/assets/uploads/TDT%20Report.pdf*

2.2 The TLA Vision and Objective End-State

Ultimately, the purpose of education and training in the DoD is to provide capable manpower. This involves a variety of processes to determine workforce skill requirements, design learning systems aligned with those requirements, and develop the physical infrastructure, personnel, and technology resources to deliver the education and training. Maintaining this learning pipeline also requires continual evaluation of the efficacy of the learning products[2].

The key to managing lifelong learning data within the TLA is the interoperability afforded through the technical standards, specifications, and practices that underpin an integrated data strategy. The strategy is necessary to provide the semantic interoperability required for enterprise-level analysis and decision support. Data-driven decisions are enabled through enterprise-level analyses of learning data, supporting the continual refinement of manpower skillset definitions and the creation, selection, and maintenance of learning activities necessary to achieve proficiency. These also support the delivery of learning solutions required to acquire and maintain personnel with these skillsets.

Technical specifications and standards allow different learning resources to communicate with each other using a common, agreed-upon "language." These standards establish consistent protocols that can be universally understood and adopted by any component within the TLA to exchange data about learners, activities, and experiences. These underpinnings tie together the wide range of learning resources an individual will encounter and enable the sharing of this information with other systems and platforms across institutional boundaries.

From a technical perspective, the desired end-state is the DoD-wide adoption of TLA standards, specifications, and policies that enable an interoperable fabric of learning data, federated within and across commands, agencies, and departments. As shown in **Figure 1**, the TLA is built around a four-pillared data strategy:

- Experience Index of Registered Activities (e.g., Enterprise Course Catalog);
- Enterprise Learner Records (e.g., data on experiences, credentials, career trajectory);
- Competency Frameworks (e.g., the common definition of jobs, personnel, and learning outcomes); and
- Learning Profile (e.g., tactical streaming data on learner performance).

Beyond the technical interoperability standards for integrating tools, services, and devices, TLA research includes evaluations of shared vocabularies, linked data, business rules, governance, and a data strategy to tie them all together.

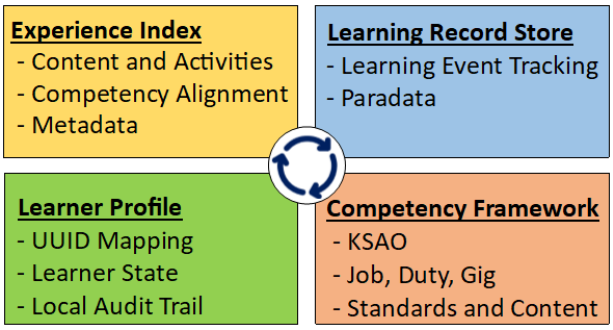

Figure 1. Integrated Data Strategy. *The TLA relies on four general data types that are stored within the "data lake" of a single TLA-compliant enclave. Core TLA services publish or subscribe to data streams that transform data into other meaningful information.*

[2] *Instructional Systems Design, Systems Approach to Training (ISD/SAT) Process in Joint and Service instructions: MIL-HDBK-29612, NAVMC 1553.1, NAVEDTRA 14300, AR 350-70, and AFM 36-2234*

Federating these data between different DoD components and their associated networks will enable enterprise-level services, including semantic interoperability, global discoverability, and security. It will provide an end-to-end system that is integrated, personalized, data driven, and responsive to changes in the threat and technical environment. This approach decouples the various learning functions typically included as part of a traditional LMS into composable data and services that address learning experiences across the continuum of learning and connect at-scale to data across the enterprise. This vision transitions the DoD from legacy, fragmented learning systems tied together with human driven processes into dynamically interoperable digital systems that provide the foundation for future improvement consistent with the DoD machine-learning strategy.

The impact of the TLA data strategy and its associated Information Technology upgrades enables the development of a flexible, modular system to optimize the time, cost, and effectiveness of learning delivery and analysis. The TLA's service-oriented approach results in interchangeable software services and databases integrated to create an efficient learning environment for the user. TLA components include specifications, software systems, tools, and services encapsulated into a Reference Implementation.

The TLA research portfolio enables these capabilities by researching, developing, and promulgating the appropriate policies, specifications, and standards, but also by investing in key component technologies and interfacing with DoD stakeholders.

2.3 Synopsis of Previous Research

The ADL Initiative began development of the TLA in 2016. This work advanced to empirical testing in 2017[3] which helped solidify the overall TLA conceptual design. The TLA Reference Implementation was developed to evaluate various software services, technical components, and learning activities, all of which exchanged data using an initial set of commercial standards. This allowed for a 2017 technical evaluation, managed by the Institute for Defense Analysis.

In that 2017 evaluation, a panel of 54 experts participated in a Delphi-style feedback process that captured detailed reactions to the TLA's perceived value, recommended technical standards to research, identified gaps, and made suggestions for increasing the likelihood of its future use. These insights informed a revision of the TLA concept, including its APIs, data models, specifications, and standards.

In 2018, the TLA Reference Implementation was structured to assess the practical functionality of different commercial standards and their applicability to DoD requirements. A 2018 TLA Test and Demonstration focused on the integration of different learning activities into a competency-based program of instruction using varied instructional modalities. A competency framework was created to house the competencies related to Combat Awareness, Combat Profiling, and Combat Tracking which are all part of the Joint Staff's *Combat Observation and Decision-Making in Irregular and Ambiguous Conflicts* (CODIAC) course.

The 2018 TLA Test and Demonstration was held to test general system functionality, evaluate and refine candidate standards, and measure cost factors for instrumenting content. Detailed information about this event and the lessons learned are provided in the 2018 TLA Report[4].

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[3] TLA Design-Based Research Approach - https://www.adlnet.gov/assets/uploads/2017%20---%20%28IITSEC%29%20Gallagher%20et%20al.%20-%20Total%20Learning%20Architecture%20Development.pdf

[4] 2018 Reference Implementation Specifications and Standards - https://apps.dtic.mil/dtic/tr/fulltext/u2/1077398.pdf

The 2018 event exposed technical gaps and identified architectural concerns about state management and the point-to-point messaging infrastructure. The 2018 components also used closely coupled datastores that did not accurately reflect the data streaming architectures currently in use by DoD.

For the 2018 event, learning activities were instrumented with the Experience API (xAPI). Upon analysis of the data, inconsistencies with the quality and uniformity were identified, including invalid statements and data formatting from 3rd party systems. The 2018 dataset contained invalid xAPI statements due to empty object identifiers, choice interaction components having an empty string for an ID, or an invalid statement ID within a reference object. Learner data collected from 3rd party systems were also stored in formats that could not be used by other TLA components.

Key factors hindering the quality of the dataset included:

- *Inconsistency in actor, verb, object naming patterns* – Many statements were missing fields, such as the object activity definition. Non-unique IDs and/or other fields were also being used as unique identifiers. It is essential to have at least one unique identifier for each entity type, and that uniqueness must be maintained.
- *Hidden links in recommender and competency management system* – A loss of traceability into "black box" components made it difficult to reconstruct evidentiary chains. Data generation processes designed in relation to the recommender were *update-in-place*, including the Experience Index. This resulted in the loss of valuable time-series data.
- *Poorly formatted objects* – Different objects followed different schemes for capitalization, space padding between fields, and field order. There was a significant amount of inconsistency across statements of the same types.
- *Inconsistent labeling of competency levels* – Internal competency data did not match external documentation, and learning resources described different relationships between these terms. The Experience Index contained undefined and unnecessarily excessive data. Additionally, the original design did not adequately protect identifier uniqueness and required an update.

The 2019 TLA research built upon lessons learned from 2017 and 2018, resulting in a complete redesign of the Reference Implementation. Integrated data services were enabled through an improved data and communication architecture built around the Kafka data streaming platform. This meant selecting *composable* data models, enhancing *portability* of devices and activities for generating or using learning data, designing *scalable* services for communicating and sharing these data, and *extending* control over the data to address privacy and cybersecurity concerns.

As the TLA progresses toward an Initial Operational Capability in 2021, near-term research goals are focused on establishing tools, technologies, and policies that maximize adoption of the API (xAPI) and reduce barriers to entry (e.g. cybersecurity compliance) across the DoD. This foundation enables the collection of learner-related data to support enterprise learner analytics. Longer term research focuses on integrating machine learning and artificial intelligence with this analytic capability to build adaptive instructional systems for career management within the human capital supply chain.

2.4 A Decentralized Approach

The TLA vision features non-monolithic, decentralized solutions to the big-data challenges faced by DoD's education and training enterprise. There is no TLA mainframe, no single data repository, no TLA bureaucracy to manage its systems and services.

By providing a set of executable policies, specifications and standards for data collection and sharing (essentially an *integrated data strategy* for DoD education and training), the TLA enables the modernization of DoD learning systems, and their ultimate integration within the agency's enterprise management business processes. In most cases, this can be accomplished with phased upgrades or augmentations to current systems, rather than costly replacements and new-systems acquisition.

The desired transition is from fragmented legacy systems tied together with human driven processes, to a dynamically interoperable digital system that supports automation and is responsive to changes in the threat and technical environment.

3.0 RESEARCH INTO COMMERCIAL STANDARDS

In 2018, a wide range of commercially available standards were evaluated on their ability to support different aspects of an integrated data strategy. Research was performed through different 'lenses' to identify how standards and specifications might be used at various stages of a career trajectory, and across institutional boundaries. This research highlighted candidate standards that warranted further evaluation to determine their ability to meet future DoD requirements.

To mature the data strategy, 2019 efforts included participation in multiple standards initiatives and industry working groups, and collaboration with other DoD stakeholders. Vendors under contract with ADL Initiative were required to provide technical reports that detailed how their tools, technologies, and capabilities addressed specific elements of the data strategy. These reports provided insight into the strengths, weaknesses, commonalities, and challenges of relevant standards and technical approaches being used to support education and training across the DoD. TLA standards development in 2019 fell into five broad categories:

- Overarching TLA specification (e.g., business rules, implementation requirements, cybersecurity, protection of personally identifiable information (PII))
- Competency-based learning
- Learning activity tracking
- Learning activity and resources metadata
- Learner records

The evaluation of candidate standards started with the development of use cases derived from literature reviews, interviews with subject-matter experts, and collaboration with stakeholders. **Figure 2** shows the iterative method used to develop design hypotheses and prototype the experimental test bed to evaluate candidate standards.

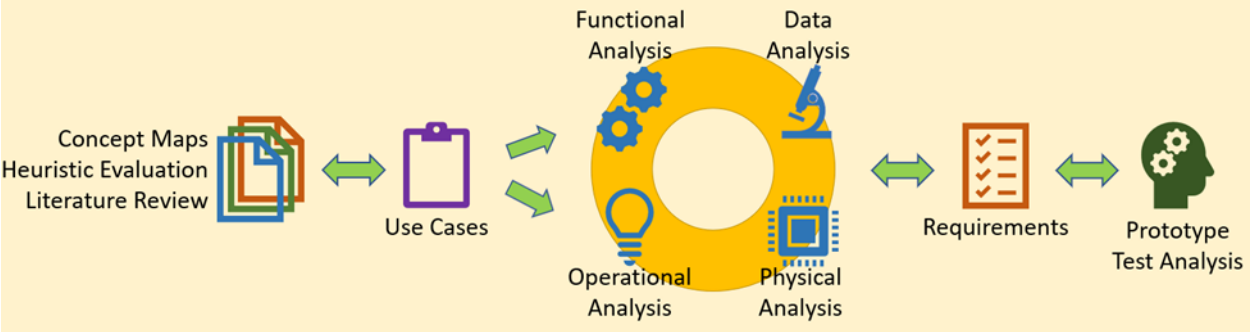

Figure 2. TLA Research Methodology. *Iterative processes were used to establish an integrated TLA data strategy. The TLA technical team was comprised of engineers, learning scientists, designers, and developers. Use cases were developed to guide experiments that validate key concepts.*

The research team used this approach to define requirements and develop models[5] describing the physical, functional, semantic, and operational architecture required to evaluate the adequacy of each standard. This approach also allowed the team to measure the impact each standard has on other related standards and overall system performance. Each standard was verified iteratively and mapped to the features and capabilities of each TLA system node and its associated interfaces.

TLA technical specifications and standards allow different learning resources to communicate with each other using a common language. These standards serve as building blocks for lifelong learning by establishing consistent protocols that can be universally understood and adopted by any new learning capability, enabling data exchange about learners, activities, and experiences. This section describes the baseline TLA standards that were defined through this design/build/test process, as well as stakeholder engagements used to validate them.

3.1 Overarching TLA Specification

TLA standards follow a model analogous to the SCORM specification, which allows the standardization of packaging, launch, and performance tracking of digital content so that it is reusable across different LMS platforms. SCORM is comprised of multiple commercial standards from the Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standards Committee (LTSC), IMS Global, and the Aviation Industry Computer-Based Training Committee (AICC). The SCORM specification pulls these standards together into a Reference Model that dictates how they interoperate. Similarly, the ADL Initiative anticipates that the overarching TLA specification will pull together a multitude of other accepted standards to dictate how systems, platforms, and technologies will interoperate within the future learning ecosystem.

Figure 3 shows how this specification might support the modernization of the Defense Health Agency (DHA) education and training infrastructure, linking commercial standards, cybersecurity policies, and business rules together to support the Military Healthcare System (MHS) Continuum of Learning.

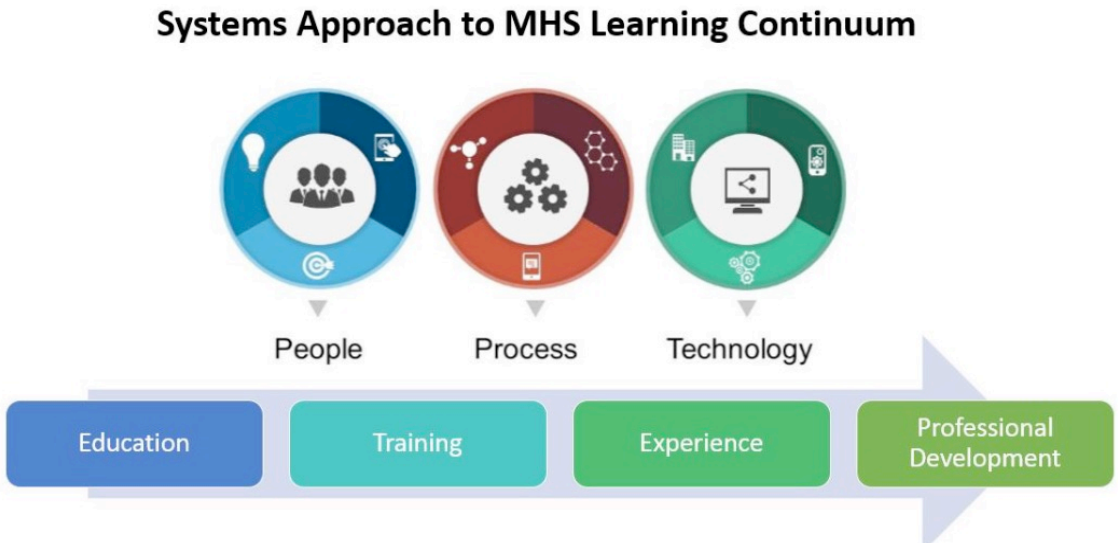

Figure 3. Systems Approach to the Military Healthcare System's Learning Continuum. *The DHA relies upon the unified performance of people, processes, and technology components across the DoD enterprise.*

[5] *Model Based Systems Engineering (MBSE) methods – Systems Engineering Body of Knowledge 2.1 https://www.sebokwiki.org/wiki/Guide_to_the_Systems_Engineering_Body_of_Knowledge_(SEBoK)*

The ADL Initiative supported the Naval Air Warfare Center, Training Systems Division (NAWCTSD) in their development of requirements to support the DHA modernization. These requirements are not unique to DHA but illustrate the types of systems and technologies at play across the DoD. DHA uses various learning technologies (e.g., computer-based training, classroom instruction, intelligent tutoring, patient simulators, continuing education) across a widely distributed collection of facilities, schoolhouses, and training sites. This work validated the requirements defined within the OUSD(I) TDT project for an overarching TLA specification that ties commercial standards, policy guidance, governance strategies, and business rules to facilitate interoperability across the enterprise.

Recognizing the value of this approach, the IEEE began updating the **IEEE 1484.1 Learning Technology Systems Architecture** (LTSA) standard. A study group[6] was formed to use the U.S. Department of Education's Common Education Data Standards (CEDS) Normalized Data Schema (NDS), coupled with other IEEE standards and other TLA standards and specifications to create a *Conceptual Model for Learning Technology Standards (CM4LTS).* This work will eventually result in an updated IEEE LTSA standard which outlines an architectural framework of systems, components, functions, and their related data standards.

Figure 4 shows how different components of the TLA map to different commercial standards under the CM4LTS approach. This effort is relatively new but has broad support throughout the community. It has potential to become the overarching TLA specification, but additional work is needed to add other standards to support *Federated Identity, Credentials, and Access Management* (FICAM), Zero Trust Networks, and cybersecurity compliance using NIST 800 and other risk management controls.

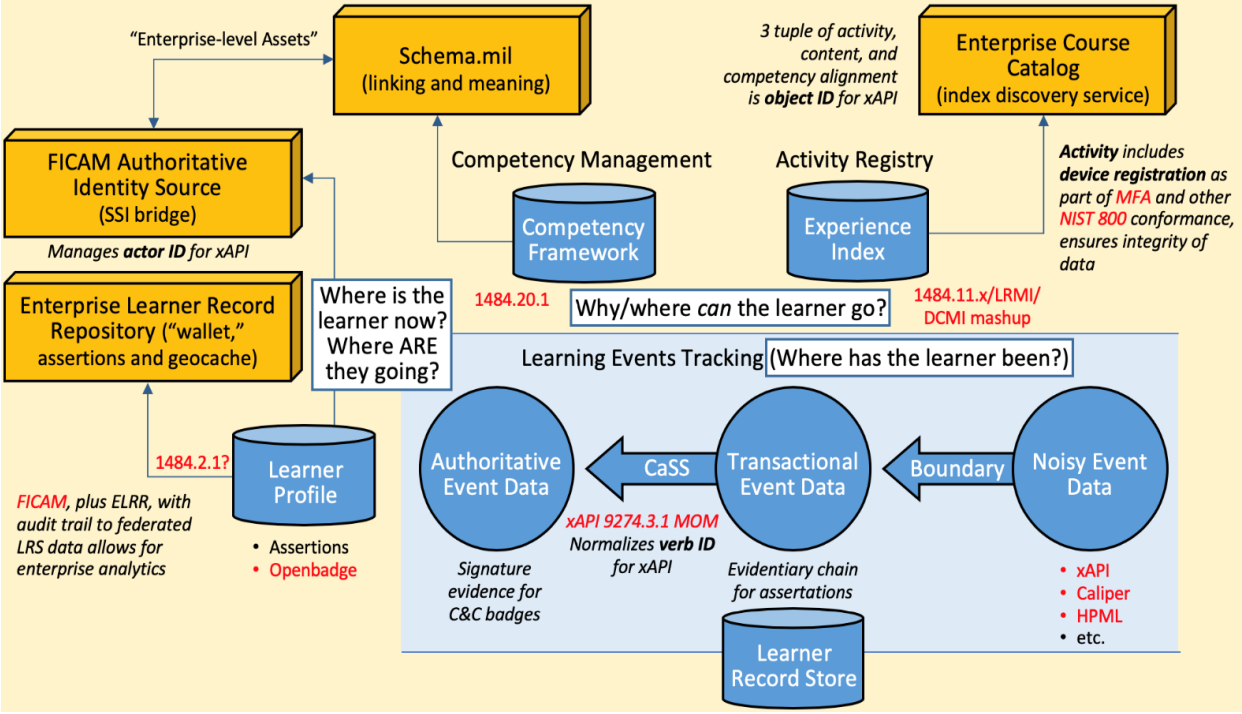

Figure 4. Federated Data Approaches within the IEEE CM4LTS Study Group*. This illustration shows where different commercial standards are applied across a range of enterprise learning technologies.*

[6] *IEEE Conceptual Model for Learning Technology Standards (CM4LTS) Study Group Charter*

3.2 Competency-Based Learning

Competency-based learning represents a transition from curricula focused on abstract knowledge and pursuit of certificates to curricula built around authoritative learner performance and proficiency indicators. Competencies describe specifically what people need to do to be effective in their roles, and clearly establish how their roles relate to organizational goals and success. Each job has its own set of competency requirements. *Proficiency* is another critical concept that requires relevant, trusted data as evidence of mastery of specific skill requirements.

Competency management requires the generation of rich, traceable data about learning experiences, how they relate to skill proficiency, and the KSAOs that individuals need to do their job. A Competency Framework is a structure for defining the KSAOs required to do a job. Competency Frameworks are widely used in business for defining and assessing competencies within organizations for successful job performance. There are numerous competency frameworks available and numerous specifications that drive them. Some of these are included later in this section.

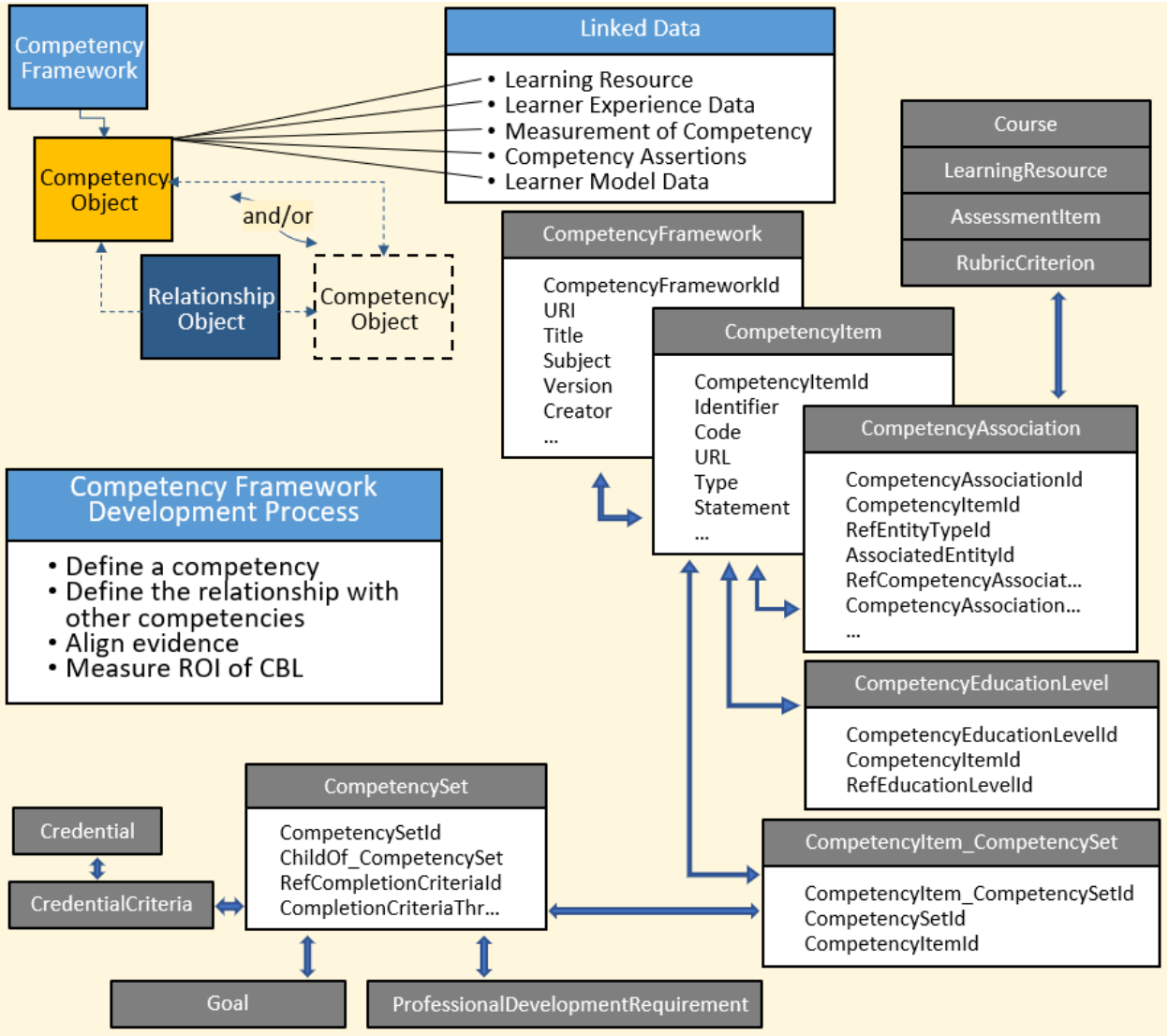

Figure 5. IEEE 1484.20.1 Reusable Competency Definition. *The RCD standard provides a mathematical formalism for defining competencies and describing the relationships among competencies within a Competency Framework.*

Through 2019, the ADL Initiative technical staff continued working with the **IEEE 1484.20.1 Reusable Competency Definition (RCD)** study group. As shown in **Figure 5**, the RCD standard uses linked data to define all aspects of a competency including key performance indicators, formal assessments, and other measures of proficiency. The RCD standard is the mathematical underpinning of the TLA's approach to competency-based learning. It provides a format for defining competencies and associating them with other competencies in the context of an overarching Competency Framework.

Mathematically, the RCD must behave as a Directed Acyclic Graph (DAG). In graph theory, a DAG structure comprises nodes connected with edges. Each node in the graph corresponds to a competency object, and the edges define the relationship between them. Within the TLA, each RCD node includes a unique identifier that can be referenced by other TLA components using other TLA standards. For example, the Learning Resource Metadata Initiative[7] (LRMI) and the Credential Transparency Description Language[8] (CTDL) both reference these identifiers to provide an alignment between learning activities, competencies, and awarded credentials.

Competency models and frameworks exist in many different formats that are supported by different communities, including the Federal Government. The ADL Initiative, through the development of authoring tools for the Competency and Skills System (CaSS), worked with the Air Force A3J Competencies Division and participated in working groups across industry, academia, and government to better understand how competencies are derived. A report titled *The Competency Framework Development Process*[9] was collaboratively authored to document these processes within the Air Force and across different industries. These projects provide a good understanding of the complexities and differences in how competencies are derived across different DoD organizations.

The CaSS authoring tools project follows this development process and is creating intuitive workflows for importing and exporting other Competency Frameworks such as OpenSALT, the Achievement Standards Network (ASN), the Competency and Academic Standards Exchange (CASE) specification, and Medbiquitous. CaSS also supports CTDL and the IMS Global OpenBadge specification.

As shown in **Figure 6**, the TLA Reference Implementation uses CaSS to process and align evidence of learner performance against a Competency Framework. The management system asserts levels of proficiency for individuals or teams, allowing credentials to be awarded based on those assertions.

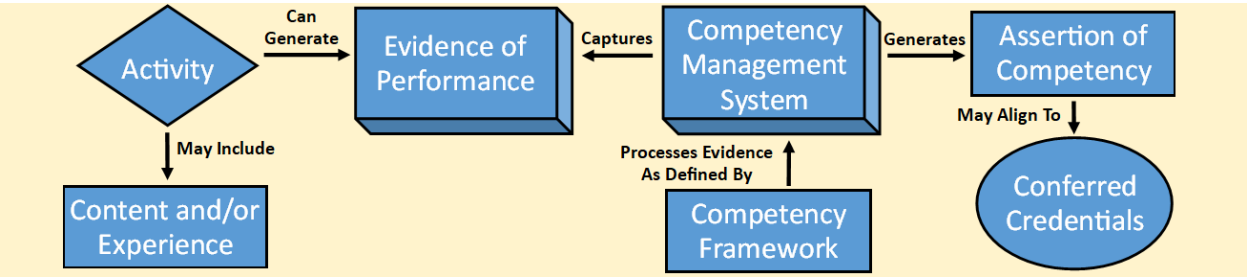

Figure 6. Relationship of Competency and Assertions. *Learning activities generate evidence of performance that is processed by a Competency Management System. The Competency Management System aligns the evidence to the Competency Framework and asserts levels of proficiency for individuals or teams. Credentials may also be awarded based on assertions.*

[7] *Dublin Core, About LRMI - https://www.dublincore.org/about/lrmi/*
[8] *Credential Transparency Description Language Handbook - http://credreg.net/ctdl/handbook*
[9] *Currently going through the government acceptance process*

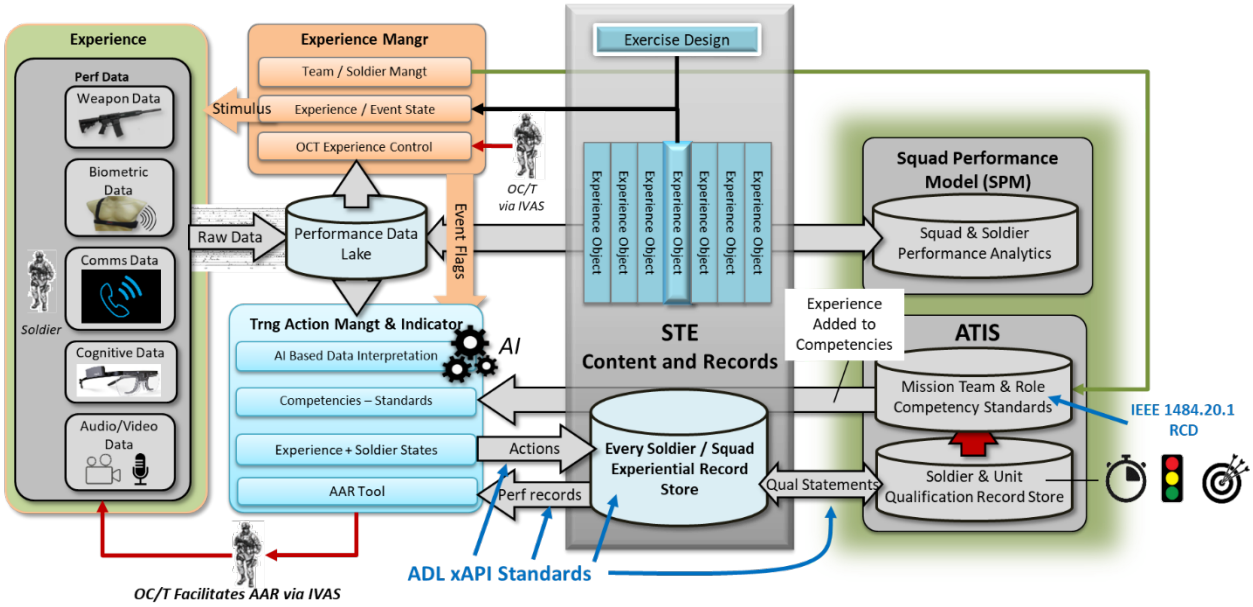

Figure 7. Relationship of Competencies and the Squad Performance Model. *At any given moment, dozens of competencies, measures of effectiveness, and measures of performance can be happening simultaneously. This is especially true in collective training where team competencies such as trust, confidence, and communication create different types of evidence than individual competencies.*

In another 2019 competency-oriented project, described in **Figure 7**, the ADL Initiative supported the Army's design and development of a Squad Performance Model and a prototype capability to track and measure individual and team competencies. The Army's *Synthetic Training Environment – Experiential Learning (STEEL)* project intends to develop a prototype capability that tracks and measures individual and team competencies across all Synthetic Training Environment (STE) Training Aids, Devices, Simulators and Simulations. These activities connect to STE Training Management Tools to communicate individual and team performance information to update the Squad Performance Model and report to the Army Training Management Capability that maintains individual and unit training records as part of the Army Training Information System (ATIS) program.

Competency-based learning standards intersect with numerous other TLA standards.

- IEEE 9274.1 xAPI is used to track learning experiences and make assertions that can be read by a Competency Management System.
- LRMI is a metadata framework developed by Creative Commons and the Association of Educational Publishers for describing and tagging educational resources in web-based instruction and training. LRMI includes the ability to align educational resources to the competencies within the RCD Competency Framework.
- IMS Global Open Badge is a technical specification and set of associated open source software to enable the creation of verifiable credentials across a broad spectrum of learning experiences. Badges are used to represent successful completion of key milestones within a program of instruction (e.g., successful completion of a learning activity).
- The CTDL is a vocabulary comprised of terms that describe each credential. Credentials are related (linked) to other entities in the credentialing ecosystem such as assessments, learning opportunities, requirements, costs, and conceptual frameworks (e.g., competencies, classifications of occupations, and instructional programs).

3.3 Learning Activity Tracking

DoD Instruction 1322.26 recommends the *IEEE 9274.1* xAPI[10] standard as the contemporary method for managing learner-performance data. During 2019, the xAPI specification entered the final stages of becoming a standard through the IEEE-LTSC[11], with *xAPI 2.0* targeted for final approval in 2020. The ADL Initiative established a DoD working group to identify challenges and roadblocks for adopting xAPI across the DoD enterprise. This group exposed several challenges associated with cybersecurity and the availability of DoD accredited *Learning Record Store* (LRS) solutions. Their findings were summarized in a paper titled *Cybersecurity Strategies for Accrediting xAPI[12].*

The xAPI specifies a structure to describe learning experiences and defines how these descriptions can be exchanged electronically. The main components of xAPI are the data structure called *Statements* and the LRS data storage/retrieval capability. The xAPI specification has stringent requirements on the structure of these data and the capabilities of the LRS. Statements are data triples that use an Actor, a Verb, and an Object to describe any experience. Each statement also includes timestamps and unique, resolvable identifiers. The transport is HTTP/HTTPS with JavaScript Object Notation (JSON) payloads.

Any enabled device can send xAPI statements, including tablets, phones, simulators, patient mannikins, and any number of other learning systems. When collecting data from these systems, organizations need to be able to shape their xAPI data, standardize it semantically, and identify unique patterns and contexts. The *xAPI Profile Specification* (IEEE 9274.2) offers a common way to document the vocabulary concepts, extensions, statement templates, and patterns that are required for xAPI to be implemented consistently across the spectrum of learning activities an individual will encounter. Upon the successful approval of the xAPI 2.0 specification, the IEEE working group will begin standardizing the xAPI Profile Specification.

An xAPI Profile Server project was started in 2019 to provide the xAPI developer community with a platform for authoring, sharing, and validating xAPI profiles that conform to the specification. The xAPI Profile Server project also provides tools to support the management, discovery and governance for adding or modifying data elements and properties within each profile. One of the best-known examples of an application-specific xAPI Profile is the *cmi5[13] specification*. The cmi5 specification defines a set of rules for importing, launching and tracking online courses using an LMS and xAPI. Technically, cmi5 is an xAPI Profile, which means it inherits the characteristics mandated by the xAPI specification, but cmi5 also imposes additional requirements. These include interoperability rules for content launch, authentication, session management, reporting, and course structuring. The xAPI working group found that many DoD LMSs and authoring tools do not support cmi5, and others lack a cmi5 conformance test suite for validating adherence to the cmi5 specification.

While the xAPI and xAPI Profile specifications are extensible and can be integrated into any activity used for education and training, the TLA *Master Object Model* (MOM) (IEEE 9274.3.1) normalizes the way xAPI evidence is reported from each learning activity to the TLA core (see Section 4.3). The MOM contextualizes how the evidence is gathered, and how the learning environment is organized.

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[10] ADL Initiative GitHub - https://github.com/adlnet/xAPI-Spec
[11] IEEE LTSC TAGxAPI - https://www.tagxapi.org/
[12] Cybersecurity Strategies for Accrediting xAPI - https://s3.amazonaws.com/amz.xcdsystem.com/44ECEE4F-033C-295C-BAE73278B7F9CA1D_abstract_File4313/PaperUpload_19308_0616074810.pdf
[13] The cmi5 Project - https://aicc.github.io/CMI-5_Spec_Current/

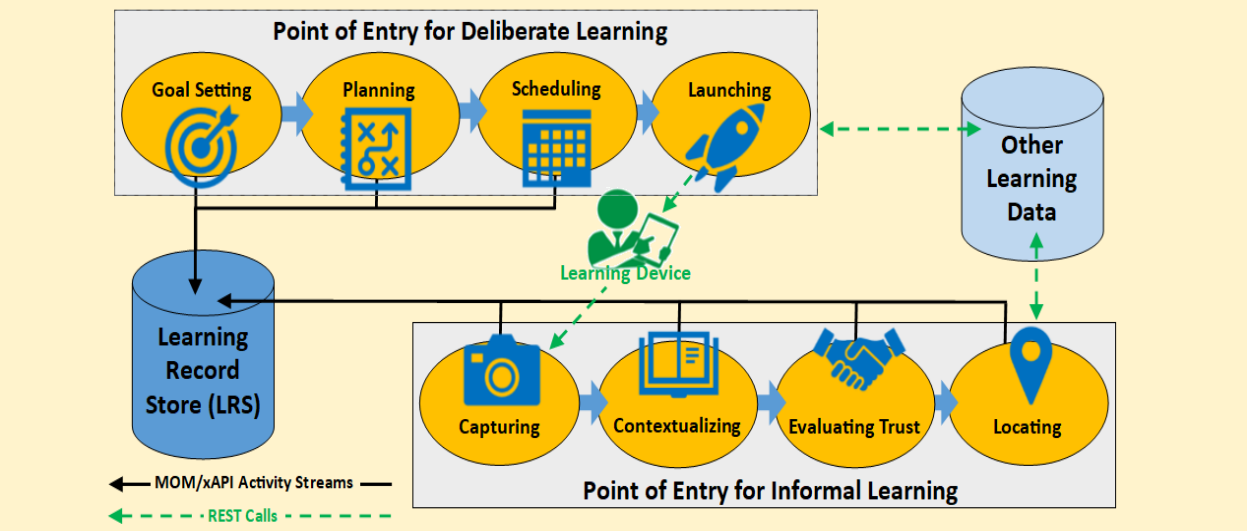

Figure 8. The Learning Lifecycle. *The MOM learning cycle is captured in the TLA DoDAF and outlined in the draft IEEE specification attached as Appendix B. This lifecycle accommodates deliberate learning (planned or required) and informal learning captured from casual interactions with instrumented media.*

As shown in **Figure 8**, the TLA MOM abstracts performance adjudication to edge systems by following the *learning event lifecycle*. Learning activities report success or failure using the cmi5 verbs, whereas lower level performance data may be kept on a local LRS. This enables the evaluation of trust in the evidence used to update competencies and credentials. It also provides reference points within collected performance data to filter and organize enterprise analytics within the decision support system. Most importantly, it normalizes the events necessary to trigger microservices to take actions without an overall state manager. This forms the decoupling and data segmentation approach used for LRS federation.

Within the TLA MOM are embedded chains of evidence that ensure "learner centricity" is preserved across a wide range of learning activities or other TLA components. This establishes an auditable trail of demonstrated competency to back-up each awarded credential. It also preserves the digital signatures of those trusted to review and confer credentials. Since the TLA MOM allows for learner context generated by any number of locations in the federation, it also ensures resiliency to system changes over time. The draft IEEE 9274.3.1 TLA MOM standard is included in **Appendix B**.

The xAPI standard intersects with numerous other TLA standards including:

- The xAPI Profile Specification (IEEE 9274.2) provides a common vocabulary and identifies specific contexts and patterns using linked data.
- The TLA MOM (IEEE 9274.3.1) represents a learner's state in the context of a learning experience within a continuum of learning.
- The cmi5 specification is used to replicate the functionality resident with SCORM managed courses delivered using an LMS.
- SCORM is currently being extended through the IEEE LTSC to maintain the DoD investment into SCORM conformant courses. It will continue to play a role until content can be migrated to other specifications (e.g., cmi5).
- The ePUB3 standard for eBooks that use *Personalized eBook for Learning* (PeBL) extensions enables generically instrumented eBooks for learning.

3.4 Metadata about Learning Activities

The 2018 TLA demonstration relied heavily on the LRMI metadata framework for describing and tagging educational resources. The LRMI is a metadata framework developed by Creative Commons (CC) and the Association of Educational Publishers (AEP). It is used for describing and tagging educational resources in web-based instruction and training. A primary benefit of the LRMI specification is its inclusion of an "*AlignmentObject*" to describe an alignment between a learning resource and a competency node in an RCD framework.

2019 research continued the process of mapping the relevant attributes of existing metadata standards including LRMI, IEEE 1484.12.1 Learning Object Metadata[14] (LOM), Schema.org, and the Dublin Core Initiative. The ADL Initiative participated in a series of technical working group meetings that included the working groups from various metadata standards initiatives, industry partners, and other organizations working to harmonize across available standards. This work informed a draft metadata strategy that was initially created to support the migration of Adobe Flash content to an HTML5 friendly format. The draft metadata strategy merged the LOM standard with LRMI to support newer learning modalities (e.g., Augmented- and Virtual-Reality, instructor-led, serious games, simulations).

Through the TLA working group's subcommittee on metadata, ADL Initiative staff continued to evolve the metadata strategy based on the technical interchange with different DoD stakeholders. These discussions helped align the goals of the subcommittee with the DoD's programmatic requirements across different modernization efforts. This stimulated the standards community to start the formal process of updating the IEEE 1484.12.1 LOM standard. The LRMI working group and the LOM working group started working together to formally merge LRMI and LOM into a LOM 2.0 standard. This effort is expected to be formalized into an IEEE study group in 2020.

Based on this work, the 2019 TLA Reference Implementation expands the types of learning activities a learner may encounter by acknowledging the relationship between instructional content and the various instructional activities where that content is presented to the learner. The term "activity" describes the context of the work, such as simulation, LMS, eBook, or classroom lecture. The term "content" describes the digital artifacts used in the activity, such as a scenario, Sharable Content Object, checklist, or technical manual.

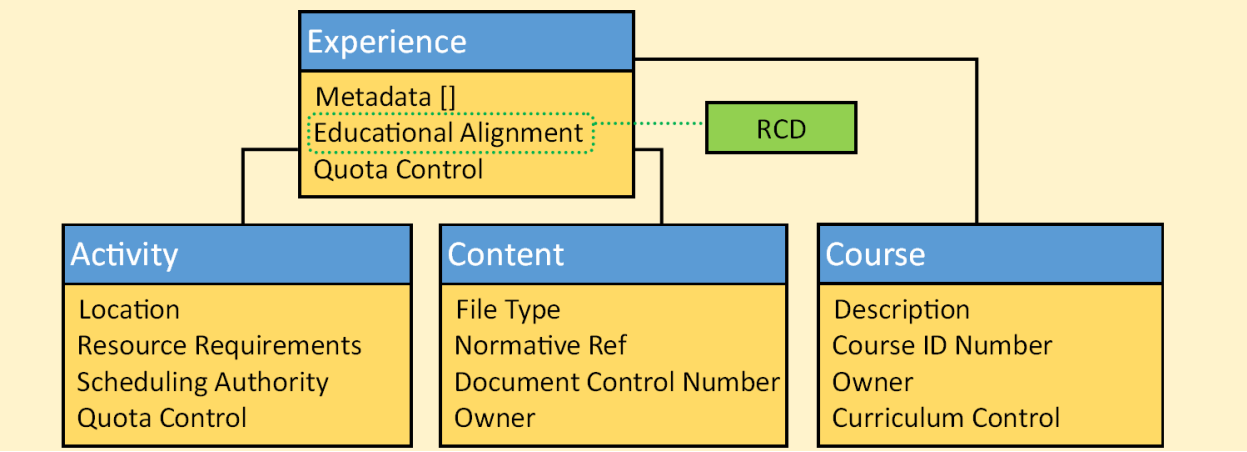

Figure 9. Relationship between Experience, Activity, Content, and Course. *Data elements segmented for configuration management and search performance and exported in a modified LRMI format.*

[14] *IEEE Standard for Learning Object Metadata - https://ieeexplore.ieee.org/document/1032843/*

The draft LOM 2.0 metadata strategy created in 2019 provides a broad framework for describing learning objects to facilitate search, evaluation, acquisition, and use. This relationship, shown in **Figure 9**, is encapsulated into a learning experience aligned with a fragment of a Competency Framework that includes one or more competencies.

A large component of the 2019 research involved defining the lifecycle of metadata across human-readable and machine-readable formats. While human-readable metadata is typically created during the development of instructional activities, the next generation of learning tools will automate the process of creating machine-readable metadata that uses *paradata*[15] about how each activity and its content is being used across the enterprise. The Navigator for Integrated Learning Experiences (NILE) project[16] studied this topic in detail and delivered detailed documentation describing how their algorithms automated this process. The NILE project found that many human-readable metadata formats such as Dublin Core and LOM were unusable by adaptive instructional systems.

While standard search algorithms can find resources relevant to key terms and to a given competency if alignment data are present, this often requires manual labor. The greatest need for curating learning resources using machine learning and artificial intelligence is access to usage data. Within NILE, paradata can be used to automatically create or update metadata describing relevance, engagement, and efficacy.

This is especially relevant to the DoD's *Enterprise Digital Learning Modernization* initiative, led by the DoD Chief Management Office (CMO), as department-wide and/or service-specific governance strategies are developed to manage an integrated data strategy. In 2018, the CMO's Reform Management Group issued a decision memo instructing DoD to develop a common catalog of education and training courses. The *Enterprise Course Catalog* (ECC) project intends to provide a globally searchable directory of DoD course listings and ancillary training resources, pulling metadata from local sources/catalogs. More than just another static course catalog, the ECC will federate numerous local course catalogs such that DoD users see one seamless interface to access course information at the time and place of need.

ADL Initiative research in 2019 informed requirements for key features of this work including the ability to perform semantic search services across *Federated Experience Indices* at scale, managing paradata to continually update metadata, and an underlying messaging architecture that conforms to the DoD Chief Information Officer's policy for Information Enterprise Architectures[17].

Learning activity metadata intersects with other TLA standards and capabilities including:

- Competency-based learning assertions in the form of IEEE 9274.1 xAPI statements use an Object ID that is included in the LRMI/LOM metadata for each activity. A Competency Management System uses this ID to pull metadata about the learning activity that generated the assertion.
- The LRMI Educational Alignment field can be used to map each learning activity that the unique identifier included in each IEEE.1484.20.1 RCD node.
- Metadata describing learning activities and their associated content is stored in the TLA Experience Index for use by other TLA components.

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[15] Paradata describe data generated as a by-product of the data collection process.
[16] Navigator for Integrated Learning Experience - https://adlnet.gov/projects/nile/
[17] DoD Enterprise-level Architectures - https://dodcio.defense.gov/In-the-News/DoD-Information-Enterprise-Architecture/Transformation-Context/

3.5 Learner Records

The current way learner records are managed is insufficient for the evolving needs of instructors, learners, and organizations. Today, academic institutions use a *transcript* to record learners' permanent academic records. Typically, a transcript only includes the most basic of information such as courses taken, dates, grades received, and degrees conferred from a formal academic institution. Transcripts offer little visibility into individuals' past performance, such as what other instructors have noted about them, the informal or nonformal learning they've experienced, or their strengths, weaknesses, and individual needs.

The ADL Initiative supported multiple projects that could enable more expansive DoD access to learner records. Described below, these projects are being led by the T3 Innovation Network (T3 Network), the American Association of Collegiate Registrars and Admissions Officers (AACRAO), the National Association of Student Personnel Administrators (NASPA), and the American Workforce Policy Advisory Board (AWPAB). In many instances, pilot projects are moving forward focused on academic, military, and workforce domains. These projects provide opportunities for ADL Initiative staff to engage and leverage lessons-learned and related solutions to ensure the military perspective is accurately and comprehensively represented.

The persistent theme across these efforts is that current projects limit their focus to *harmonizing* credentials, over the *distribution* and *optimization* of credentials for jobs. Overemphasizing credential portability leaves them vulnerable to being devalued, and if an organization relies solely on the accrediting body there is no mechanism to review the chain of evidence for the credential's conferral. Forensic analyses following any negative impacts on readiness are complicated, especially for credentials that require different learning modalities where behaviors imparted in traditional learning may not always be transferred.

3.5.1 T3 Network

Established through collaboration between the U.S. Chamber of Commerce Foundation and the Lumina Foundation, the T3 Network[18] is leading eight pilot projects to establish an open, distributed, public-private data infrastructure that supports access and opportunity for American students and workers. The ADL Initiative is engaged in three of these pilot projects to represent the interests of DoD and garner lessons-learned for the TLA project.

The three pilot projects are described below.

- **Data Standards Harmonization (PP1)** – Designed to identify gaps in commonly used data standards, and work across projects and standards to improve and harmonize data standards.
- **Comprehensive Learner, Worker, Military Records (PP3)** – Designed to identify gaps in standards to ensure that records are complete with their full range of competencies and credentials.
- **Competency Data Exchange (PP5)** – Designed to develop business models to incentivize the sharing and distribution of competency frameworks and develop protocols and processes for sharing competencies across networks.

[18] *U.S. Chamber of Commerce, The T3 Innovation Network - https://www.uschamberfoundation.org/t3-innovation*

3.5.2 AACRAO & NASPA

In 2017 AACRAO and NASPA completed Phase One[19] development of a Comprehensive Learner Record (CLR) to meet the needs of a broad number of U.S. colleges and universities. The CLR is intended to capture, record, and communicate learning when and where it happens in a student's higher education experience. In their Phase 2 report, *Standardized Components for a Competency-Based Educational Record*[20], the team described their success in: 1) scaling of CLRs in up to 150 colleges and universities; 2) standardizing the components of a competency-based education transcript/record; 3) addressing data integration issues; and 4) leveraging existing degree audit technologies to track progress toward learning outcomes. The ADL Initiative is monitoring this effort to apply lessons learned to DoD requirements.

3.5.3 AWPAB

In support of the National Council for the American Worker (NCAW), AWPAB is developing recommendations across four focus areas. The TLA's interests are most aligned with the Data Transparency working group, which is focused on enabling a system for translating comprehensive education, training, and work experience to a record of transferable skills and credentials throughout a worker's entire learning lifecycle. In September 2019, the Data Transparency working group released a report on Interoperable Learning Records[21] (ILR), featuring key ILR terminology and a forward-looking ILR ecosystem vision. The ILR approach includes three objectives:

- Create an ILR inventory (October 2019)
- Convene an expert group to develop a project plan (December 2019)
- Champion fast-track prototyping (2nd Quarter 2020)

This industry-focused effort largely defined learner records according to *use-cases* that were established to represent the learner and employers. These use-cases did not consider how adaptive instructional systems might use learner records. They were derived to represent how individual learners might use a CLR to manage career growth, or how employers might use learner records to support the human capital supply chain and workforce planning in the context of a Job Data Exchange[22].

The ADL Initiative continues to monitor this work through the close coupling of this initiative with the T3 Network's pilot projects.

3.5.4 IMS Global Comprehensive Learner Record

The IMS Global CLR[23] standard is a promising format for an expanded, more data-rich academic transcript which captures detailed learning experiences and learner achievements such as prior learning, internships, experiential learning, coursework taken and completed, competencies, skills, and co-curricular achievements. The CLR standard lays the groundwork for contextualizing learning data at the institutional level and enables basic interoperability by allowing organizations to digitally maintain and transfer credentials throughout a learner's career.

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[19] *Integration of Data Across Institutional Platforms to Create Comprehensive Learner Records* - https://www.aacrao.org/docs/default-source/signature-initiative-docs/clr/data-integration-white-paper-9_2018.pdf

[20] *Standardized Components for a Competency-Based Educational Record - https://www.aacrao.org/docs/default-source/signature-initiative-docs/clr/competency-based-educational-record-report-092019.pdf*

[21] *White Paper on Interoperable Learning Records - https://www.commerce.gov/sites/default/files/2019-09/ILR_White_Paper_FINAL_EBOOK.pdf*

[22] *Job Data Exchange - https://www.uschamberfoundation.org/workforce-development/JDX*

[23] *Comprehensive Learner Record - http://www.imsglobal.org/activity/comprehensive-learner-record*

The major components of the CLR include information about what the learner learned (e.g., achievements, their relationship to an educational framework, and relationship to other achievements), evidence of their achievement (e.g., assertion, endorsement claim, evidence (artifacts like text, media, and website that provide supporting evidence for the record), and verification), and personal information (e.g., address, identity, profile). The tangible result is a web-ready linked-data document that can be shared externally. It supports JavaScript Object Notation for Linked Data (JSON-LD), allowing it to interface with the data ecosystem of digital credentials.

These capabilities only partially meet DoD requirements. The current CLR structure uses six core classes to define its data properties; 1) CLR, 2) Learner Profile, 3) Publisher Profile, 4) Assertions, 5) Achievement, and 6) Association. Five service interfaces help manage access to the relevant CLR components and can be used to share this data with other TLA components. The core components of the CLR are largely focused on achievements represented by credentials, their relationship to an educational framework, and their relationship to other achievements. There is a risk that without access to localized learner records where evidence of competency often resides, credentials could become conflated with the evidentiary chain required to support CBL. DoD requires access to an authoritative chain of evidence which will be stored across DoD in various LRS solutions.

3.5.5 IEEE 1484.2 Integrated Learner Record (ILR) Study Group

In June 2019, the IEEE LTSC obtained approval for the IEEE 1484.2 Integrated Learner Record (ILR) study group to move forward, with a goal to provide interoperability across numerous learner record initiatives. This group is comprised of standards-focused members from the Department of Education, IMS Global, the Postsecondary Educational Standards Council (PESC), and other related IEEE standards groups. The ILR Recommended Practices will build upon the CEDS V8 Conceptual Data Model and provide best-practice guidance for self-sovereign Identity and Access Control Trust Networks, open ontology references, and verifiable assertions.

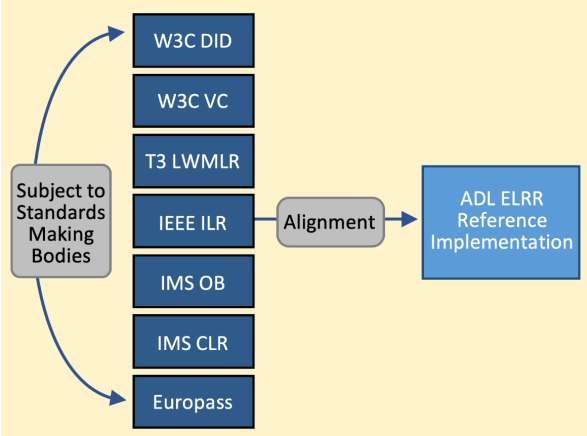

Figure 10. IEEE 1484.2 Integrated Learner Record. The ILR provides interoperability across numerous learner record initiatives.

This project started to address requirements set by the T3 Network and AWPAB, and to facilitate integration with other standards initiatives. As shown in **Figure 10**, the ILR intends to be compatible with different learner records that might be used across different communities. The IEEE is accepted as a neutral standards organization that could be successful at aligning and harmonizing relevant specifications; however, the project is in its infancy and no standard is available for evaluation.

3.5.6 AETC

In addition to participating with and monitoring the various public-private partnerships, ADL Initiative staff collaborated with AETC's Airman Learner Record (ALR) program office to understand how this record might be used across the DoD education and training enterprise. The ALR captures and consolidates the entirety of an airman's training, education, experiential development, and competencies obtained on the job, off-duty throughout their career, and prior to joining the military.

In 2019, the ALR was focused on assessing functionality, developing and evaluating the front-end design, and validating requirements for three major use cases: Learner, Civilian, and Leadership. In September 2019, the ALR 1.0 framework was delivered to the Air Force Learning Services Ecosystem (AFLSE) test environment. The ADL Initiative continues to meet regularly with the ALR program office to monitor progress, ensure technical compatibility with other TLA standards, and better understand Air Force requirements as they continue to evolve.

3.5.7 ELRR

The DoD's Enterprise Digital Learning Modernization initiative, through the DoD CMO, has also issued guidance to develop a common learner record repository. The *Enterprise Learner Record Repository* (ELRR) intends to track an individual's summative experience in education and training across systems, platforms, and organizational boundaries in the form of competencies and credentials. Data standards are required to support federated data contracts and services that can integrate data from authoritative sources owned by DoD organizations (e.g., Army ATIS, AETC ALR, Navy Electronic Training Jacket). These connections will be managed by *Authorities to Connect*.

The ELRR stores the digital version of each credential (or micro credential) and assertion of competence, with pointers to the evidentiary chain of local records from each location maintaining records of the learner's career history. Assertions include other information such as physical/psychological/behavioral attributes, personal preferences, and competencies not associated with a credential (such as second languages). Each data element is properly tagged to implement privacy settings in conjunction with federated identity, credential, and access management.

As the requirements for credentials change over time, there is no architecture in place to track the impact of those changes. A true ELRR capability will rely on expanded use-cases that look at both civilian and military requirements across different time scales, from in situ learning to an entire career arc. For example, learner data such as engagement, preferences, misperceptions, misconceptions, and motivational attributes can provide a wholistic view of the learner, which can optimize learning at the activity and course level to increase the velocity toward the learner's goal.

3.5.8 Control Loops

Lifelong learning data that are stored within learner records can be abstracted into five control loops that describe the continuum of learning throughout a career, as shown in **Figure 11**. These control loops provide a framing mechanism for the TLA data strategy where each control loop has its own data sources and sampling requirements. Optimizing the results within each control loop, through data-driven decisions and eventually automation directly supports mission effectiveness.

- Control Loop One (Learning Activities) involves the data required to optimize the current learning activity. Control Loop One optimizes performance in the task at hand.
- Control Loop Two (Credentials) involves the data required to support the planning of learning activities in pursuit of credentials, which may require completion of multiple courses.
- Control Loop Three (Job) involves the data required to optimize competencies and credentials in support of an individual's current job. This includes feedback mechanisms for de-credentialing if proficiency is not maintained in certain skills.

- Control Loop Four (Career Arc) involves data to support the planning, placement, and evaluation of individual career growth, including planning development trajectories that are aligned with organizational needs.
- Control Loop Five (Career Transition) involves selecting a new career option, such as selecting a new Occupational Specialty or pursuing a substantively different line of work.

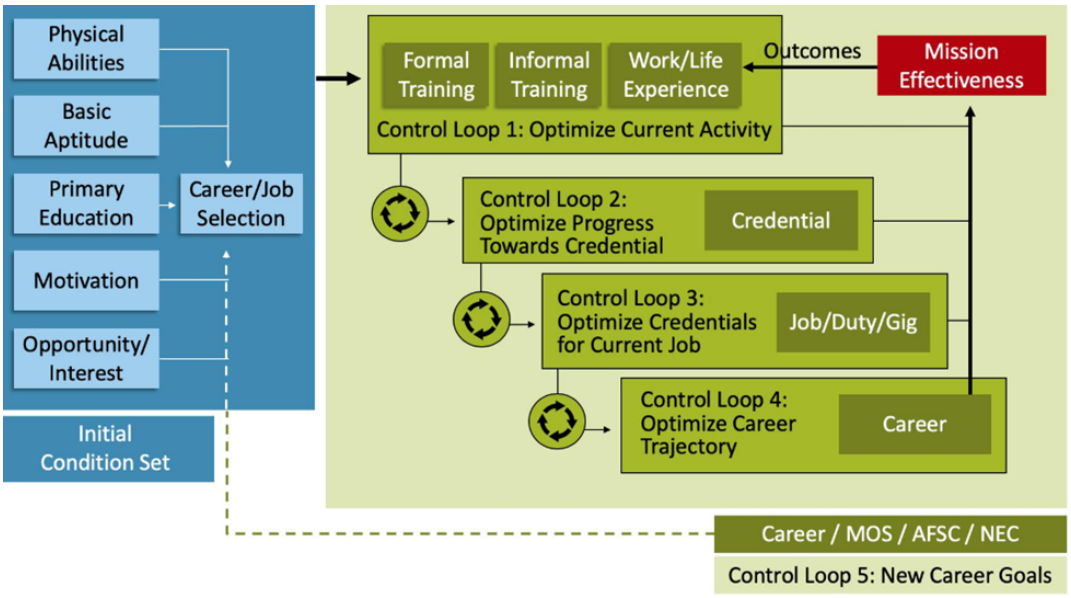

Figure 11. TLA Control Loops. *To reduce complexity, the TLA decomposes lifelong learning into a series of five control loops. Each loop focuses on a different aspect of individuals' learning paths throughout their careers.*

There are numerous challenges in creating a lifelong learning record that still need to be determined. The IEEE 1484.2 ILR and the IMS Global CLR are both promising solutions but there are more questions that will need attention in 2020. What elements of the learner profile should the learner be in control of? How does learner information pass from one organization to another? What Authoritative Systems have permissions to write to the learner's profile? How do we represent learner context?

Taken together, these different learner record initiatives set a fast drumbeat toward establishing a knowledge base allowing individuals and employers to gain deeper insights into required workforce competencies and learning achievements.

4.0 2019 TLA Reference Implementation

The 2019 TLA Reference Implementation provided the test and evaluation environment for conducting research required to validate TLA specifications, standards, technical designs, and other TLA-related services. It also established a 24/7 testing capability to evaluate different approaches for federating data.

The 2019 Implementation built upon lessons learned from 2018 to better represent a true ecosystem of microservice-based enclaves of data, services, and learning devices federated across multiple locations. A key focus for 2019 was to replace the point-to-point communications of the 2018 system with a modern publish/subscribe (pub/sub) type message service. Pub/sub services are much more scalable than point-to-point links and are more representative of the architectures used across the DoD. This allowed the ADL Initiative to better evaluate different TLA components in the context of an operational environment.

Another 2019 focus was to decouple the learning management functions of an LMS into composable "microservices" that communicate using scalable and open protocols. The TLA engineering team chose Kafka, a streaming type messaging service, to provide the pub/sub infrastructure. The research uncovered the impact of using streaming messages on the system topology, and the impact on standards such as xAPI, defining the structure of the passed messages. The team evaluated the proposed core/edge architectural pattern and the performance of the Kafka data streaming service.

4.1 Design

The Reference Implementation is comprised of three core microservice groups, a data lake composed of the four data stores associated with the TLA data strategy, and the Kafka pub/sub messaging service. This approach was used throughout 2019 to conduct numerous experiments for testing the architectural designs, integration with streaming messages, and the types of data and protocols used at scale.

The TLA topology relies on the heuristic of distinguishing core services from edge systems. Core refers to mandatory functions and data sources, while edge refers to optional or externally federated systems or data sources. The System/Sub-System Design Document attached as **Appendix D** describes the detailed logical, hardware and software architecture, components, interfaces, and concept-of-execution for the Reference Implementation**.** Hosting is provided through Amazon Web Services (AWS), coordinated by USALearning with an Ubuntu 16.x, Hadoop, Docker, and VMWare component stack.

While 2019 focused on the establishment of a development cluster, the Reference Implementation is designed to support a three-tiered configuration management pipeline that includes a development environment, a testing and evaluation environment, and production environments. Additionally, the development operations (DevOps) pipeline made it easier to compose the final system by progressively adding components or microservices deployed as Docker containers.

4.2 Requirements

Using concept maps and design structure matrices, basic LMS functionality was decomposed into functions, attributes, and data. This analysis provides the foundation for identifying the physical deployment of data and services, which are collected into three *core* and two *back-end* service groups. The behavior and functionality of each service is defined and aligned with TLA business functions. Input-output data flows are identified and aligned with the required TLA data stores. TLA Functional Requirements are attached as **Appendix A**.

It is impractical to have a single repository for each type of data for all DoD components because of horizontal scale, multi-level security, and implementation costs. Thus, learning technologies, such as the LMS were abstracted away to *edge* systems. As shown in **Figure 12**, the services layer acts as the bridge between learning devices, other TLA components, and federated data stores across the DoD enterprise. The federation requires standardized interfaces and governance to maintain identity management and integrity of authoritative data sources between installations.

The services and data communicate with the web-standard Representational State Transfer (REST) pattern based on the Open API and HTTP. Each service exposes stored data to an application so they can be transformed into meaningful information used by other TLA components. Each service includes control logic and user interfaces for a set of functions. The data contracts between data and service layers are shown based on the nature of the data exchanged.

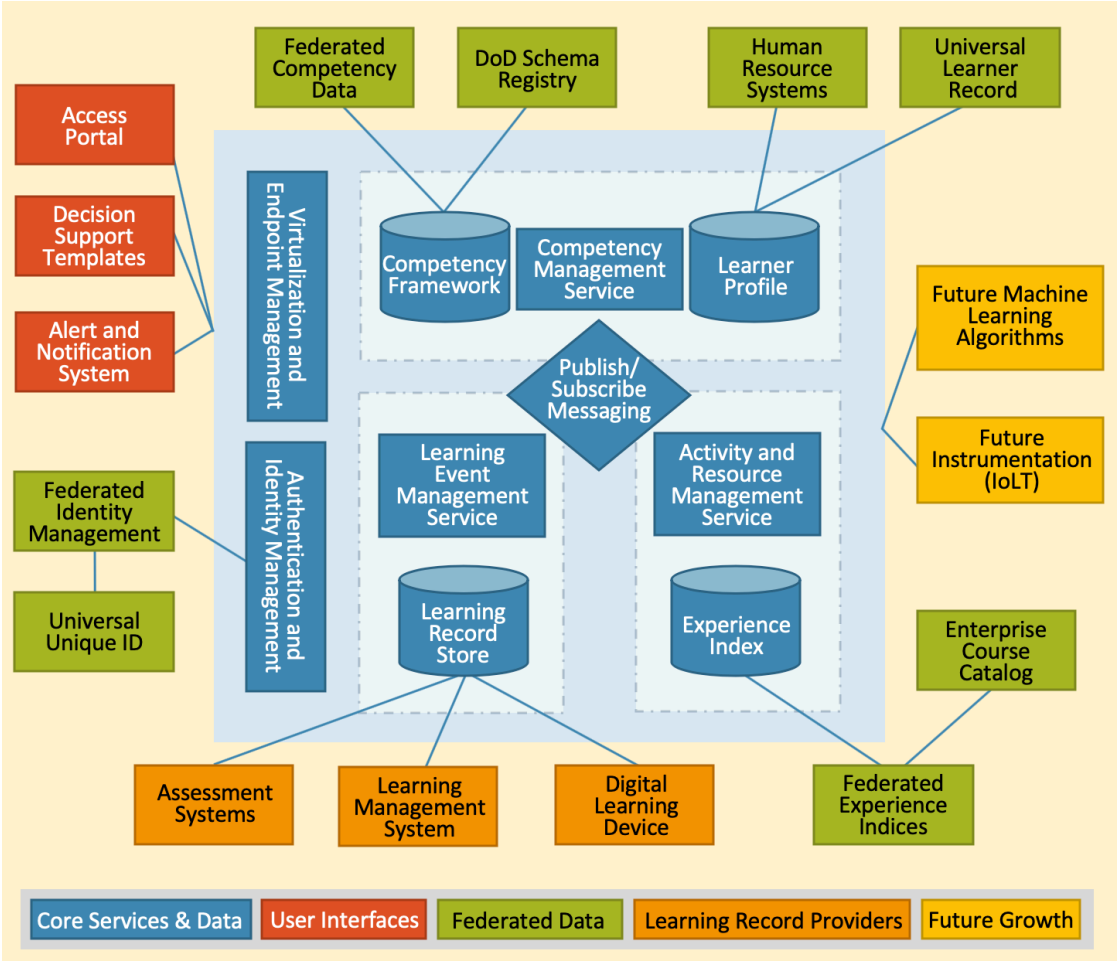

Figure 12. Core TLA Functions and Data. *Core services provide access to the core data structures and act on data provided from learning technologies to manage current learner state.*

4.3 Core TLA Software Components

The TLA Reference Implementation encapsulates core technology platforms, microservices, and data equities that may be federated, combined, linked, and merged as the ecosystem grows. Thus, the term core does not mean centralized. The core services and data identified in **Figure 12** include:

- ***Competency Management*** - This refers to a set of services that manage evidence of individual or team KSAOs. Within the TLA context, the xAPI *activity streams* stored in the LRS provide the evidence upon which competency assertions are made. Evidence is aligned with competency objects that are encapsulated into an RCD Competency Framework. These services also verify chains of evidence, handle the associated trust functions, generate authoritative assertions of capability (credentialing or de-credentialing), and makes estimations of competence based on granular or inferential data.
- ***Learning Event Management*** - This refers to a set of services concerned with scheduling learning activities and capturing data output from those activities. Scheduling learning activities may involve, for instance, a scheduling service, potentially aided by a recommender or content curation service. This component consumes xAPI statements from the Kafka stream and relays that information to the learner profile. It triggers relevant MOM events for the statement and updates paradata.

- ***Activity and Resource Management*** - These services are concerned with the registration and maintenance of accurate references to the location of learning resources and their metadata, as well as the verification of the resources required to access them. Key features include the ability to generate and manage metadata, taxonomies and ontologies, the alignment of content with competencies, paradata, semantic search services, and machine-actionable metadata.
- ***Learner Data – The Learner Profile*** - Each TLA enclave is expected to house local learner records, with user data and locally generated assertions of competence. User data includes learner state and personal attributes relevant for local learning and reporting. Local learner records may also link to external learner records (e.g., global preferences collected from the DoD ELRR) that support local actions, such as learning event adaptation and scheduling. The competency or credential evidence earned locally, stored initially in a local learner record, can be forwarded to these other systems, and conversely, federated competency or credential data from edge systems can be ingested into the local learner profiles.
- ***Competency Data – The Competency Framework*** - Competency Frameworks store the data describing competencies, their granular components (e.g., KSAOs and information like attitudes and motivation), and relationships among individual competencies (e.g., prerequisites and co-requisites). Also, these frameworks relate competency data with measures of performance and effectiveness, based on demonstration requirements for a given level of mastery in performance of a job or duty.
- ***Learning Experience Data – The LRS*** - LRSs are the server-side component of the xAPI specification. They archive xAPI-encoded performance data from learning activities or experiences, which provide evidence of competence to the Competency Management Services.

  The mandatory LRS is known as a Transactional LRS which stores "actionable information" regarding human performance data. At the simplest level, the Transactional LRS can be analogous to a gradebook. The Transactional LRS contrasts with "noisy" LRSs, which may optionally be part of a given activity provider (e.g., a simulator or LMS) and are used to capture finer-grained information (e.g., each page turn or button press) for local analysis. This separation moves raw performance adjudication away from the core systems.
- ***Data About Learning Activities*** – ***The Experience Index*** - An Experience Index stores local information about available Activity Providers and their available learning content. An Experience Index also stores information on the relationships among content, competencies, activity and content metadata, and evaluated paradata.

  Together, these data describe the learning experiences represented within the activity-content-competency triplet. The metadata are used for activity scheduling and evaluating the impact of a given learning experience on competence. Each TLA enclave may have its own Experience Index, and globally available elements listed in these Experience Indices can be federated into the ECC.

Figure 13 shows how the 2019 Reference Implementation collected xAPI data from activity providers conforming to the TLA MOM. xAPI messages flowed through the other core systems, especially the Competency Manager, which generated assertions of competence based on the xAPI evidence. Learning Activities streamed statements to a local LRS. Each activity also streamed xAPI statements conformant to the TLA MOM to a transactional LRS. The Transactional LRS fed the Competency Management System to process MOM statements and update the Authoritative LRS. All xAPI statements eventually ended up in one of the two LRSs.

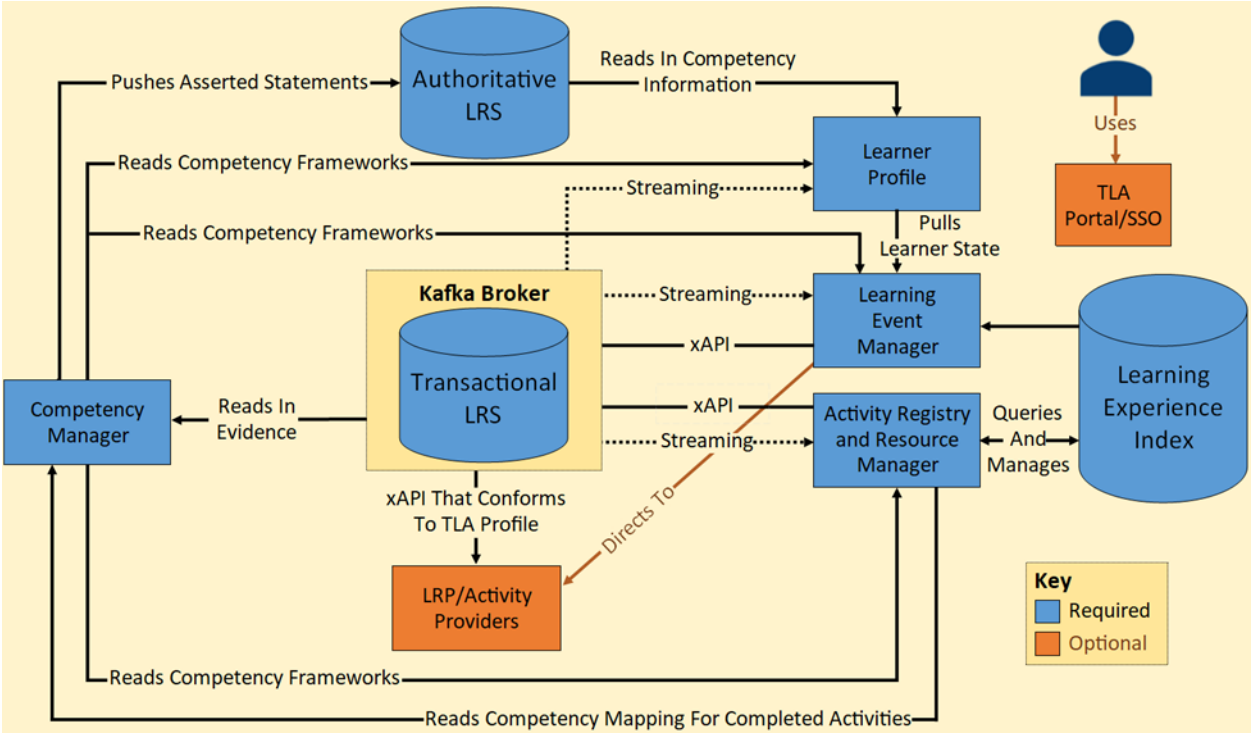

Figure 13. TLA Software Component Architecture. *This diagram illustrates how xAPI data are used across the TLA to support different purposes.*

4.4 Back-End Services

The TLA Reference Implementation evaluated different approaches to manage back-end services and to implement a DevOps Security pipeline to expedite integration and testing of all TLA components. The system of systems comprising the Reference Implementation were configured in accordance with the DoD CIO's draft policy for FICAM. This configuration will be used to support additional testing to ensure the protection of PII associated with learner data that is stored across the DoD enterprise as it is communicated to other TLA components

- ***Identity Management*** - Personnel's education and training data are currently locked in IT silos. Federated Identity Management allows organizations to securely and ethically verify learner data (e.g., evidentiary chain) across network enclaves and institutional boundaries through Authorities to Connect.
- ***Virtualization Management*** - Generally provided by cloud solution providers, virtualization includes the services required to dynamically process addresses for virtualized networks, server instances, and data clusters (e.g., VSphere and Hadoop). Virtualization is closely tied to device management and cybersecurity.

4.5 TLA Edge Systems

TLA edge systems include LMS solutions, learning applications/devices, activity providers, web portals, back-end services, and externally federated data sources. Applications and Devices are xAPI Learner Record Providers (LRPs). The LRP is responsible for the xAPI compliant formatting and population of a Learning Record. Edge systems may have "boundary" services that normalize reporting to the TLA MOM profile and generate their own xAPI statements.

These normalized Learning Records can then be shared with the Transactional LRS. As the learning ecosystem evolves over time, edge systems may expand to include new types of instrumentation (the "Internet of Learning Things") or additional data systems.

4.6 Documenting the Objective Architecture

Throughout the development of the TLA, the ADL Initiative's development team used DoDAF views (see **Appendix C**) to document a common understanding across the team. The DoDAF mitigates complexity for specific stakeholders through the creation of viewpoints that describe how requirements are implemented and their impacts or benefits to each stakeholder.

The DoDAF views are iterative and reflect the current thinking of the TLA technical team. These views will evolve as feedback is received, designs are modified, and technical specifications are updated. They are presented for discussion and debate across the education and training community, and feedback will be actively solicited from all DoD stakeholders.

The 2019 DoDAF views are informed by the ADL Initiative's experience in supporting active stakeholder projects across the Army, Air Force, and DHA. Additional insights were collected through participation in technical working groups and collaboration with industry partners and DoD stakeholder organizations. The TLA DoDAF includes the following types of views:

- The All Views (AV) provide the TLA executive summary and a dictionary of terms.
- The Capability Views (CV) describe the value propositions of TLA to the DoD Force Education and Training (FE&T) enterprise.
- The Operational Views (OV) describe stakeholder roles, responsibilities, equities, and governance.
- The Standards Views (StdV) show the specifications and standards from industry and government that define the TLA objective state.
- The Services Views (SvcV) describe the topology and functions of TLA "nodes," including core services, data stores, interfaces to learning devices, ancillary data, and back-end services.
- The Data and Information Views (DIV) describe the TLA ontologies for governance processes, logical data descriptions, and schema definitions for the elements within the TLA.
- The Project Views (PV) depict the programmatic aspects of the TLA research portfolio lines of effort.

Each DoDAF view presents a subset of elements from the same underlying model of the architecture. The elements at one level support the elements at the next level. They document the objective end-state and projected value proposition for the TLA effort.

4.7 Hardware Components

The 2019 TLA Reference Implementation uses five virtual machines hosted on AWS, which provide the back-end platform hosting, virtualization, and Domain Name Service resolution functions. Each machine was procured under contract to USALearning and maintained by the ADL Initiative.

The server instances communicate between themselves using either HTTP/S over TCP/IP or by producing and consuming messages to the centralized Kafka cluster, internally to the AWS campus. External clients accessing the portal, the hosted content, or the service redirects may be located outside the AWS campus and connect via REST, as shown in **Figure 14**.

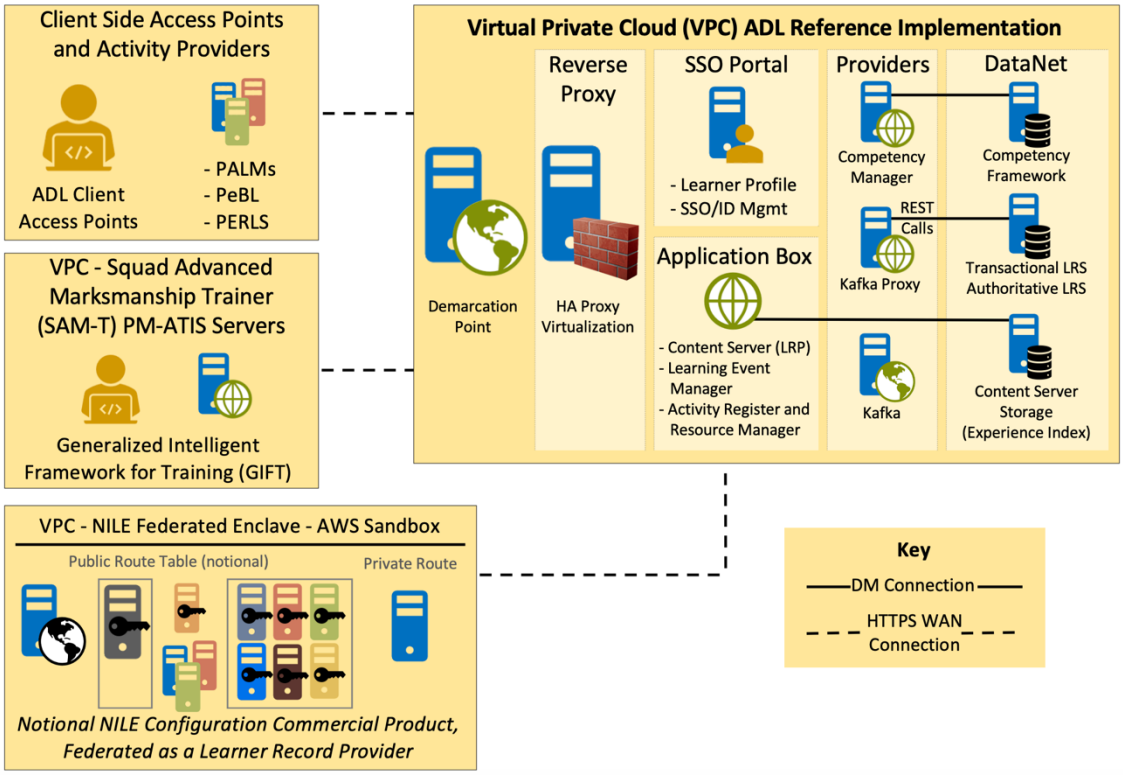

Figure 14. TLA Physical Architecture. *This figure outlines the high-level flow of information between the 2019 Reference Implementation components.*

The physical and virtual servers communicate over a Virtual Private Cloud (VPC) network. The demarcation point provides network address translation between external clients and the VPC Reference Implementation resources (e.g., LMS web clients located housed by the ADL Initiative). The network itself is also virtual, with resources allocated across multiple subnets by the AWS services stack. The virtualization management was handled by Amazon back-end services.

The TLA sandbox where the Reference Implementation is hosted is also home to different learning activity providers (e.g., Moodle LMS, Video Server, eBook player, and other mobile learning activities). Additionally, the NILE platform is hosted as an open source version of a commercial platform (NILE provides an individualized recommender service to track student competency, based on the common core model). NILE provided both a "federated LRS" and acted as a second "TLA enclave" for testing the Reference Implementation.

4.8 Interfaces

Communications between 2019 Reference Implementation components involved either HTTPS, WebSocket, or Kafka streams. Given the popularity and general simplicity of RESTful APIs in modern web services, HTTPS continues to facilitate most traffic within the 2019 Implementation with two exceptions: notification of new xAPI statements and learner profile updates. The primary protocol and data types are shown in **Table 2** with fields listed as JSON being small datatypes that do not belong to an established specification.

Table 2. TLA Reference Implementation Protocol and Interface Matrix. *Primary protocol and interface usage for each component within the 2019 Reference Implementation.*

Serves	Receives										
	XI	AI	AR	LP	IdM	CF	CM	LRS	LEM	Portal	LA
Experience (XI)			JSON						JSON		
Activity Index (AI)			LRMI								
Activity Registry (AR)		LRMI			OIDC			xAPI		LRMI	
Learner Profile (LP)									JSON	JSON	
Identity Manager (IdM)			OIDC	OIDC						OIDC	OIDC
Competency Framework (CF)	CASS			CASS			CASS				
Competency Manager (CM)				xAPI				xAPI			
Transactional LRS (LRS)				xAPI			xAPI		xAPI		
Learning Event Manager (LEM)								xAPI			
Portal					OIDC			xAPI			
Learning Activities (LA)								xAPI			
		Key:	HTTPS	Kafka							

These services and data structures were reviewed with ADL stakeholders to evaluate their applicability to all DoD components. The minimum materiel requirement for the 2019 Reference Implementation included the Transactional LRS, the Kafka messaging service, the Experience Index, the Identity Manager (i.e. Keycloak) and the create/read/update/delete (CRUD) service. Full integration of the Competency Management service is delayed until a CaSS hardening project is completed in 2020. This work is being done to support an *Interim Authority to Test* for evaluating CaSS and to measure return-on-investment for competency-based learning. This work will initially involve competencies developed to support Air Force Specialty Codes but is expected to expand to support additional experimentation with the Army and Navy. The TLA testbed currently includes a static message test harness that emulates CaSS messages. The Learning Event Manager is still under development.

4.9 TLA Sandbox

The 2019 TLA Reference Implementation was configured to support additional testing of stakeholder modernization efforts related to education and training. Other ADL Initiative projects are currently hosted within the TLA sandbox and will be integrated into the overall testing and evaluation capabilities available to ADL stakeholders. The DATASIM project is creating an authorable xAPI simulator that ingests xAPI Profiles and generates learner data at the scale and scope required to support DoD. The *Data Analytics and Visualization Environment* (DAVE) is providing an open source analytics toolkit with a library of data cards, analytics algorithms, and visualizations that can be tailored to provide different types of analytics depending on stakeholder needs.

5.0 TLA Testing and Evaluation

Architecture development is governed by heuristics[24]. The general heuristic for the TLA service topology was that the goals of the future learning ecosystem mirrored many “business to business” (B2B) web-based solutions that moved from single companies with their own software to integrated supply chains using interoperable business software. A common pattern in B2B processes is the Enterprise Service Bus, which separates the diverse set of data sources as “edge” systems, linked by centralized “core” data services that handle the translation and transport functions between them.

[24] *M.Maier & E. Rechtin. (2002). The Art of Systems Architecting. CRC Press, Washington D.C.*

The primary governing heuristic for the architectural refactoring effort was to decouple functions from data stores, decouple system performance from high uncertainty elements, decouple system performance from critical nodes, and decouple components from proprietary interfaces. The method for defining the details of the learning service and data topology was a data-driven analysis followed with a design structure matrix[25]. This matrix is a variation of N^2 chart analysis, based on the linear decoupling principle. A secondary heuristic governing the service topology was managing computational complexity to ensure that the proposed architecture would retain acceptable performance levels at the scope and scale required to support an enterprise DoD architecture.

This section describes the analytic methods used to develop each design hypothesis and organizes them within the experimental plan. Based on an analysis of a 2018 TLA Test and Demonstration, five high-level goals were adopted for deploying the 2019 Reference Implementation:

- *Implementation of communications at scale* – Demonstrating the use of Kafka streaming to implement a pub/sub messaging service instead of point-to-point, as pub/sub is more scalable and more resilient to morphology changes.
- *Decoupling of components* – Demonstrating the removal of dependencies on a central state manager by establishing a core/edge microservices based architecture. The 2018 Reference Implementation relied upon a recommender system that acted as a single state manager across all data components.
- *Federation of data* – Evaluating options to enable horizontal scalability and preserve local command equity in data. The TLA architecture is composed of different network enclaves, communicating in federations, within the ecosystem that complies with the specifications of the ecology.
- *Evaluation of candidate standards* – Integrating stakeholder programs of instruction into the TLA Reference Implementation and migrating to appropriate TLA standards to evaluate their ability to meet stakeholder needs.
- *Risk buy-down for DoD modernization* – Evaluating technical approaches, commercial solutions, and related policies in support of the DoD CMO Enterprise Digital Learning Modernization effort.

The data federation experiments included an independent variable with multiple combinations of data nodes and users, as well as multiple network configurations for the test federation. The dependent variables included the observations regarding throughput performance and feasibility. Results were fed back into the requirements, the underlying architecture, and the specifications documents that ultimately comprise the TLA. This work was also incorporated back into the Reference Implementation.

5.1 Enabling Communications at Scale

Message streaming services like Kafka are high quality-of-service, high throughput technologies used to support the development of scalable web-based solutions. They are similar to other pub/sub services where components react asynchronously when necessary but aren't required to react to every message or transmit full changes in each message according to a predefined schedule. However, data streams must be unaltered as they are communicated from the service or edge system creating the message to the TLA data lake. This demands consideration of the data topology for systems because any data transform, or modification of the message payload, must be transmitted as a new data stream.

[25] *Nam Suh. (2001). Axiomatic Design: Advances and Applications. Oxford University, England.*

Because any data transform gets transmitted as a new data stream, there is potential to create logic loops when communicating these data back to the originating system. This is especially hazardous in systems that use linked data, as these data must exist in complete form before and after the statements referencing them are generated.

The experiments for vetting this design relied on the Agile software development technique of continuous integration and test. The TLA technical team verified the core and edge design paradigm through peer-review design meetings held with various standards organizations, working groups, and industry associations. The general concept is that learning activities generate messages via xAPI statements streamed through a Kafka broker. Core TLA systems subscribe to this data stream and generate additional data streams that define and refine the context of learner performance within each activity. As additional data streams are generated by core components, they also stream through the Kafka broker and are categorized based on the TLA data strategy.

Key to maintaining the event-driven streaming topology was the establishment of the TLA MOM. This results in an event-driven design where events described in the TLA MOM propagate changes in a learner state. The data for verifying the MOM came from case studies built around stakeholder efforts. Each of the TLA's core systems was configured to listen to all xAPI statements to test the viability of a learner-centric data model. Five sets of 200 users were simulated for different learning activities. These were emulated by sending TLA MOM-compliant xAPI statements to the TLA's Transactional LRS in an order that follows the learning lifecycle. The Transactional LRS forwarded all statements to their respective Kafka data streams to trigger an update to the learner's state.

This highlights the complexity of the data topology within any streaming architecture. It also becomes a caution when using linked data, as the linkage must preserve the ordering of statements. Statements that link to another concept must do so after the first concept is instantiated with a statement or they will cause a memory fault, corruption, or crash. In this configuration, there are streams that "loop" around to create those references.

The Kafka system can manage millions of xAPI statements, which presents some unique challenges. The xAPI specification recognizes an LRP as a system that generates an xAPI statement, and a Learner Record Consumer (LRC) as a system that uses xAPI statements. In the Reference Implementation, TLA core components accomplish both these capabilities. If chained together in a serial fashion, data may be obfuscated, and the total throughput of the system may be diminished as the same messages are created and transmitted repeatedly. A reverse proxy was used to establish an LRS-agnostic mechanism for forwarding xAPI statements, resulting in a parallel bus of LRPs, including not only edge systems but also core systems generating MOM verbs, as shown in **Figure 15**.

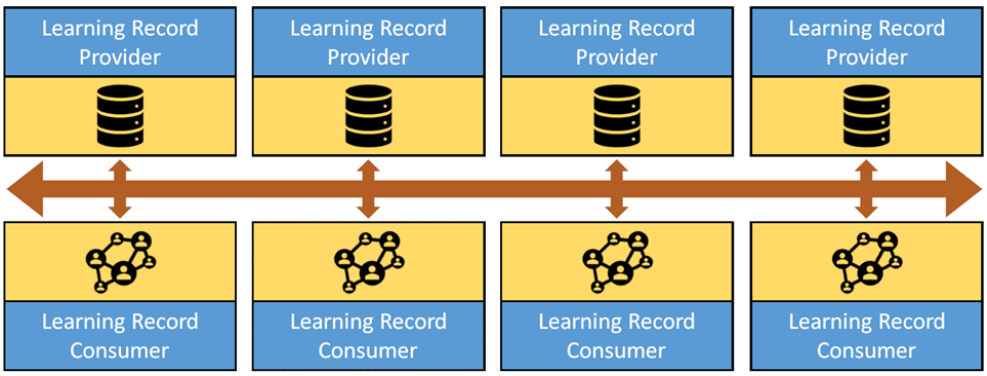

Figure 15. Parallel Bus Topology of Learning Record Providers and Learning Record Consumers.

5.2 Decoupling TLA Components

The event-driven streaming topology for services and interfaces was key to decoupling TLA functions and data. This allowed independence between each component internally and allows the alignment of TLA components to other stakeholder modernization efforts. Each service reacts to events, without having to know the sequence of events and services upstream or downstream. All events eventually end up as persistent records in the data lake.

The 2019 design had to enable a true ecosystem, where different learning theories and approaches can be used with a dynamic mix of learning activities. The use of the services approach discussed in the TLA DoDAF dictates the presence of learner-centric event messages that trigger services to perform data functions. Each of these functions could happen in isolation, independent of their order in the overall execution, meaning that the overall system is not "stateful." In the 2019 Reference Implementation this was accomplished by normalizing everything to the TLA MOM profile.

The TLA MOM provides guideposts for filtering data to support the presentation of information in the correct time horizon for the appropriate TLA control loop. The MOM maintains a focus on collecting actionable information from learning activities and forces the adjudication of performance to occur at the edge. The learner is the only component of a learning solution guaranteed to be present, so the MOM profile normalizes data about learner actions and the context of how that learning takes place.

The experimental design for validating the MOM includes the standup of multiple federations, demonstrating a range of potential configurations, internal components, and associated edge learning activities. These include legacy LMSs, adaptive learning systems, simulators, or other learning devices. If the MOM can be used with minimal changes to the specification and minimal changes to systems being integrated, it will provide evidence of architectural stability. The following questions were used to evaluate the stability of the MOM qualitatively:

1. Does the MOM accommodate all required *learner state* data?
2. Is the learner-centric model a viable technique?
3. Is streaming all xAPI data a viable data management technique?
4. Is using xAPI messages to create a ledger of *learner state* a scalable approach?
5. Will the xAPI data generate an auditable chain of evidence?
6. Do the xAPI data generated give insight into adapting the learning environment to the learner?
7. Does the MOM accommodate a range of learning activities and theories, including LMS, intelligent tutors, and self-regulated learning devices?
8. Does the MOM capture enough context information about the learning environment to allow analyses of learner preferences?

Part of this work includes contextualizing the evidentiary chain of xAPI verbs included within the MOM. Each xAPI statement represents trusted xAPI data that determines the learner's location within their career trajectory. All trusted statements include a link to the statements used as evidence, as well as to the nodes within the Competency Framework they reference. In the current reference implementation, the creation of conferrals and assertions is simplified for testing purposes to monitor response time and data loss. In an operational TLA system, the creation of authoritative statements would be logic driven, including layers of business logic encoded in the Competency Framework.

The decoupling experiments generated evidence to validate the TLA MOM event trace in place of a singular state manager by sharing data across network enclaves. As shown in **Table 3**, this also allowed the team to verify the TLA standards used to support the TLA data strategy and allowed benchmarking for performance. Performance was evaluated based on the number of users, number of records, and across different network topologies to emulate the scope and scale of data generated across the DoD. Federated Identity Management was tested using Open ID Connect and benchmark testing for search and retrieval times.

Table 3. Subordinate Technical Objectives for Establishing a Decoupled Architecture. *The results of these technical outcomes are captured in the DoD Architectural Framework (DoDAF) views and design artifacts.*

Element	Purpose	Comments
Define topology for components and interfaces	Decoupling of data and services, in order to better provide an adoption and migration strategy.	Migration defined in the TLA Capability Maturity Model (CV-3) and decoupling of core and edge services and data defined in SV-1.
Minimize stateful nature of system	Part of enabling a true "ecosystem" which increases resiliency.	Enabled through the TLA MOM and the DoDAF which allows for event-driven services.
Enhance composability of ecosystems	Accommodate ad hoc mix of learning technologies without re-engineering efforts for every change.	Defined the TLA enclave as a function of interfaces and governance structures (OV-2).
Enhance performance at scale	Verify use cases to ensure that solutions based on proposed standards and best practices will scale.	Conducted experiments into federated identity and federated data (LRS, Experience Index, etc.).

5.3 Federation of Data

The 2019 Reference Implementation provided an operational context for the development of key enterprise level technologies required to field the future learning ecosystem. This line of research was informed through coordination with external stakeholders, OUSD(I), and the Army Simulation and Training Technology Center (STTC), specifically focusing on issues required to:

- Field an accredited LRS to move toward Capability Maturity Model (CMM) Level 1;
- Establish an ECC;
- Establish Federated Identity Management to support enterprise analytics with the LRS data; and
- Enable the ELRR.

This experiment hypothesized that the ECC might be deployable as a service searching from multiple TLA compliant enclaves' Experience Indices, rather than making a copy and managing from a central repository. Federating a Learning Experience Index to a central service allows learners to discover new content and experiences as updates are published. For the TLA to resolve learning experiences between enclaves, administrators must register the local Learning Experience Index with a global Experience Index. For this experiment, it was assumed that learning experiences are already unique within the TLA federation, as data equity and governance processes will manage the transition to a common catalog and maintain configuration over its life.

As shown in **Figure 16**, the 2019 research tested the scalability performance of a federated Experience Index. A challenge arose when multiple TLA enclaves owned similar courses that map to a similar competency. These similarities or differences needed to be aligned during the learning activity registration process. This is a process where metadata about a learning activity was uploaded to the Experience Index so that all TLA components were aware of its existence. This research employed an augmented version of LRMI as a transmittal format for exchanging data that federated to the ECC.

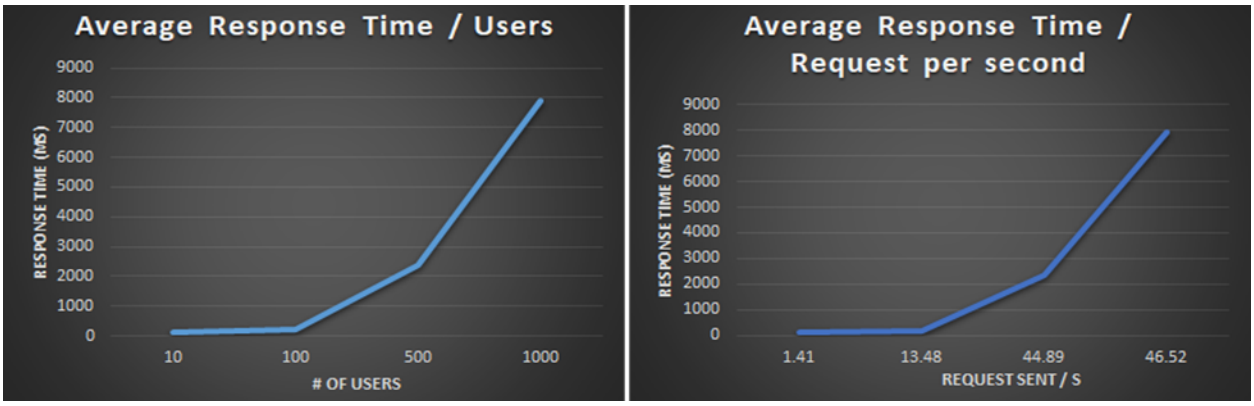

Figure 16. Federated Experience Indices Throughput Performance. *Benchmark tests of 50 sites with between 5-400 records for a total of 10,000 courses, representative of the data size and loading for a distributed ECC.*

A containerized activity registry and resource management service with its own Experience Index was put onto an AWS server instance. A local hosted Experience Index was also configured. A script was written to load example metadata to both learning Experience Indices. The main function of the local Experience Index was to lookup activities and content within TLA enclaves. It was load tested over a Wide Area Network with 10, 100, 500, and 1000 simultaneous users all making queries to the federation service for 25 minutes to simulate realistic loads for this service at any given time.

The LRMI metadata schema allows anyone who publishes or curates educational content to provide education-specific metadata about their resources with confidence that major search engines would recognize it. As part of a linked-data strategy, metadata and Competency Framework information must trace back to a single semantic authority through a schema server.

5.4 Federated Identity Management

In the management of federated learner identities, one challenge was that not all systems store user information the same way. Learners may also use different local account names for different purposes. This is especially relevant to the Intelligence Community, where individuals maintain different personas on different networks. There is no guarantee these accounts, or systems know about each other, so a federated approach to Identity Management is required to resolve this issue.

For a TLA compliant federation of multiple enclaves and/or devices to resolve multiple accounts, the learner must register an account with the TLA. To do this, the learner logs into the TLA and selects an external ID provider. The learner then logs into the external provider's account and registers that account as an alias to their master account within the TLA.

This system minimized human interaction, and no PII was transmitted throughout these transactions. However, the inclusion of PII is still a possibility as an LRP could choose to use PII as its actor name. The TLA federation negotiation rules and device registry will address this by requiring non-human identifiable actor IDs and synchronizing between device and core systems.

To test the feasibility and scalability of this approach, a containerized learner ID management service as described previously was put onto an AWS server instance with an 8GB hard drive. A script was written to register 100, 1K, 10K, 20K, and 100K users, each with three different aliases. After an initial slow response rate, the database of learner aliases was indexed and the map retrieval was nearly consistent, as shown in **Figure 17**.

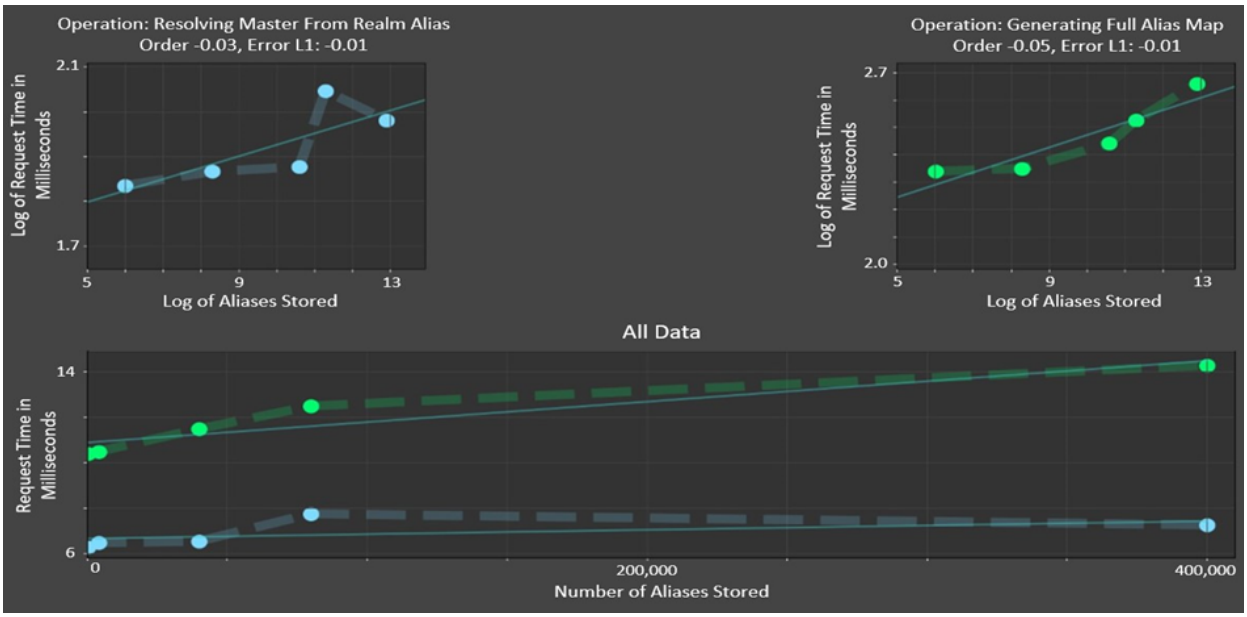

Figure 17. Indexed Results. *The Reference Implementation uses a containerized learner ID management service for test and evaluation. Proper indexing substantially improved performance.*

The evaluation of candidate standards and risk buy-down goals for testing and evaluating the TLA are outlined in previous sections. Section 3 *Research Into Commercial Standards* outlines the work performed to evaluate candidate standards while this section reviews the architectural considerations for the DoD CMO's Enterprise Digital Learning Modernization initiative and other DoD modernization efforts. The results of these experiments were used to inform functional requirements and next steps in the development of the ECC and ELRR programs.

6.0 CONCLUSION AND NEXT STEPS

The principle technical objectives of the 2019 effort included evaluating candidate standards, replacing the point-to-point communications, decoupling system components, and exploring federated data strategies. These objectives were successfully met during the 2019 work on the TLA.

6.1 Research Results and Successes

The 2019 Reference Implementation migrated to a core/edge microservices based system using Kafka streams as a communications method. The switch to Kafka required iteration with the TLA MOM to identify the correct activity streams and ensure an event-driven system with the correct flow of messages between components. The streaming capability allowed the team to capture performance benchmarks using different technical approaches for key TLA components. The design effort yielded several tangible results for validating the required TLA standards, as well as a wealth of best practices and lessons learned.

As the granularity of the TLA's scope increased, naming conventions became a hurdle. TLA component name choices and the subsequent responsibilities of services sharing those terms caused duress throughout the design and development process. *Activities*, *content*, *resources*, and *experiences* are tightly coupled concepts with distinct places in the 2019 Reference Implementation and the TLA overall, but these were synonymous for 2018. As such, services carried over from 2018 became tedious to maintain and adapt to 2019 updates due to their now-contradictory naming conventions.

A basic feature of any system is its cybersecurity posture, including privacy, non-repudiation, integrity, security, and reliability. Technical personnel must coordinate closely with these policy owners for key capabilities including, *Memoranda of Agreement* and *Authorities to Connect* for federated systems, authorities to operate in multi-level security cross-domain environments, network and server virtualization, dynamic endpoint management, and Global Information Grid integration (see the DoDI 8500 series).

Similarly, the federated data structures will require broad coordination for networking and file management services (e.g., federated IDs), maintaining data integrity and searchability (e.g., the ECC), and asynchronous data management (e.g., for deployed units or individuals). Finally, the identity management requirements within the DoD will necessitate ongoing coordination for virtualized identity management, encryption, tokens, digital signatures, universally unique identifiers (UUIDs), and PII protection, with the latter including clean-room server policies.

The overarching goal of the TLA research portfolio is the selection or generation of the standards, specifications and policies necessary to instantiate the future learning ecosystem. This includes the interconnected learning devices, computational assets and data equities, as well as the enterprise level approach for learner records, an ECC, federated identity management, and enterprise analytics.

6.2 Policy Guidance

The DoD Instruction 1322.26[26] establishes policy, prescribes procedures, and establishes information requirements for developing and deploying distributed-learning content for DoD military and civilian personnel. Fungible references address emerging learning technology concepts and challenges by providing additional policy guidance or implementation instructions related to education and training.

While the ADL Initiative is the steward of the DoDI 1322.26, the fungible reference updates are matured, validated, and approved by the Defense ADL Advisory Council (DADLAC), composed of military and civilian leaders in the distributed learning field. As the TLA matures, incremental updates to the fungible references will include guidance to help DoD stakeholders confirm TLA standards are implemented to ensure the interoperability of learner data.

The future learning ecosystem described in this report requires the selection or creation of standards and specifications across two categories: *data metamodels* to ensure semantic interoperability (presentation layer), and *data interface models* to ensure connectivity (transport/application layer). Interface standards are built from web commerce protocols. Interservice communication uses REST protocols. Event traces among components are normalized as activity streams using the MOM xAPI profile. The launch of remote devices uses Learning Tools Interoperability[27] (LTI) protocols. Remote ID authentication uses Open ID Connect[28] (OICD) protocols.

The data metamodels describe the data within the four pillars associated with the TLA data strategy**:**

- **IEEE P9274.1 xAPI 2.0** – Learning activity tracking uses the xAPI and JSON standards to capture learning activity streams. The cmi5 specification and the TLA MOM are also contained within this data pillar since they contain an xAPI profile. xAPI 2.0 is targeted for approval in 2020.

[26] *DoD Instruction on Distributed Learning - https://www.adlnet.gov/policy-dodi*
[27] *IMS Global LTI - https://www.imsglobal.org/activity/learning-tools-interoperability*
[28] *OpenID Connect - https://auth0.com/docs/protocols/oidc*

- **IEEE 1484.12.1 LOM 2.0** – Descriptions of learning activities and their associated content are stored in the TLA's Experience Index and use a modified version of the LRMI standard.
- **IEEE 1484.20.1** RCD - The Competency Framework includes the definition of a competency, the relationship to other competencies, and the alignment of evidence to help measure proficiency of the competency, are included in the RCD standard. This standard is expected for approval in 2020.
- **IEEE 1484.2 ILR** or **IMS Global CLR** - The Learner Profile will include credential sharing with OpenBadge 3.0 and the CTDL.

Implementation guidance and business rules for how to use these interoperability standards is established by IEEE 1484.1 CM4LTS, a broad standard that is equivalent to the overarching TLA specification. Device federation will likely be a NIST standard as it is driven by device management cybersecurity concerns. Data access and device registry for anything located outside of the enclave firewall must be consistent with cybersecurity policy, to maintain security, integrity, system availability, and non-repudiation of enterprise data.

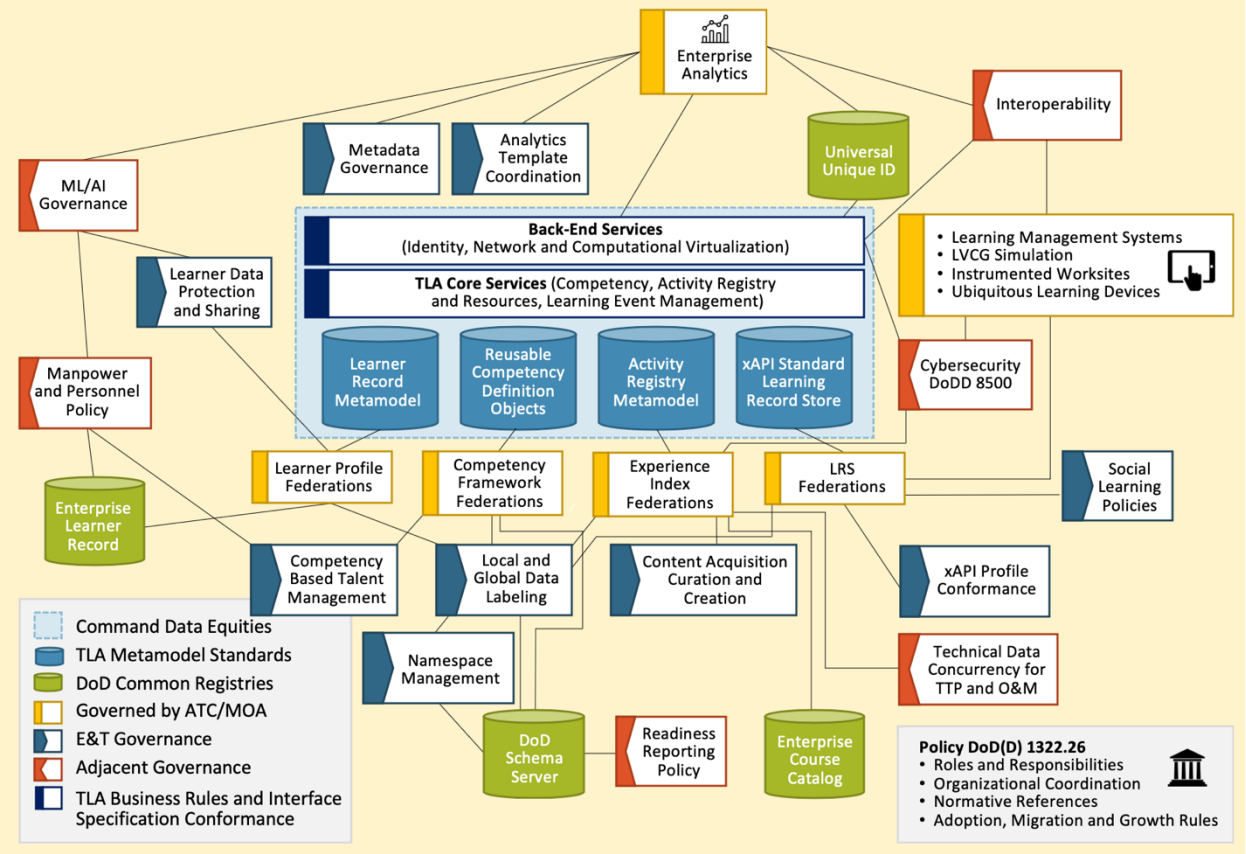

Figure 18. The TLA Ecology. *The TLA defines metamodels, interface specifications, and business rules that define requirements for making existing learning technologies interoperable at the enterprise level. Organizational governance procedures allow for progressive adoption, migration, and growth.*

Figure 18 depicts the relationship between DoD data equities, governance, policies, and TLA specifications. Learning system features need to be separated into services associated with the data structures they support, and they must be deployed within and across TLA compliant enclaves. Device and data connections are governed by DoD cybersecurity policies. The specific component design may differ, as long as the business rules, data metamodels, and exchange protocols are consistent.

6.3 Migrating DoD Systems to the TLA

The migration of existing DoD education and training systems to the TLA will be phased over time and can be modeled as a CMM, shown in **Figure 19**. Sites migrating toward TLA capability maturity start at *Level 1* by migrating from a SCORM managed, LMS-centric solution to an xAPI conformant solution where learner performance is stored within a centralized LRS. The LRS provides analytics beyond the "counting and completion" statistics typically available within an LMS.

Level 2 supports the aggregation and analysis of learning data at the enterprise level. It requires enterprise level services to track global progress and the adoption of governance procedures to standardize learner identity, data labeling, and data reporting to enable enterprise analytics. *Level 3* adoption further decouples learning solution functionality within the enterprise. Each function previously performed by a single LMS is now a decoupled service or set of services. Federation is driven by cybersecurity policies and is enabled by enterprise-level services developed in *Level 2*.

CMM *Levels 4* and *5* focus on automation and full integration into the human capital supply chain. These levels represent the objective state of policy, technical specifications, and standards that will enable the future learning ecosystem characterized by interconnected devices and interoperable data. The standards that comprise the TLA technical specification act as a "distributed ledger" for learner data that is globally discoverable and usable across the DoD enterprise. This capability enables efficiencies for DoD stakeholders across the entire lifecycle of education and training including the identification of need, discovery of resources, and evaluation of learning opportunities to enable capable manpower.

6.4 Governance Considerations

Governance for a system as complex as the TLA will require steps at multiple levels within the overall system of systems. Global governance occurs at the DoD enterprise level and requires the maintenance of global metamodels for describing learners and competencies. A minimum set of metadata attributes for the *ECC and ELRR* initiative is also needed. Coordination, continual review, and regular updates are necessary for federated data and systems. Governance procedures must continuously address data structure compatibility, message interoperability, coordination between enclaves, and data mappings.

Global governance will include new organizational processes and DoD-wide policies that facilitate the collection, analysis, and use of data across the DoD enterprise. Different DoD functional components will be responsible for governing different aspects of cybersecurity or interoperability applicable to their own command's data equities. Local and regional governance will define ownership and labeling requirements. Agencies and military command organizations, for example, will have attributes they must gather and evaluate that are unique to their organizations.

Other governance considerations include the need to federate the development and maintenance of Competency Frameworks across DoD functional components. Competency Frameworks will be comprised of numerous competency owners that maintain and update specific parts of an overall framework. This is already prevalent across the DoD and is exhibited by the Air Force Competency Directorate and the U.S. Army Training and Doctrine Command.

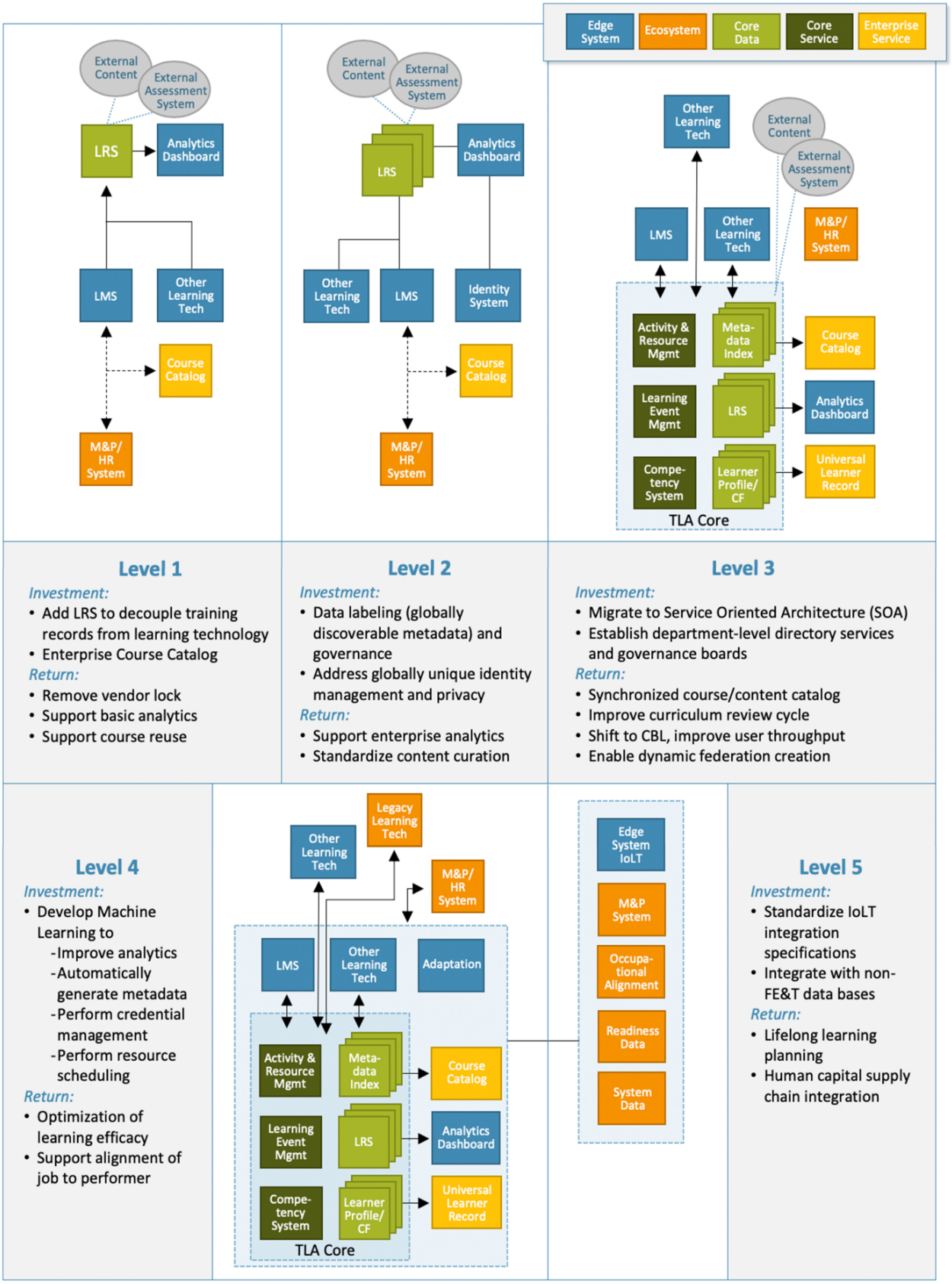

Figure 19. TLA Capability Maturity Model. *The CMM allows for gradual migration of legacy systems to a microservice-based infrastructure of core services that federate data across DoD components.*

6.5 Future Research and Next Steps

The 2019 TLA Reference Implementation established a solid foundation for more robust experimentation in 2020. By migrating to a more modern data streaming approach, the Reference Implementation can be used by stakeholder organizations to test and evaluate the functionality and interoperability of their TLA-compliant systems. This capability will allow 2020 collaborations with the Defense Acquisition University, the Army's STEEL and Squad Performance Model projects, AFLSE, DHA, and others.

As the DoD migrates from legacy "data silos" to more integrated systems, it must start with the organization and technical structures from the legacy systems. Education and training records of DoD personnel are distributed across a variety of systems and locked into countless disparate data formats. Transport, control, management, governance, and ownership of such data are not easily accomplished—particularly across technological and organizational boundaries. The ADL Initiative's 2020 TLA research agenda adds new milestones to several 2019 projects, advancing toward the transition of foundational TLA capabilities. The 2020 research goals include:

1. **Federated Identity and Access Management.** Data must be accurately aggregated across education, training, and operational learning experiences to create an accurate portrait of personnel and their learning states. For education and training systems there is no cross-domain solution for connecting across enclaves. The DoD requires a way to securely integrate learning data across these boundaries while maintaining an individual's unique *identity* across systems and meeting cybersecurity and PII requirements. Identity management includes not only UUIDs for personnel but also the internal references for managing learning resources. This work will investigate best practices for anonymizing actor fields in an xAPI statement so that xAPI can be transmitted in accordance with DoD policy.
2. **Enterprise Learner Record Repository.** The ELRR must combine data from locally maintained learner profiles with globally coordinated learner data. These data must be (safely and ethically) portable and auditable across time, installation, and institutional boundaries. Specifically, the ELRR represents the entire career trajectory for each learner within the DoD enterprise. This line of effort requires participation in the multiple industry and standards initiatives working to harmonize learner record standards. It also requires the development of an Initial Operational Capability that can be used to support an Advanced Concepts Technology Demonstration (ACTD) that shows how these capabilities can create efficiencies across the DoD and begins to measure the potential return on investment.
3. **Enterprise Course Catalog.** To build a learning ecosystem, instructional activities across the system-of-systems must be discoverable and accessible. This is achieved with the ECC, a service that indexes the available learning resources. The ECC is built from linked *Experience Indices*, with local listings of learning activities, their available content and resources, and their alignment to a Competency Framework. The 2020 work requires participation in creating the LOM 2.0 standard and in the development of an Initial Operational Capability that can be used to support an ACTD that shows how local course catalog listings can populate local experience indices that federate to the global DoD ECC. The ACTD approach intends to provide a mechanism to test and evaluate the ECC prototype while measuring the impact, benefits, and return on investment. Automated tools for creating metadata from local course listings will also be evaluated.

4. **cmi5 Viewer and Conformance Test.** The cmi5 specification is critical for recapitalizing SCORM content. The cmi5 specification defines how LMS solutions launch content using xAPI as the content-to-LMS communication layer. Many of the underlying standards used in SCORM do not sufficiently support the myriad technologies used in modern learning environments. The cmi5 specification was created to replicate the SCORM content package to replace SCORM in the delivery of online courses and traditional computer-based training. Research will focus on producing a freely available, open source cmi5 content player and conformance test. This work is expected to be awarded in 2020 but will not be completed until 2021.

5. **Accredited LRS.** This work will audit ongoing or previous LRS accreditation efforts being performed by other DoD components (e.g., Navy, Army). As different DoD components work to secure the proper National Intelligence and Security Agency (NIST) and Defense Information Systems Agency (DISA) accreditations required to deploy different xAPI conformant LRS solutions across the DoD, USALearning will establish a repeatable process for integrating LRS solutions that conform to the Federal Information Security Management Act (FISMA) and Risk Management Framework (RMF) best practices, supports reciprocity between DoD components, and documents expectations for following common process, security controls, testing activities, and outcomes. This work supports the adoption of xAPI across the DoD services by creating policies, type accreditations, and a *Security Technical Implementation Guide* to support LRS accreditation across DoD networks.

6. **Culture Change for Competency-Based Learning.** The TLA vision relies upon interoperable data across functional and organizational boundaries. This necessitates a paradigm shift and an investment in competency-based talent management. Competency-based learning emphasizes the demonstration of personnel capabilities rather than the measurement of instructional characteristics, better linking human performance to mission effectiveness. Key to the acceptance of this approach will be establishing common rules and workflows to support the development of frameworks and the sharing of data.

TOTAL LEARNING ARCHITECTURE

2019 Report - Appendix A - TLA Functional Requirements Document

Prepared by
The ADL Initiative

Table of Contents

1.0 SCOPE

1.1 Identification

This document covers the objective end-state for Department of Defense (DoD) learning organizations migrating to Total Learning Architecture (TLA) compliant data and microservices. This is issued as the 0.9 draft version of the document. Comments and feedback on all TLA artifacts are expected and updates will be made to each artifact as the TLA matures. Requirements will continue to evolve; therefore, these documents are iterative in nature. As the tools, technologies, and methodologies used in the future learning ecosystem change, TLA artifacts will be updated accordingly.

1.2 System Overview

The TLA defines a microservices based architecture for managing the data associated with learners, curricula, learning activities and content, competency tracking, and credential issuing. TLA policies include existing and emerging standards and specifications that enable interoperability between learning sites. They maintain education and training data to enable lifelong learning, and define business rules and governance strategies for managing the lifelong-learning data infrastructure.

1.3 Document Overview

The TLA Functional Requirements Document outlines the critical modes and states, capabilities and interfaces required for establishing a future learning ecosystem for the DoD. The TLA policy framework relies on existing and emerging specifications and standards to develop the data and services needed for the ledgering of performance data for "total learning" activities across the DoD human capital supply chain.

The human capital supply chain is a complex system with inherent challenges to accommodating TLA operability. The specific composition and arrangement of technologies at any location will differ and change over time. Capabilities come not from individual installations or databases, but the connections between installations and the enterprise-level data sharing, collection, analysis, and dissemination that support the planning and controlling of human capital accession, detailing, and especially, education and training.

This document introduces the overall requirements for elements of a TLA compliant installation. It provides detailed requirements for each of the service segments that enable the ledgering capabilities. The TLA architecture is derived from the four pillars of the integrated data strategy:

- A **Learner Profile** to record learner credential history, aptitudes, local and global preferences, and local state -- which can be shared at the enterprise level (leveraging federated identity to protect privacy) to provide a complete portrait of human performance.
- A **Competency Framework** to define the elements, relationships, standards, contexts, and levels of mastery required to perform jobs and to certify the credentials used to define job placement.
- A **Learning Record Store** to store the records of learning experiences that improve performance and operational data indicating effective learning transfer and impact on mission effectiveness.
- An **Experience Index** to list and describe the activities that provide a context for a learning or assessment opportunity, and the content that is provided within that context. Activity-Content tuples are linked with competencies that they trigger into "experiences" which can be scheduled or launched for learners.

2.0 REFERENCED DOCUMENTS

- IEEE P9274.3.1 TLA Master Object Model Profile: included as Appendix B
- IEEE P9274 Experience Application Program Interface (xAPI): https://site.ieee.org/sagroups-9274-1-1/
- Learning Resource Metadata Initiative (LRMI): https://www.dublincore.org/specifications/lrmi/
- IEEE P1482.20.2 Reusable Competency Definition Objects: https://standards.ieee.org/project/1484_20_1.html
- cmi5 specification: http://aicc.github.io/CMI-5_Spec_Current/
- OpenBadge: https://openbadges.org/
- Credential Transparency Definition Language: https://credreg.net/ctdl/handbook
- Enterprise Learner Record Repository Metamodel: TBD
- Learning Tools Interoperability (LTI): https://www.imsglobal.org/activity/learning-tools-interoperability
- Open Identification (OpenID): https://openid.net/

3.0 REQUIREMENTS

The requirements defined in this document specify the functions and interfaces that would be deployed at a given location to enable the ledgering and interoperability requirements that create the TLA capabilities. Migration from the legacy systems will occur in stages, as a key component of the overall TLA strategy is legacy recapitalization of a learning organization's existing IT infrastructure. This means not all requirements need to be deployed in the initial rollout. The model showing TLA migration priorities is included in Section 4 of the main TLA report.

3.1 Required Modes and States

TLA compliant systems are intended to operate continuously. Servers deploying data and components should be selected for robust scalability and availability. Operations on TLA components happen in two main modes – maintenance mode and training mode.

- **Maintenance mode**. The TLA compliant services and data provide a ledger of information about learners, the things these learners learn (competencies) and the way this learning occurs or is evaluated (activities and content). There is both a real-time and a static component to the data that provide this ledgering capability. Maintenance mode is concerned with the update of the static components that manage the introduction of new users, or movement of users between locations, the assignment and metadata attribution of new activities and content, and the import, export or modification of competency elements.

- **Training mode**. The TLA compliant services working in conjunction to search static data and historic performance data, to plan and control new learning opportunities, collect performance data about them, and update learner state based on those data define the training mode. Training mode is continuously in operation. All learner data are not collected in real time but do have a quality of service associated with time of receipt and processing.

Maintenance mode is essentially stateless at the system level, although individual databases have login, data entry, commit, and verification states depending on the technology used. The training mode similarly has component states based on the products being used. The entire federation is also viewed as stateless. A core 2019 research objective was the removal of the singleton state manager used to support the 2018 TLA Reference Implementation.

This decoupling was accomplished by modeling the learner state. Since the learner is the only component of any particular TLA instance that can be guaranteed present, we can standardize the behavior of event-driven services by documenting what occurs as the learner interfaces with each component in the system, independent of where that interaction occurs. We can then contextualize it within the services required for that learner state by generating xAPI statements to document each event. These statements are detailed in the Master Object Model (MOM) through the verb sequence used to model the learner state. Each MOM verb is generated as an activity stream signaling services to perform functions.

Learning may unfold in a deliberate or informal fashion. In deliberate learning, the learner is explicitly organizing learning goals, building lists of activities into tasks to achieve those goals, and scheduling the performance of tasks through available resources. This represents the learner's configuration of their learning environment. This configuration may happen exclusively in "edge devices" or in the interplay between edge devices and the core services. Activities are then launched by the TLA services and learning results are captured.

Alternatively, learning may occur ad hoc, where an instrumented activity is experienced outside the context of a planned learning activity. In this case, the activity's impact is still captured and contextualized. In either case, the evidence of the learning experience is evaluated against the records of competency and objective credentials, to include trust in the veracity of evidence collected. The learner's competency and credential states are then "located" or updated in the globally discoverable records. This learner state cycle is depicted in **Figure 1**.

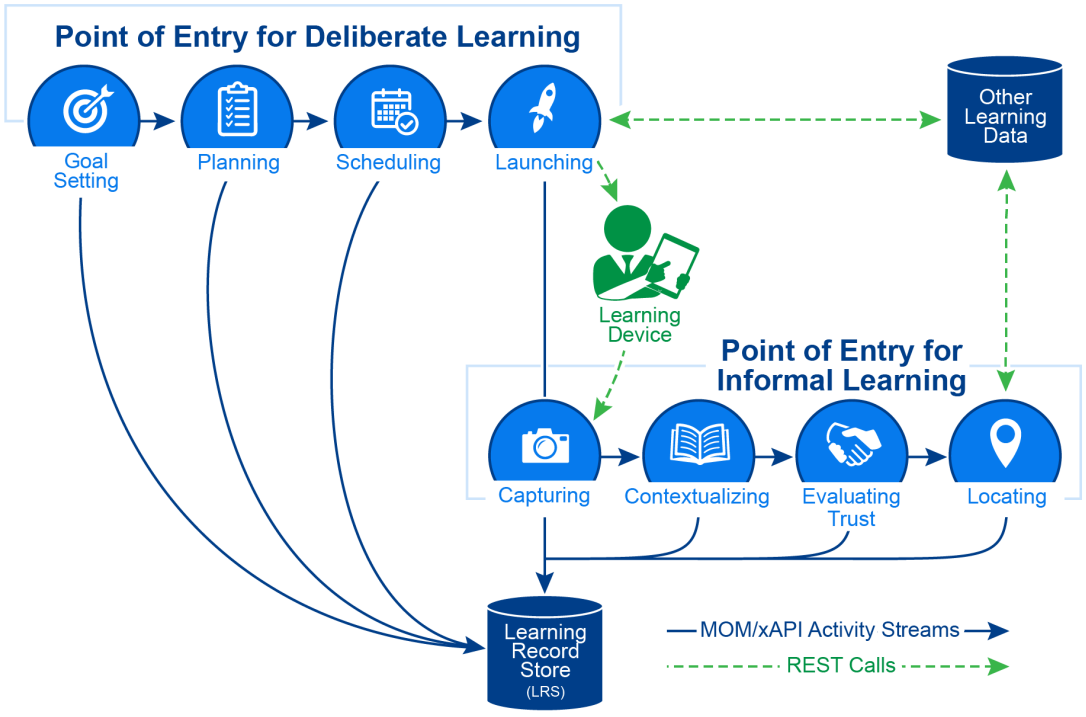

Figure 1. Learner State as a Function of the Learning Lifecycle. *Allowable learner state transitions that amplify this model are defined in the Master Object Model (MOM). The MOM captures as events the interactions between the learner and either edge or core devices and interfaces to trigger TLA services to act on learner data.*

3.2 System Capabilities

TLA compliant systems have a defined set of core services and core data stores. Each of these has associated requirements, but these requirements may be satisfied, or allocated to different components, if the functions and interfaces are satisfied. The 2019 TLA Reference Implementation uses a microservices architecture with streaming communication services that replaces the singleton-based point-to-point communications used in the 2018 Reference Implementation.

3.2.1 Learning Event Management

TLA compliant systems use different approaches for the goal setting, planning, scheduling, launching and capture of learning events. Learning events place a learner in an experience, composed of an activity, optionally viewing some content within the context of that activity, to achieve a learning goal or set of goals. The performance of the activity generates performance records, which are contextualized within the overall learning environment according to the MOM profile.

Learning Event Management is most closely associated with the Learning Record Store (LRS) component of the core data, which is the server-side component of the xAPI specification. Learning Event Management requirements are presented in **Table 1.** Learning Event Management includes managing the learning path, setting goals, and validating resources available to conduct learning.

Table 1. Learning Event Management Requirements. *The Learning Event Manager is a set of services associated with goal selection, learning planning, scheduling of events and capture and contextualization of those events. The Learning Event Manager is associated with the Learning Record Store.*

Header	Requirement	Priority	Comments
Learning Record Store			
Learning Record Store	TLA compliant systems shall maintain a persistent storage of learning activity records (i.e. LRS)	2019	
Learning Record Store	TLA compliant systems shall capture all xAPI statements generated from learning record providers	2019	
Learning Record Store	TLA compliant systems shall ensure that xAPI statements are complete and well formed	2019	
Learning Record Store	TLA compliant systems shall provide a mechanism for administrators to purge old xAPI records		
Learning Record Store	TLA compliant systems shall maintain a record of purges to show that data has been altered		
Learning Record Store	TLA compliant systems shall provide a mechanism to ensure the integrity of xAPI data stored	2019	
Learning Record Store	TLA compliant systems shall allow storage of xAPI statements for the current user UUID stored as actor	2019	
Learning Record Store	TLA compliant systems shall allow use of filters on retrieving xAPI data by Actor (user, user interest group), date/time, activity type (object), verb, user specified extension field values	2019	
Learning Record Store	TLA compliant systems LRS shall support federated data storage, search and retrieval between the noisy, transactional and Authoritative LRS	2019	
Learning Record Store	The Authoritative LRS shall be able to federate data from transactional LRS located in multiple enclaves	2019	
Learning Record Store	TLA compliant systems transactional LRS shall be sized to support a 10-year digital data retention store of all evidence	ELRR	

Header	Requirement	Priority	Comments
Learning Record Store	TLA compliant systems shall include a transactional LRS as part of core data that stores only data generated according to the TLA MOM profile (IEEE P9274.3.1)	2019	
Learning Record Store	TLA compliant systems shall have an Authoritative LRS that stores digitally signed xAPI statements of “conferral”, “qualification” and “certification” for competency assertions.	ELRR	
Learning Record Store	TLA compliant systems shall preserve the traceability between evidence, assertions, qualification/certification/conferrals and globally discoverable digital badges for credentials	ELRR	
Learning Record Store	TLA compliant systems shall use "noisy" LRS to segregate data for device specific profiles	2019	
Learning Record Store	Noisy LRS profiles shall comply with IEEE P9274.2.1	2019	
Learning Record Store	TLA compliant systems shall identify a "boundary" learning record provider that conforms to the TLA MOM for all edge devices generating learning evidence (operational data sources or learning activities)	2019	
Learning Record Store	TLA compliant systems shall identify an Authoritative LRS for storage of conferred user credentials	ELRR	
Learning Record Store	The LRS shall comply with the server-side component of the xAPI specification (IEEE P9274)	2019	
Manage Learning Path Logic			
Manage Learning Path Logic	Learning Event Management service shall manage progress through sub-goals until selected goal is achieved	2019	
Manage Learning Path Logic	Learning Event Management service shall be able to schedule launch of single experiences from the learning experience catalog	2019	
Manage Learning Path Logic	Learning Event Management service shall be able to launch a course from a catalog	2019	
Manage Learning Path Logic	Learning Event Management service shall be able to launch from a user or observer/instructor/controller/ supervisor (OICS) curated content list	2019	
Manage Learning Path Logic	Learning Event Management service shall support courses of a single content resource, or multiple resources	2019	
Manage Learning Path Logic	Learning Event Management service shall support default paths through multi-asset course or content set	2019	If SCORM and more than one SCO, using S&N tags
Manage Learning Path Logic	Learning Event Management service shall send selected courses or experiences to the learner profile as pending tasks	2019	
Manage Learning Path Logic	Pending tasks shall include a suspense date	2019	

Header	Requirement	Priority	Comments
Manage Learning Path Logic	Learning Event Management service shall generate a "scheduled" MOM message when experiences or courses are listed as pending in the learner profile	2019	
Manage Learning Path Logic	Learning Event Management service shall support user selected paths through a multi-asset course or content set	2019	If SCORM and more than one SCO, then user select sequencing. Courses may be created w/o SCORM packaging, and using their own defined logic in which case, each content element is registered independently
Manage Learning Path Logic	Learning Event Management service shall determine if courses require permission to launch or schedule		
Manage Learning Path Logic	Learning Event Management service shall generate a "requested" xAPI message when experiences or courses require OICS approval		
Manage Learning Path Logic	Learning Event Management service shall allow the OICS to approve attendance in a course or experience		
Manage Learning Path Logic	Learning Event Management service shall allow the OICS to assign a learner or identity group attendance in a course or experience	2019	
Manage Learning Path Logic	Learning Event Management service shall generate a "directed" xAPI message when experiences or courses were directed by the OICS	2019	
Manage Learning Path Logic	Learning Event Management service shall allow for machine learning to create a list of applicable content customized to the individual learner and current learner state	Outyear	"recommenders"
Manage Learning Path Logic	Learning Event Manager service shall generate a "socialized" xAPI message when a curated list is shared between learners	2019	
Manage Learning Path Logic	Learning Event Management service shall allow learners to select from their assigned or created curated lists	2019	
Manage Learning Path Logic	Learning Event Management service shall be able to capture registered learning device that load or launch content	2019	
Manage Learning Path Logic	Learning Event Management service shall generate a "captured" xAPI message when unscheduled experiences or courses are launched	2019	
Manage Learning Path Logic	Learning Event Management service shall generate an "augmented" xAPI message if a selected goal is already a demonstrated competency		Objective for 2019
Manage Learning Path Logic	Learning Event Management service shall be able to launch selected activities on the same client as the LEM is accessed	2019	Content server

Header	Requirement	Priority	Comments
Manage Learning Path Logic	Learning Event Management service shall be able to launch selected activities on remote client devices that have been registered with the network	2019	"in the wild"
Manage Learning Path Logic	Learning Event Management service shall be able to associate experiences that were launched locally with the appropriate task if they were previously scheduled	2019	Decouple "launching" from "scheduling"
Manage Learning Path Logic	Learning Event Management service shall be able to verify that an activity has closed out with completed, abandoned or terminated		Objective for 2019
Manage Learning Path Logic	Learning Event Management service shall generate the "abandoned" xAPI message after activity timeout		Objective for 2019
Goal Setting			
Goal Setting	Learning Event Management service shall allow selection of one or more goals at an arbitrary level from within a selected competency framework	2019	
Goal Setting	Selected learner goals shall be assigned a priority	2019	
Goal Setting	Selected leaner goals shall be stored persistently until achieved	2019	
Goal Setting	Learning Event Management service shall provide a default path through the selected competency graph as a sequence of sub-goals	2019	Key finding and update from 2018
Goal Setting	Learning Event Management service shall enable a user defined or configured path through the sub-competency goals	2019	Key finding and update from 2018
Goal Setting	Learning Event Management service shall enable algorithmically defined or configured path through the sub-competency graph	Outyear	Recommender (macro adaptation)
Goal Setting	Learning Event Management service shall allow an OICS to assign a goal to a learner or identity group	2019	Stub class for testing, pending CASS
Goal Setting	Learning Event Management service shall generate a "projected" xAPI message when the learner or adaptation service created the sub-goals path	2019	Key finding and update from 2018
Goal Setting	Learning Event Management service shall generate an "organized" xAPI message when the learner used the default sub-goals path	2019	Key finding and update from 2018
Goal Setting	Learning Event Management service shall filter the experience catalog by selected goals and subordinate sub-goals when active	2019	Key finding and update from 2018
Goal Setting	Learning Event Management service shall allow the user to select single level or fully recursive filters for experience selection	Optional	Key finding and update from 2018
Goal Setting	Learning Event Management service shall generate a "directed" xAPI message when the OICS passes a goal to the learner or identity group	2019	
Goal Setting	Learning Event Management service shall generate a "planned" xAPI message when a leaner has selected goals and/or sub-goals	2019	
Error Trapping			

Header	Requirement	Priority	Comments
Error Trapping	Learning Event Management service shall be able to identify incoming xAPI statement with an actor that is not a valid user, registered component, or identity group		
Error Trapping	Learning Event Management service shall be able to identify if an incoming xAPI statement is not well formed		
Error Trapping	Learning Event Management service shall be able to identify that an incoming xAPI statement is not from a registered device		
Error Trapping	Learning Event Management service shall be able to identify that an incoming xAPI statements references an invalid catalog item		
Error Trapping	Learning Event Management service shall generate an administrator alert if invalid xAPI statement is received		
MOM Profile			
MOM Profile	TLA compliant enclave and federation shall be able to process learner state IAW the TLA MOM (IEEE P9274.3.1) as received from edge devices	2019	
MOM Profile	TLA compliant enclave and federation shall be able to process learner state IAW the TLA MOM (IEEE P9274.3.1) as received from the alert and notification system	2019	
MOM Profile	TLA compliant enclave and federation shall be able to process learner state IAW the TLA MOM (IEEE P9274.3.1) as received from a user interface	2019	
MOM Profile	TLA compliant enclave and federation shall be able to process learner state IAW the TLA MOM (IEEE P9274.3.1) as detected from interaction with TLA data resources and services	2019	
MOM Profile	TLA compliant core services and data shall process performance evidence from actionable information IAW the TLA MOM (IEEE P9274.3.1)	2019	
MOM Profile	TLA compliant system shall process learner career state IAW the TLA MOM as received from user interfaces	2019	
MOM Profile	TLA compliant system shall process learner career state IAW the TLA MOM as received from federated HR systems	Outyear	Requires a future interface to M&P systems
xAPI Profiles and Fields			
xAPI Profiles and Fields	The xAPI profiles of TLA compliant edge systems shall include templates for all learning content, activity, and experience types applicable to the federate instance		IAW P9274.2.1
xAPI Profiles and Fields	The xAPI profiles of TLA compliant edge systems shall include a complete object life cycle (from requirement, to selection, launch, work, and closeout) for each training technology type		IAW P9274.2.1
xAPI Profiles and Fields	TLA compliant edge systems shall include an xAPI profile validation server to ensure compliance with the profile	Profile Server	
xAPI Profiles and Fields	TLA compliant core systems shall include a TLA MOM xAPI profile validation server to ensure compliance with the profile	Profile Server	

Header	Requirement	Priority	Comments
xAPI Profiles and Fields	TLA compliant systems xAPI profile shall include data elements required to audit evidence of assertions of competence	Profile Server	
xAPI Profiles and Fields	TLA compliant systems xAPI profile shall include data elements to specify context under which a work event was experienced	Profile Server	
xAPI Profiles and Fields	TLA compliant systems xAPI profile shall include data elements to specify context under which an assessment was evaluated	Profile Server	
xAPI Profiles and Fields	TLA compliant systems xAPI profile shall include data elements to specify standard context under which an OJT event was experienced	Profile Server	
xAPI Profiles and Fields	TLA compliant systems xAPI profile shall include data elements to specify areas not achieved during exams (i.e. grade<100%, what was missed?)	Profile Server	
xAPI Profiles and Fields	TLA compliant systems shall include verification against the profile conformance suite as part of enclave deployment or update	Profile Server	
xAPI Profiles and Fields	TLA compliant systems shall include verification against the profile conformance suite as part of federation development and edge device registration	Profile Server	
xAPI Profiles and Fields	TLA compliant system xAPI profiles shall include fields for simulator and lab exercises to capture details of learner's role, actual scenarios employed, and competencies triggered as paradata	Profile Server	
Resource Validation			
Resource Validation	Learning Event Management system shall be able to verify availability of resources prior to launching event	2019	
Resource Validation	Resources listed in the Experience Index shall include valid URL and available resources for web content, whether internal or external to the enclave	2019	
Resource Validation	Resources in the Experience Index shall include a digital verification method when the resource is stored external to the enclave		OPSEC consideration. eHelm would satisfy
Resource Validation	Resources listed in the Experience Index shall include consumables, computational assets, rooms, instructor/facilitators, and instrumentation	Outyear	
Resource Validation	TLA compliant systems shall be able to schedule constrained learning resources	Outyear	Probably interface to another system or set of systems

3.2.2 Activity Registry and Resource Management

The Activity Registry and Resource Manager is associated with the creation, review, update and deletion of learning experiences, which are composed of activities, content, and metadata that combine to describe each experience. These metadata also define the competency alignment of the experience, its nature and modality, and fitness for use in an instructional, evaluative, or heutagogical setting. The metadata model for the 2019 TLA Reference Implementation is based on a modified version of the Learning Resources Metadata Initiative (LRMI) published by Dublin Core Initiative.

The Activity Registry and Resource Management services also support an Enterprise Course Catalog (ECC) capability. The actual composition of the Activity Registry and Resource Management services may change from location to location but federate to the ECC. The Activity Registry function is most closely associated with the Experience Index in the TLA data strategy. The Activity Registry function also includes device registration, such that devices are authorized delivery mechanisms for activities. The computational node generating the xAPI stream is the registered device, so if it is a server (like a traditional Learning Management System) it will handle its own client connections and only the server will be registered as an activity provider for purposes of TLA device registry.

Device registry works with back-end services (identity and virtualization management) for security and integrity of data generated and processed from mobile platforms or other "ubiquitous learning devices" (which may include instrumented systems, QR Code readers, and any number of future technologies). Specific requirements are listed in **Table 2.**

Table 2. Activity Registry and Resource Management Requirements.

Header	Requirement	Priority	Comments
Enterprise Course Catalog (ECC)			
Enterprise Course Catalog	TLA compliant enclave shall provide a consolidated catalog of courses and registered content available for learning	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	The ECC shall list courses by course name and supporting data	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	Common Course Supporting data shall include service unique identifier, provenance and quota control information, availability, points of contact, registration and pre-requisite information	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	The ECC shall indicate courses required for regulatory compliance	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	The ECC shall have a mechanism to discover all enclaves with Enterprise Course Catalog data	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	Users shall be able to access the Enterprise Course Catalog from any TLA compliant enclave	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	TLA compliant enclaves shall be able to share applicable Enterprise Course Catalog data	ECC	Simple features as applicable for 2019
Enterprise Course Catalog	Updates to the course catalog shall generate a notification to associated user interest group(s)	ECC	
Enterprise Course Catalog	The ECC shall be able to add additional field or enumerated values to display based on the decisions of governance boards	ECC	
Enterprise Course Catalog	The ECC shall require identity credentials for access to read, update, delete, or create entries	ECC	
Enterprise Course Catalog	The ECC shall require identity credentials for access to modify the reporting of constituent Experience Index course data	ECC	
Enterprise Course Catalog	The ECC shall be able to list associated media for courses that may be shared, including simulation scenarios, part task trainers, IETMS and digital libraries of electronic publications, computer-based training aids, and others	ECC	
Enterprise Course Catalog	The ECC shall be able to accommodate service/agency specific course identification numbers	ECC	
Enterprise Course Catalog	The ECC shall be able to display information reported from financial control data sources pertaining to course provenance	ECC	

Header	Requirement	Priority	Comments
Enterprise Course Catalog	The ECC shall be able to display information reported from material control data sources pertaining to shareable resource inventory	ECC	
Enterprise Course Catalog	Users shall be able to filter returned courses in the Enterprise Course Catalog based on selection of any of the indicated attribute field enumerated values	ECC	
Enterprise Course Catalog	The ECC shall integrate with the alert and notification system to send updates or new course listings to select interest groups	ECC	
Enterprise Course Catalog	The ECC shall pull data from connected experience indices	ECC	
Enterprise Course Catalog	The ECC shall be able to synchronize with an authoritative source for competency and credential data to populate educational alignment fields	ECC	
Enterprise Course Catalog	The ECC shall support mapping data in the LOM and LRMI formats as appended for TLA	ECC	
Enterprise Course Catalog	The ECC shall be able to return and filter results within five seconds	ECC	
Enterprise Course Catalog	The ECC shall be able to resolve missing or blocked Experience Index resources without a critical halt	ECC	
Enterprise Course Catalog	The ECC shall generate an alert to an identified administrator if an assigned Experience Index resource times out during connection attempts	ECC	
Experience Index			
Experience Index	The Experience Index shall distinguish between data that is owned by an instance/enclave (authoritative source) and that which is copied to an instance/enclave from the authoritative source	2019	DIV2
Experience Index	The Experience Index shall distinguish between formal course, supporting content (assets for course) and ancillary activities and content (not associated with a course)	2019	DIV2
Experience Index	The Experience Index shall include activities that are digitally instrumented contexts under which learning content or in situ tasks can be experienced (e.g. simulators, LMS, readers, mobile devices)	2019	DIV2
Experience Index	The Experience Index shall include content and its associated activity or activities in the form of digital assets that support the experience (e.g. eBooks, scenarios, SCORM and cmi5 packages, Portable learning device corpus)	2019	DIV2
Experience Index	The Experience Index shall allow for experiences composed of activities without content	2019	DIV2
Experience Index	The Experience Index shall list applicable or allowable activities for use of content	2019	DIV2
Experience Index	The Experience Index shall include metadata for each activity, content and experience that describes its educational purpose as intended	2019	LRMI+ until XI/ECC metamodel established
Experience Index	The Experience Index shall include metadata for each activity, content and experience that describes its provenance and authority, its creation and version information, and its nomenclature	2019	DIV2

Header	Requirement	Priority	Comments
Experience Index	The Experience Index shall include metadata for each activity, content and experience that describes an object handle for use in xAPI statements	2019	DIV2
Experience Index	The Experience Index shall include metadata for each activity, content and experience that describes details regarding its modality, instructional style and impact on learner cognitive or physical attributes such that two experiences otherwise labeled identically can be evaluated and prioritized for an individual learner	2019, but data labeling and ECC	DIV2
Experience Index	The Experience Index shall allow for the listing of a single SCORM/cmi package as a collection of associated competencies and metadata for a single experience	2019	Supports recapitalization and "object ownership"
Experience Index	The Experience Index shall allow for the listing of a decomposable SCORM/cmi package as a collection of associated competencies and metadata for each uniquely launchable portion of the experience	2019	Supports recapitalization and "object ownership"
Experience Index	The Experience Index shall allow for the creation of a hierarchical course from any allowable combination of activities and content which have not been packaged using SCORM or cmi5	2019	Supports recapitalization and "object ownership"
Experience Index	The Experience Index shall include named "content set" lists of experiences compiled by a learner or OICS	2019	Supports recapitalization and "object ownership"
Experience Index	Experience Index Content Set lists shall by default be visible to the learner that created them		Supports recapitalization and "object ownership"
Experience Index	OICS shall automatically share Experience Index content set lists with learners in their assigned identity groups		Data privacy settings
Experience Index	Learners shall be able to select Experience Index content lists to be shared with other learners or OICS		Akin to sharing a playlist
Experience Index	The Experience Index shall also register applicable OJT/work experiences as activity types		Required for full competency-based tracking in maturity level three. May be federated such that only local work opportunities are managed within a given instance within a local version of the Experience Index
Experience Index	The Experience Index shall be able to register local devices as activity types		
Experience Index	The Experience Index shall be able to list one or more other resources for an activity		
Experience Index	The Experience Index shall be able to map any locally loaded content on devices as unique experiences		
Experience Index	The Experience Index shall include ordered sets of subordinate activities and content as a course		

Header	Requirement	Priority	Comments
Experience Index	The Experience Index shall include ordered sets of subordinate activities and content as a user curated list		
Experience Index	Learners may share their curated lists with other users		
Experience Index	OICS may create curated lists and direct all or a subset of their learners to complete the list		
Search Function			
Search Function	The search function shall allow filtering and search of elements in the Experience Index by job, credential, competency defined at any level, level of mastery, activity type, authority	2019	Establish indices
Search Function	The search function shall generate a "explored" xAPI message if a search is similar to recent content searches		
Search Function	The search function shall generate a "clarified" xAPI message if a search is similar to recent competency goal support searches		
Resource Management			
Resource Management	TLA compliant systems shall ensure resources (classroom materials, instructors, facilities, server resources) necessary to schedule content are available		Probably a separate class scheduling app
Resource Management	TLA compliant systems shall reserve the required resources when a content session is requested		Probably a separate class scheduling app
Resource Management	If the resource is an OICS, a notification shall be sent to that system user of their schedule		Probably a separate class scheduling app
Resource Management	TLA compliant systems shall manage facility/OICS resource requests in batches tied to registrar end date		Probably a separate class scheduling app
Resource Management	Computational resources shall be scheduled when required to run simulations or host content		May be offline process
Resource Management	TLA compliant systems shall verify on-line (WWW) and digital in-house content is available including the server up and file path is valid	2019	
Resource Management	TLA compliant systems shall provide a binary level content verification method for registered content which is external to the enclave and on unprotected resources (e.g. WWW)		Interface requirement- possibly eHelm
Activity Registry			
Activity Registry	The Activity Registry shall generate an alert to the Content/Competency Management Service s advertising updates		Interface to alert and notification system
Activity Registry	The Activity Registry shall support definition of simulations or other laboratory exercises within an overall curriculum	2019	
Activity Registry	The Activity Registry shall support definition of instructor led training curricula	2019	
Activity Registry	The Activity Registry shall allow for creation of curated lists	2019	
Activity Registry	The Activity Registry shall associate additional activities and supporting content with formal courses (e.g. for ancillary teaching materials, extra learning or tutoring, lesson plans and trainee guides)	2019	Supports ILT/ blended learning curation process for ancillary teaching aids

Header	Requirement	Priority	Comments
Activity Registry	The Activity Registry shall generate a "curated" TLA MOM message when experiences or courses were grouped in a content set list by the OICS or learner	2019	
Activity Registry	The Activity Registry shall support decomposition of simulator content to the lowest tracked level of execution (e.g. scenario, MSEL, Initial Condition Set, etc.)		2019 Objective
Activity Registry	The Activity Registry shall be able to register web content external to the TLA enclave as an experience		2019 Objective
Activity Registry	External content registered as an experience shall otherwise comply with cybersecurity restrictions for the appropriate security level for that security level		
Activity Registry	The Activity Registry shall be able to register a content management system internal to the TLA enclave as an experience	2019	
Activity Registry	The Activity Registry shall generate an alert shall require an admin, course manager, or curriculum manager to authorize content for use		Interface to alert and notification system
Activity Registry	The Activity Registry shall generate an alert for content that is a normative reference which has as updated configuration	Outyear	Requires interface to PDSS systems
Activity Registry	The Activity Registry shall allow delisting of experiences from the Experience Index	2019	
Activity Registry	The Activity Registry shall allow content and Competency Management Service s to update metadata associated with content, activity and experiences	2019	
Activity Registry	The Activity Registry shall be able to filter, and search based on educational alignment objects which have been updated	Outyear	Interface to CMS - cascading impact of changes
Activity Registry	The Activity Registry shall allow OICS to list simulators, labs, OJT, EPSS, and user defined work experiences to be registered as valid activity types	2019	DIV2
Activity Registry	Updates to owned experiences shall generate alerts to federated systems that share experiences		
Activity Registry	The Activity Registry shall maintain a log of all changes by source, date, record affected, old and new version		
Activity Registry	The Activity Registry shall be able to import a named content set list from a federated Experience Index		
Device Registration			
Device Registration	The Activity Registry shall be able to register authorized devices as activities within a federation		2019 Objective
Device Registration	Registered devices shall include operational data sources or middleware systems (i.e. anything that will generate xAPI statements for the transactional LRS)	Outyear	As applicable
Device Registration	Registered devices shall include handheld devices	2019	
Device Registration	Registered devices shall include content repositories or middleware (i.e. anything that will generate xAPI statements for the transactional LRS)	2019	
Device Registration	Registered devices shall include learning management servers (i.e. anything that will generate xAPI statements for the transactional LRS)	2019	

Header	Requirement	Priority	Comments
Device Registration	Registered devices shall include any other client device, computer or middleware application that that will generate xAPI statements for the transactional LRS.	2019	e.g. GIFT
Device Registration	Device registration shall expose endpoints for xAPI messages and launch commands		2019 Objective
Device Registration	Device registration shall include the use of LTI descriptors for tools		2019 Objective
Device Registration	Device Registration shall include Synchronization of user data to the enclave anonymization tokens		2019 Objective
Device Registration	Device registration shall include synchronization of device content to Experience Index object handles appropriate		2019 Objective
Device Registration	Device registration shall include a dynamically assignable multi-factor authentication (MFA) process.		
Device Registration	Registered devices shall be able to map local identity to the centrally managed identity in the TLA core		
Device Registration	Connected devices shall support remote launching		
Device Registration	Connected devices shall provide time out alerts to administrators, learners and OICS, and error handling if they are unavailable for a remote launch		

3.2.3 Competency Management

Competency management includes the services associated with defining competency frameworks that define the required levels and behaviors of human performance with the jobs and credentials that require that *knowledge, skills, abilities and other* (KSAO) behaviors. Competency objects are defined by the reusable competency definition model and a directed acyclic graph (DAG). This type of hierarchy allows for multiple parents, enabling sharing of competency fragments to show how knowledge gained in one discipline may bolster capability in another. Competency management includes the maintenance of frameworks and the evaluation of performance evidence to make assertions of individual competence. Competencies are generated from local materials in accordance with the reusable competency definition (RCD) objects**.**

Competency and credentials are managed at the DoD enterprise level and require a digital trust system. This system of digital trust provides auditability, transparency, non-repudiation, privacy and data integrity for the data associated with capable manpower as a critical national capability. The digital trust system includes encrypted, digitally signed, credential management and a global system of governance that allows for customization. It also facilitates discoverability and sharing of common components while ensuring traceability to a single owner for configuration management.

Learners encounter learning activities that present opportunities for instruction and assessment. These are aligned with competencies using alignment objects that are part of the LRMI specification. As a learner interacts with each learning activity, they generate *evidence* of competence. The evidence is evaluated based on a trust value and on an efficacy value. Evidence is normalized according to the cmi5 profile and the contextualization of the TLA MOM. Evidence of competence, along with assertions of competence based on evaluation of this evidence, are stored as xAPI messages in the transactional Learning Record Store (LRS). This maintains the “chain of evidence” for competency. A Competency Management System evaluates evidence from the transactional LRS to predict learner mastery.

These mastery estimates are housed in the form of a credential and are stored within the Authoritative LRS as xAPI statements, along with the digital signature of a trusted individual who has been empowered to make the conferral of credential. This maintains the "chain of custody." Authoritative LRS messages are linked to an Open Badge or CTDL portable badge version of the credential in the learner profile database, which can be shared across the enterprise through the Enterprise Learner Record Repository. This chain of evidence and chain of custody is shown in **Figure 2.**

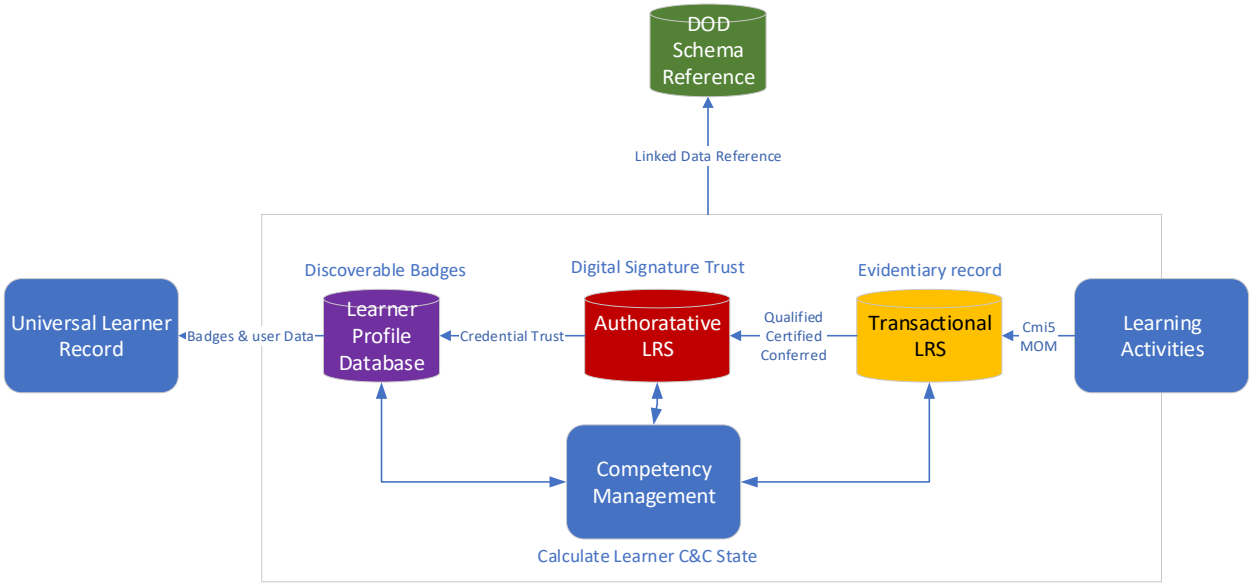

Figure 2. Chain of Custody for Competency and Credential Management. *Adjudicated performance records are collected in the transactional LRS, along with calculated assertions of competence and contextualization data. These xAPI present an evidentiary chain for supporting the award and review of credentials, which are stored as digitally signed xAPI within the Authoritative LRS. Learner State data, local and global learner preferences, and universally discoverable OpenBadge3 versions of credentials located in the learner profile database, and all data owners with credential records for a leaner are maintained and visible through the Enterprise Learner Record Repository.*

Table 3. Requirements for the Competency and Credential Management Services.

Header	Requirement	Priority	Comments
Learner Profile			
Learner Profile	The local learner profile shall be developed consistent with the TLA learner profile metamodel (Spec TBD)		
Learner Profile	The learner profile shall link back to an authoritative identity management service for PPI (personal data: name, rank, SSN, address, phone, UIC)	2019	LP is broken out separately at maturity level three, at one and two is probably student management service of LMS, or HR system organic capability
Learner Profile	The learner profile shall use the internally generated anonymization token for storing user data	2019	
Learner Profile	The learner profile shall maintain a list of asserted competencies and effective dates	2019	
Learner Profile	The learner profile shall maintain a list of conferred credentials, CEU state, and effective dates	2019	LP is broken out separately at maturity level three, at level one and two is

Header	Requirement	Priority	Comments
			probably student management service of LMS, or HR system organic capability
Learner Profile	The learner profile shall maintain a list of authorized access roles	2019	May be tied to identity management system or back-end security services
Learner Profile	The learner profile shall be able to store user specified attribute data defining learner preferences	2019	
Learner Profile	The learner profile shall maintain a change log of updates to the profile	2019	
Learner Profile	The universal learner profile shall support deployment as a federation of multiple local learner profiles, at multiple levels of security	ELRR	
Learner Profile	The learner profile shall be able to link logically lower level enclave data with higher level data to form a complete picture of performance	ELRR	
Learner Profile	The learner profile shall be able to link digitally lower level enclave data with higher level data to form a complete picture of performance	ELRR	Only where CDS available
Learner Profile	The universal learner profile shall be able to follow the learner/user through multiple assignments	ELRR	
Learner Profile	The learner profile shall store current performance goals and sub goals as job, duty, gig, competency, or credential hierarchies or elements of hierarchies	2019	
Learner Profile	The learner profile shall store current learner state and assigned tasks/experiences	2019	Modified or informed by ELRR
Learner Profile	The learner profile shall indicate when tasks have been satisfied by events	2019	
Learner Profile	The learner profile shall allow for the creation, retrieval, update and deletion of learner records	2019	
Learner Profile	Deleted learner records shall be recoverable/auditable		
Learner Profile	The learner profile shall provide a mechanism to ensure credentialing and de-credentialing comes from a non-repudiable and authoritative source		May be separate process. Can CASS process the whole conferral review process? Use “signatures” as a class of evidence – from a non-repudiable approval tracking system?
Learner Profile	Individual learner profile records shall enable an administrator to conduct a full record purge after a specified period		
Learner Profile	The learner profile shall indicate the current possible career trajectories (badges, jobs, etc.)		Future interface requirement to M&P systems
Learner Profile	The learner profile shall maintain a mechanism to prevent hacking/loss of data integrity	ELRR	Simple for 2019
Learner Profile	The learner profile shall be able to assign learner personas	ELRR	

Header	Requirement	Priority	Comments
Learner Profile	The learner profile shall maintain a record of aptitude definitions (as locally defined name value pair sets)	2019	Include airman learning record type fields, as well as anything required to support adaptation algorithms of decision support
Learner Profile	The learner profile shall integrate with the competency and Credential Management Services	2019	This is part of the definition for level three maturity
Learner Profile	Roles and Personae shall depict an arbitrary level of hierarchical specificity		Simple for 2019
Learner Profile	The learner profile shall store all applicable personae or roles associated with the person pertaining to a unique portion of their total learning	ELRR	
Learner Profile	The learner profile shall support global discovery and federated data structures between enclaves	2019	This is part of definition of level three maturity
Learner Profile	The learner profile shall maintain an auditable log of changes	ELRR	May be separate service
Learner Profile	The learner profile shall provide a digital export of credentials for civilian portability	ELRR	May be separate service
Learner Profile	The learner profile shall allow for deletion of records from searches by an administrator	ELRR	May be separate service
Learner Profile	The learner profile shall allow for “hiding” (non-permanent deletions) of user data from searches and displays by an administrator	ELRR	
Learner Profile	The learner profile shall provide the unit identification data for where credentials were awarded to the enterprise level record repository	ELRR	
Learner Profile	The learner profile shall provide unit location data for credentials being awarded	ELRR	
Learner Profile	The learner profile unit location data shall include location data for mobile, deployed or mobilized units	ELRR	
Manage Competency Framework			
Manage Competency Framework	Competency Frameworks shall be developed IAW IEEE 1484.20.1 RCD model	CASS	
Manage Competency Framework	The Competency Management Service shall maintain a list of jobs/duties required of each user role within the organization	CASS	Likely included as part of HR system for maturity level one and two, transition to Competency Management Service for level three
Manage Competency Framework	The Competency Management Service shall store the knowledge, skills, abilities, and other (KSAO) behaviors required to perform a job or duty	CASS	Likely included as part of HR system for maturity level one and two, transition to Competency Management Service for level three

Header	Requirement	Priority	Comments
Manage Competency Framework	Each KSAO shall include relationships between competency definition objects and associated context/conditions and standards	CASS	Content Aggregation Model (CAM) within LMS courses maintains a hierarchy for maturity levels 1 & 2, but this will be replaced with directed acyclic graph of competency objects and evidence maps for level 3
Manage Competency Framework	The context and standards under which competencies were acquired shall support determining fitness of the person for a specific job or employment	CASS	
Manage Competency Framework	The Competency Management Service shall define related competency objects (cognitive, psychomotor, affective, social, and metacognitive domains, standards, and context/conditions) at multiple levels of mastery	CASS	Levels of mastery might be implicit in LMS course structures but may become a lower level attribute in maturity level three competency frameworks
Manage Competency Framework	The Competency Management Service shall specify the competencies and level of mastery required for each job/duty	CASS	Included in HR system mapping to required courses in maturity level one and two
Manage Competency Framework	The Competency Management Service shall be able to distinguish between qualification, proficiency, and mastery	CASS	May have additional categories specified – shows currency of capability
Manage Competency Framework	Credentials defined for a job/duty shall link to competency objects required to perform a job/duty	CASS	Credentials may include a traditional “degree” or “certificate” as well as “necessary qualifications” to do the job
Manage Competency Framework	The Competency Management Service shall be able to update any inference weights	CASS	
Manage Competency Framework	The Competency Management Service shall generate an “inferred” message if weights have been updated	CASS	
Manage Competency Framework	The Competency Management Service shall be able to import operational performance data to validate the elements and weights of a DAG	CASS	Outyear requirement
Manage Competency Framework	The Competency Management Service shall generate a “validated” xAPI message if the weights have been updated	CASS	Outyear requirement
Search Function			
Search Function	The Competency Management Service shall allow a learner to search on all credentials associated with a job	CASS*	Might be separate service, support LEM
Search Function	The Competency Management Service shall allow a learner to search on all competencies associated with a job	CASS*	Might be separate service, support LEM

Header	Requirement	Priority	Comments
Search Function	The Competency Management Service shall allow a learner to search on all competencies associated with a credential	CASS*	Might be separate service, support LEM
Search Function	The Competency Management Service shall allow a learner to search on all sub-competencies associated with a competency	CASS*	Might be separate service, support LEM
Search Function	The Competency Management Service shall allow a learner to search on changes to competency framework by date	CASS*	Might be separate service, support LEM
Search Function	The Competency Management Service shall allow a learner to search by competencies with different levels of mastery (i.e. what jobs are associated with each level, and what standards and context applies)	CASS*	Might be separate service, support LEM
Search Function	The Competency Management Service shall generate a "clarified" xAPI message if a competency is selected that reinforces a recently completed experience that is not on the current goal-activity plan	CASS*	Might be separate service
Search Function	The Competency Management Service shall generate a "augmented" xAPI message if a competency is selected that reinforces a recently completed competency that is not on the current goal-activity plan	CASS*	Might be separate service
Search Function	The Competency Management Service shall allow a learner to search on competency owner	CASS*	Might be separate service
Search Function	The Competency Manager Service shall export search results as a serialized array of competency objects	CASS*	Might be separate service-used to support LEM goals
Update Learner Competency			
Update Learner Competency	The Competency Management Service shall generate assertions of competence based on evidence of mastery	CASS	Supported in transition from course-based to competency-based
Update Learner Competency	The Competency Management Service shall maintain an evidentiary history of local training events/exercises attempted and completed, as well as scoring data	CASS	May use linked data to LRS at maturity level three when the LP is broken out.
Update Learner Competency	Evidence of mastery shall include feeds from any instrumented digital learning device that can generate xAPI	CASS	This is preserved in the LRS and is key to the first migration level
Update Learner Competency	LRS shall federate data at TLA compliant core boundary by using TLA MOM verbs for Learner record provider state (equivalent to cmi5 states)	CASS	
Update Learner Competency	The Competency Management Service shall process cascading evidence chains through associated competency frameworks (showing all competencies demonstrated by the evidence)	CASS	Real world scenarios may indicate mastery of knowledge that is related to multiple competencies (e.g., many to many relationships instead of the one to many hierarchies used in SCORM's CAM, which mirrors course structures

Header	Requirement	Priority	Comments
Update Learner Competency	The Competency Management Service shall be able to calculate progress toward a related credential as a sequence of demonstrated competencies	CASS	This is analogous to testing out of scholastic requirements.
Update Learner Competency	The Competency Management Service shall be able to import learner Career state	Outyear	Future M&P system intersection, or this information can be input manually
Update Learner Competency	The Competency Management Service shall be able to calculate progress toward competencies not associated with a credential	CASS	
Update Learner Competency	The Competency Management Service shall determine when minimum evidentiary thresholds for demonstration/assertion of competency are achieved	CASS	This provides the ability to push grading to edge systems, or to be preserved within the competency framework for maturity
Update Learner Competency	The Competency Management Service shall be able to obtain verification of untrusted evidence from a trusted authority	CASS	
Update Learner Competency	The Competency Management Service shall ensure that achievement of a credential requires review and approval by an authorized approval authority	CASS	May be an offline process for maturity level one and two
Update Learner Competency	The Competency Management Service shall evaluate the trust in evidence based on the life cycle defined in the TLA MOM (IEEE P9274.3.1)	CASS	
Update Learner Competency	The Competency Management Service shall update the learner profile on learner competency states	CASS	
Update Learner Competency	The Competency Management Service shall generate an “assessed” xAPI message if a test activity is completed	CASS	
Update Learner Competency	The Competency Management Service shall generate a “socialized” xAPI message if an instrumented social media post was captured and addressed a media or competency element	CASS*	Might be separate service, support LEM
Update Learner Competency	The Competency Management Service shall generate a “verified” xAPI message if an untrusted piece of evidence is separately approved by a trusted agent	CASS	
Update Learner Competency	The competency system shall continuously update the state of assigned goals	CASS*	May be extra process
Skill Decay			
Skill Decay	TLA compliant systems shall track the requirement for proficiency, check ride, or continuing education units for conferred credentials	CASS	LMS or HR system may have business rules for lower maturity levels that can also accomplish
Skill Decay	TLA compliant systems shall allow admins, OICS, content managers, and Curriculum managers to set proficiency timers and content requirements to a user interest group or user	CASS	User controlled business logic for proficiency alerts. Works in concert with notification system

Header	Requirement	Priority	Comments
Provide Configuration Control of CF Over Time			
Provide Configuration Control of CF Over Time	The Competency Management Service shall allow authorized users to create, read, update and delete elements of a competency framework	CASS	
Provide Configuration Control of CF Over Time	The Competency Management Service shall generate an alert when an element has been modified	CASS	
Provide Configuration Control of CF Over Time	The Competency Management Service shall maintain a record of changes (user, authority, name-value pairs)	CASS	
Compatibility Translation			
Compatibility Translation	The Competency Management Service shall provide a mechanism to allow mapping of one competency framework to another	CASS	Dependent on Competency Management Service migration at maturity level three
Compatibility Translation	The Competency Management Service shall provide a mechanism to allow mapping of one credential framework to an equivalent credential	CASS	Dependent on Competency Management Service migration at maturity level three
Compatibility Translation	The Competency Management Service shall provide a mechanism to allow mapping of one credential framework to an equivalent credential with assigned experiences to close any gaps	CASS	
Compatibility Translation	The Competency Management Service shall provide for import and export of competency framework data whole or in part	CASS	Dependent on Competency Management Service migration at maturity level three
Credential Management Service			
Credential Management	The Credential Management Service shall maintain an auditable log of trust and/or evidence that led to the credential	CASS	Might include linked data (JSON-LD) in xAPI, can include archival of LMS data for maturity levels one and two
Credential Management	The Credential Management Service shall preserve a digitally signed badge showing the credential achieved, active date, conferral authority, and conferees name and service number	CASS	May require full competency and credential system with blockchain or similar technology on top of JSON-LD
Credential Management	The Credential Management Service shall provide a validated digital export of the digitally signed badge	CASS	
Credential Management	The Credential Management Service shall be able to assign user specified business rules for validating credentials to a user interest group (beyond assessments) to include source agency, military record, time in rate/job, assignment, multiple signature authorities	CASS	May be offline process in maturity level one and two

Header	Requirement	Priority	Comments
Credential Management	The Credential Management Service shall be able to generate non-repudiable alerts to OICS role users to establish required conferral and validation signatures	CASS	The "signature obtained" becomes the trigger to update credential
Credential Management	The Credential Management Service shall monitor achievement of CEU/PDU requirements and issue de-credentials or updates as necessary	CASS	May be interface to/from AGILE at maturity level one and two, need to update record as well as create notifications
Credential Management	The Credential Management Service shall provide a user configurable name for digital badges (e.g. diploma, certificate, badge)	CASS	
Credential Management	TLA compliant systems shall updated the learner profile with all completed and in progress credentials for users	CASS	
Credential Management	TLA compliant systems shall validate credentials required for a user acting in an OICS role for access, observation, or assessment	CASS	Instructor permissions for LMS in maturity level 1
Credential Management	TLA compliant systems shall provide a secure digital badge for showing a credential has been conferred	CASS	Portable credentials will require MOA with the parent organizations
Credential Management	TLA compliant systems shall provide an administrator configurable type for naming type of credential: (e.g. degree/diploma, badge, license, certificate, and professional rating)	CASS	
Credential Management	The TLA Credential Management Service shall be able to export credentials using OpenBadge3	CASS*	Tied to ELRR work, may be separate process
Credential Management	The TLA Credential Management Service shall preserve the chain of evidence between globally discoverable credentials, local copies of credentials, the assertions of underlying competencies, and the evidence gathered for the assertion.	CASS*	Tied to ELRR work, may be separate process
Credential Management	The TLA credential chain of evidence shall be severable for purpose of transport or data federation (e.g. assertions sent without evidence in message payload, but still preserving discoverable links)	CASS*	Tied to ELRR work, may be separate process
Credential Management	The underlying competencies that each credential represents will be defined using Credential Transparency Description Language (CTDL) and will reference the specific RCDs that each credential represents	CASS*	
Search Functions			
Search Functions	The TLA Competency Management Service shall allow for searches of competency objects based on job, credential or as part of an unassociated top-level competency	2019	Stub class for testing, pending CASS
Search Functions	The TLA competency search function shall return all lower level competency definition objects from a selected competency or credential	2019	Stub class for testing, pending CASS
Search Functions	The TLA competency search function shall display the directed acyclic graph of relationships between competency definition objects	2019	Stub class for testing, pending CASS
Search Functions	The TLA competency search function shall display supporting details for selected competency graphs		

3.2.4 User Interface

The TLA policy framework assumes that each service group (Activity Registry and Resource Management, Competency Management, and Learning Event Management) will have its own organic user interfaces, but that a single sign-on capability enabled from a common portal will streamline user access to comply with the concept-of-execution for the entire TLA instance as a federation of components. The portal operates through redirects and filters and serves as the access point to core services, edge decision support services, and potentially a launch context for web-based clients of learning devices.

The ADL Initiative uses the cybernetic system concept of "control loops" to model the learner as an entity requiring 'location' and 'navigation' over the course of their career through different learning experiences. The control loops are aligned with "aperture" settings in the portal to ensure that only data and time scales applicable to one control loop are presented at the same time, as an aid to the user. Especially for the higher-level control loops of 4 & 5 which may rely on access to other integrated systems. Navigated learning experiences include:

- **Control Loop 1**: Improving a learner's mastery of competencies within the current learning activity;
- **Control Loop 2**: Optimizing a learner's progress toward a credential;
- **Control Loop 3**: Prioritizing the pursuit of credentials or activities to meet requirements for a job;
- **Control Loop 4**: Planning education and training goals for an overall career trajectory; and
- **Control Loop 5**: Providing options for supporting post career transition and retraining.

A simplified version of the control loops is shown in **Figure 3. Table 4** lists the detailed requirements for the portal.

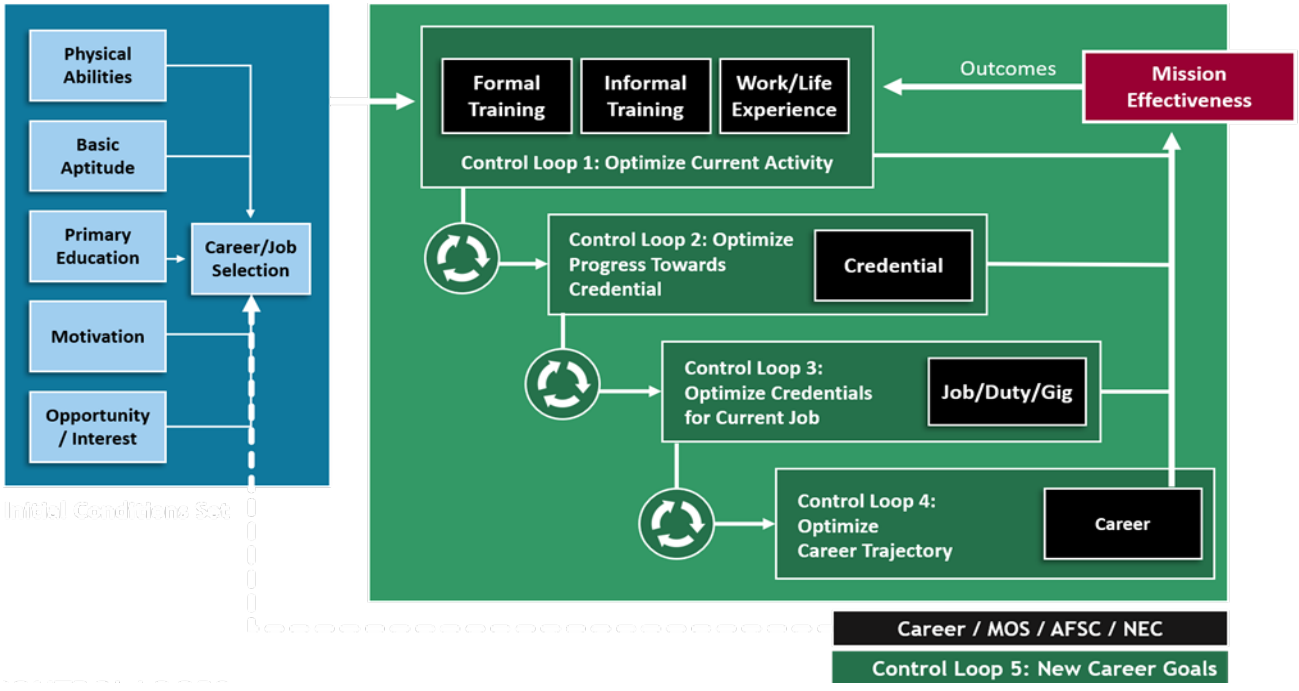

Figure 3. TLA Control Loops. *The "sensors" of the control loops are the xAPI statements generated from learning devices and operational data, and the "actuators" are the planning of learning events. The five control loops are constantly operating in parallel, but they provide a convenient way to limit and categorize data displayed in decision support aids, and the MOM profile serves to organize those filters.*

Table 4. Requirements for the User Interface Portal.

Header	Requirement	Priority	Comments
Decision Support Management Service			
General Requirements			
General Requirements	The TLA User Interface shall provide decision support view of the collected experience data	2019	
General Requirements	The decision support service shall enable search and filtering of data	2019	
General Requirements	The decision support service shall enable retrieval across multiple transactional LRS (i.e. enterprise analytics)	2019	
General Requirements	The decision support service shall be able to reconcile user identity across enclaves	2019	
Instructor Review			
Instructor Review	The decision support service shall enable analysis of efficacy of curriculum		
Instructor Review	The decision support service shall enable analysis of efficacy of assessments		
Instructor Review	The decision support service shall enable an analysis of learner performance distribution		
Instructor Review	The decision support service shall enable achievement velocity analysis by user interest group for OICS		
Content Manager Review			
Content Manager Review	The decision support service shall enable analysis of efficacy of supporting materials		
Content Manager Review	The decision support service shall enable analysis of cost effectiveness of activities, content and resources		
Content Manager Review	The decision support service shall enable analysis of media suitability for training to a competency		
Competency Management Review			
Competency Management Review	The decision support service shall enable analysis of competency frameworks suitability for assigned jobs	Outyear	
Competency Management Review	The decision support service shall enable analysis of effectiveness of proficiency requirements for credentials	Outyear	
Competency Management Review	The decision support service shall enable analysis of robustness of credentialing processes	Outyear	
Personnel Manager Review			
Personnel Manager Review	TLA compliant systems decision support shall enable analysis of workforce proficiency	Outyear	
Personnel Manager Review	TLA compliant systems decision support shall enable analysis of manning levels for projected job requirements	Outyear	
Personnel Manager Review	TLA compliant systems decision support shall enable analysis of facility and OIC manpower efficacy	Outyear	
Personnel Manager Review	TLA compliant systems decision support shall enable analysis of learner velocity through training pipeline	Outyear	
Personnel Manager Review	TLA compliant systems decision support shall enable analysis of proficiency duty cycle	Outyear	
Learner Decision Support			

Header	Requirement	Priority	Comments
Learner Decision Support	TLA compliant systems decision support shall enable individual learning progression planning for current class/event		Control Loop 1
Learner Decision Support	TLA compliant systems decision support shall enable individual learning progression planning for current competency/badge/certificate/diploma goal		Control Loop 2
Learner Decision Support	TLA compliant systems decision support shall enable individual learning progression planning for next assignment goal	Outyear	Control Loop 3
Learner Decision Support	TLA compliant systems decision support shall enable individual learning progression planning through current career arc	Outyear	Control Loop 4
Learner Decision Support	TLA compliant systems decision support shall enable individual learning progression plans for service transition or change of career	Outyear	Control Loop 5
Common Portal			
Common Portal	The portal shall provide for a user login and 2 factor authentications	2019	
Common Portal	The portal shall employ single -sign on for all connected enclaved services		Keycloak
Common Portal	The portal shall display an appropriate classification	2019	
Common Portal	The portal shall display a consent to monitoring banner	2019	
Common Portal	The portal shall allow a user to user to switch between allowable roles	2019	
Common Portal	The portal shall require a unique login for a user to act in the administrator role	2019	
Common Portal	The portal shall be able to support operation when installed at the unclassified (NIPR), GENSER Secret (SIPR) and TS SCI (JWICS) levels		
Common Portal	The portal shall support access to data and services at lower enclaves when MLS cross domain access is provided		Any CDS is outside the TLA compliant systems enclave, and MLS should be always available in the form of air gapped, encrypted transfer
Common Portal	The portal shall enable access to TLA system resources applicable to user permission level	2019	The core portal functions may be through an organic interface in the initial maturity levels, but should be a common access point for level three
Common Portal	TLA system resources other than portal will only allow access by administrators	2019	
Common Portal	The common portal shall filter all service access by user permission level	2019	
Common Portal	The common portal shall filter all data access by user permission level and identity	2019	As applicable for 2019 pending P4STLA

Header	Requirement	Priority	Comments
Common Portal	The common portal shall allow interface with the alert and notification system	2019	
Common Portal	The common portal shall allow a user to select decision support dashboards	2019	
Common Portal	The common portal shall allow a user to select Learning Goal Management	2019	
Common Portal	Portal Learning Goal Management shall include goal selection and prioritization		
Common Portal	Portal Learning Goal Management shall include goal and sub-goals path planning		
Common Portal	The common portal shall allow a user to select Learning Task Management	2019	
Common Portal	Portal Learning Task Management shall include selection of pending and assigned tasks	2019	
Common Portal	Portal Learning Task Management shall include OICS approval of requested tasks		
Common Portal	Portal Learning Task Management shall include selection of assigned, shared, or created content set lists		
Common Portal	The common portal shall allow a user to select Learning Event Planning	2019	
Common Portal	Portal Learning Event Planning shall use the selected goals if selected during goal planning	2019	
Common Portal	Portal Learning Event Planning shall use the priority goals by default to filter experience searches	2019	
Common Portal	Portal Learning Event Planning shall allow easy movement between activity centric and goal centric planning (I.e. without excessive user actions)	2019	
Common Portal	Portal Learning Event Planning shall include experience selection and scheduling		
Common Portal	The common portal shall allow a user to select User Management	2019	Limited, includes group management in outyear
Common Portal	Portal User Management shall include group membership		
Common Portal	Portal User Management shall include and CRUD functions for unprotected user data	2019	
Common Portal	The common portal shall display username without maintaining an association to SSO token persistently in the local context	2019	Clean room only
Common Portal	The common portal shall display current goals, tasks, suspense dates job, competency in work state, credential state, and identity group memberships	2019	
Common Portal	The common portal shall allow for minimize/maximize functions for each class of data	2019	
Common Portal	The common portal presentation shall preserve hierarchical relationships between goals/tasks jobs/credentials and competencies as applicable	2019	
Common Portal	Learning Task Management shall include scheduled activities and recommended activities	2019	
Common Portal	The common portal shall allow a user to view the ECC	2019	`

Header	Requirement	Priority	Comments
Common Portal	The common portal shall allow a user to view the entire Experience Index	2019	
Common Portal	The common portal shall allow a user to use the portal as an experience client device	2019	
Common Portal	Identity and configuration settings shall pass to the client context without requiring reentry	2019	
Common Portal	The client interface and TLA planning interface shall exist as decoupled services	2019	No launcher app
Learning Path Apertures			
Learning Path Apertures	The TLA portal shall be able to select between performance data "apertures" that include current lesson progress/content, current course progress/ planning, planning for next credential, planning for next job, career trajectory planning, transition to new career	2019	Loops 1 and 2 only
Learning Path Apertures	The TLA portal shall list milestones applicable to the selected aperture		
Learning Path Apertures	TLA compliant systems portal shall filter data for progression planning for current competency/ badge/certificate/diploma goal (all content, progress, velocity, gradebook, current proficiency state		Loop 3
Learning Path Apertures	TLA compliant systems portal shall filter data for next assignment: review of available jobs and duties along trajectory, projected competency state, competency gaps		Loop 4
Learning Path Apertures	TLA compliant systems portal shall filter data for overall career: Requirements for advancement, job alignment to competency, competency mapping to civilian competencies		Loop 5
Alerts and Notifications			
Alerts and Notifications	The portal shall display alerts and notifications applicable to the user and role logged in		
Alerts and Notifications	Alerts shall require acknowledgement to clear		Define alerts as modal, notifications as modeless
Alerts and Notifications	Notifications shall continue on a scrolling message area		
Alerts and Notifications	The maximum retention of notifications shall be settable by the administrator		
Alerts and Notifications	Conferral of a credential shall create an alert that learner is in maintenance phase		
Alerts and Notifications	A Just in time training requirement inserted by a content manager shall create an alert		
Alerts and Notifications	A regulatory or mandatory training requirement shall create an alert		
Alerts and Notifications	An impending (~30 days) proficiency requirement shall create an alert		
Alerts and Notifications	Changes to a previously viewed activity/content element shall generate a notification		
Alerts and Notifications	Changes to a previously completed credential or in work competency/credential shall generate a notification		

Header	Requirement	Priority	Comments
Alerts and Notifications	Updates to user information shall create a notification to the user, and any OICS, or administrators with interest groups the user is assigned		
Alerts and Notifications	Notifications from the Competency Management Service shall be sent to assigned learners with or working toward those competencies		
Alerts and Notifications	OICS shall be able to send notifications to assigned user group learners		
Alerts and Notifications	Content managers shall be able to advertise activities/content to sets of learners as notifications		
Alerts and Notifications	Users shall be able to send notifications requesting mentors or tutors in topics		
Alerts and Notifications	Notifications and alerts shall be able to federate across enclaves and agency domains		
Alerts and Notifications	Learner Requested courses shall generate a notification to the assigned OICS	2019	LMS can do this now - may be used for demo
Alerts and Notifications	Assigned tasks shall generate a notification to the associated learner	2019	LMS can do this now - may be used for demo

3.2.5 Identity Management

Back-end services are required for the operation of the federated cloud-based enterprise architecture envisioned for TLA, without directly providing learning functionality. Interface with external data sources and use of commercial products and protocols shall enable these capabilities. Identity management is concerned with non-repudiation; it allows segmentation of personally identifiable information (PII) across multiple, anonymized locations while still allowing for reconstruction of complete portraits of performance, by linking locally unique anonymization references with globally unique aliases (Universal Unique Identifier (UUID)) and further segregation of protected privacy information (PPI) from the UUID. This arrangement is depicted in **Figure 4.** Detailed requirements are listed in **Table 5.**

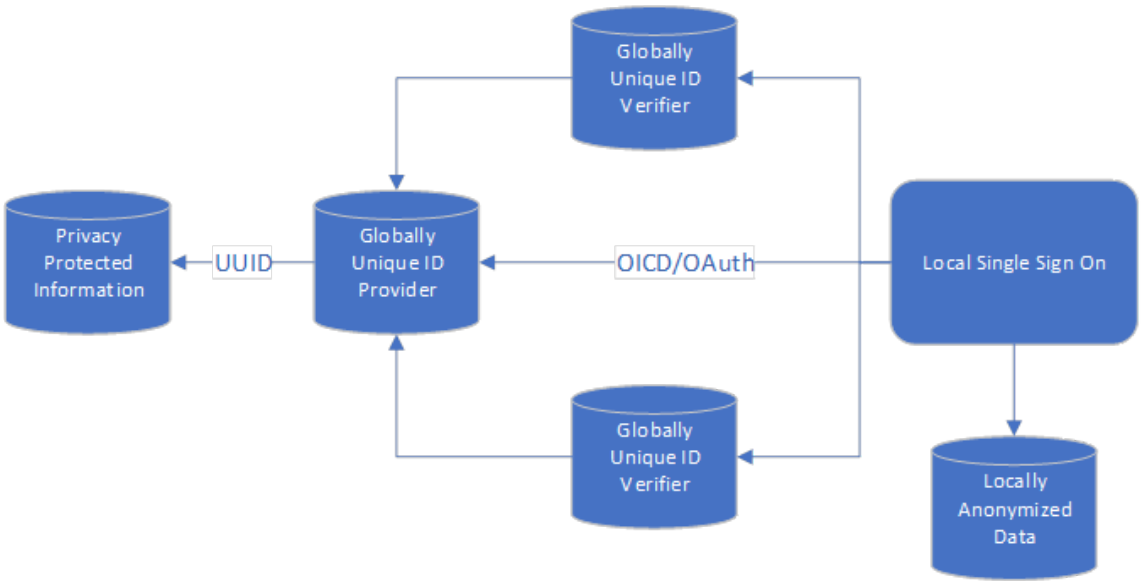

Figure 4. Segmentation of ID information. *The TLA approach to managing ID leverages industry best practices to segment PII, isolate PPI and use third party identity validation using open ID protocols to maintain integrity and non-repudiation of learner data.*

Table 5. Detailed Requirements for Identity Management.

Header	Requirement	Priority	Comments
Roles and Permissions			
Roles and Permissions	TLA compliant systems shall enable login with administrator level privileges	2019	
Roles and Permissions	Administrator level permissions shall be able to access and modify user, content, service configuration, activity, resource, and competency service data	2019	Protection of system data assets in test configuration
Roles and Permissions	Administrator level permissions shall be able to assign learners to an Observer/Instructor/Controller/Supervisor (OICS) (for filtering purposes)		Registrar function for schoolhouses
Roles and Permissions	Administrator level permissions shall be able to assign Experience ownership to an OICS (for filtering purposes)		
Roles and Permissions	Administrator level permissions shall be able to assign competency frameworks or framework segments to a Competency Management Service		
Roles and Permissions	Administrator level permissions shall be able to create protected user identity groups with assigned users and assign access to these to OICS, competency, or content managers		
Roles and Permissions	Administrator privileges shall include CRUD permissions by segment for each of the data stores (Experience Index, LRS, Learner Profile)	2019	
Roles and Permissions	TLA compliant systems shall enable login with learner level privileges	2019	
Roles and Permissions	The learner access shall be able to select, deselect and prioritize goals (Jobs, credentials or competencies)	2019	
Roles and Permissions	The learner access shall be able to select current scheduled courses	2019	
Roles and Permissions	The learner access shall be able to manage (CRUD) curated experience lists	2019	
Roles and Permissions	The learner access shall allow for launching of current selected experiences, curated lists, or assigned courses	2019	
Roles and Permissions	The learner shall be able to search the Enterprise Course Catalog	2019	
Roles and Permissions	The learner shall be able to filter and search the entire local experience list	2019	
Roles and Permissions	The learner shall be able to view learner state information from the leaner profile	2019	
Roles and Permissions	The learner shall be able to review their personal performance data	2019	
Roles and Permissions	TLA compliant systems shall enable login with OICS level privileges		Objective for 2019
Roles and Permissions	OICS level permissions shall allow for logging observed practical exercises for assigned learners as complete- satisfactory, attempted, complete-unsatisfactory		Anomalous (non LMS) content captured in LRS in first iteration
Roles and Permissions	OICS level permissions shall allow for reviewing progress toward goal, current grades and state for assigned learners		
Roles and Permissions	OICS level permissions shall allow for review of assigned learner performance on assigned activities		Objective for 2019
Roles and Permissions	OICS level permission shall allow for review of alerts and notifications sent to assigned learners		

Header	Requirement	Priority	Comments
Roles and Permissions	TLA compliant systems shall enable login with Competency Management Service level privileges		
Roles and Permissions	The Competency Management Service shall be able to create, read, update, delete competency definition objects and relationships for assigned competency frameworks		
Roles and Permissions	The Competency Management Service shall be able to create, read, update, delete links between competency definition objects from the competency framework for each credential		
Roles and Permissions	The Competency Management Service shall be able to create, read, update, delete job, duty, gigs and competency frameworks		
Roles and Permissions	TLA compliant systems shall enable login with Experience manager level privileges		
Roles and Permissions	The experience manager shall be able to register new activities, content, or content types for a learning activity		
Roles and Permissions	The experience manager shall be able to assign and attribute new activities and content for learners to experience		
Roles and Permissions	The experience manager shall be able to register activities and content from within or external to the enclave		For NIPR access to WWW or SIPR outside of enclave
Roles and Permissions	The experience manager shall be able to link content elements into courses or subordinate units (phases/modules/units)		Initially within Content Aggregation Model (CAM) in SCORM manifest as part of LMS, but refactored in later maturity levels to content and competency management records
Roles and Permissions	The curriculum manager shall be able to register experiences to educational purpose for linked competencies		
Roles and Permissions	User permission profiles shall be exportable to another federate instance of TLA compliant systems	P4STLA	
PPI/PII Protection/Privacy			
PPI/PII Protection/ Privacy	TLA compliant systems shall be able to create a locally unique anonymized identity reference	2019	
PPI/PII Protection/ Privacy	The anonymized identity token shall be used to label "user" for all locally stored data	2019	
PPI/PII Protection/ Privacy	TLA compliant systems shall otherwise use the anonymized reference when transmitting data referenced to users to another enclave	2019	
PPI/PII Protection/ Privacy	TLA compliant systems shall send UUID to anonymization references for only requested users as a separate message from the anonymized performance data		

Header	Requirement	Priority	Comments
PPI/PII Protection/ Privacy	UUID and anonymized reference keys shall be encrypted using FIPS 140.2 compliant encryption or higher, as appropriate to classification level		
PPI/PII Protection/ Privacy	Sensitive personal data (i.e. PPI) shall be only stored within or transmitted from the back-end identity management service	2019	Scrub of xAPI data handles
PPI/PII Protection/ Privacy	The portal shall utilize a FIPS 140.2 approved encryption of username to be displayed when received from Identity management services		
PPI/PII Protection/ Privacy	TLA compliant systems shall employ globally unique Identities for third party identification verification (UUID)	2019	Federated Identity
PPI/PII Protection/ Privacy	The portal shall have mechanisms to prevent human readable linkage of username and UUID	2019	
PPI/PII Protection/ Privacy	TLA compliant systems shall be able to reconcile internal identity references with UUID	2019	Use of UUID and IRI internally prevent storage of PII outside of clean room environment within enclave
PPI/PII Protection/ Privacy	The portal shall only display current name when used in the learner, admin, experience manager or Competency Management Service role	2019	
PPI/PII Protection/ Privacy	The portal shall only display names for associated learners when used in the OICS role		
PPI/PII Protection/ Privacy	TLA compliant systems Shall be able to reconcile anonymized tokens in federated data structures (between organizations and between enclaves)	2019	
PPI/PII Protection/ Privacy	TLA compliant systems shall enable configurable privacy settings at the individual datum value level		
PPI/PII Protection/ Privacy	TLA compliant systems shall have a mechanism to filter data exports or visualization based on privacy settings	PS4TLA	
Identity Groups			
Identity Groups	TLA compliant systems shall be able to associate users with identity groups that will link data common to all users within that group		
Identity Groups	TLA identity groups shall facilitate "interest" areas for learner to receive notifications (i.e. rather than just being pushed)		
Identity Groups	TLA identity groups shall interface with the alert and notification system		
Identity Groups	The TLA identity groups shall be discoverable in federations for determining applicability of learning event records		
Identity Groups	Users shall be able to create and subscribe to unprotected user interest groups		
Identity Groups	OICS and administrators shall be able to create protected interest groups and assign users to them	2019	Class creation

Header	Requirement	Priority	Comments
User Data			
User Data	Identity management services shall be able to assign personal attribute data		DIV-2
User Data	Identity management services shall be able to assign personas to a user		DIV-2
User Data	Identity management services shall be able to assign privacy data to user records	P4STLA	
User Data	Identity management services shall be able to reconcile UUID to person identity in back-end services		As applicable for 2019
User Data	Identity management services shall be able to reconcile identity across enclaves (i.e. between different anonymization tokens)	2019	
User Data	Identity management services shall be able to export a user record audit		
User Data	Identity management services shall be able to implement dynamic multi-factor authentication		
User Data	Identity management services shall be able to resolve internal identity tokens to a globally unique identity		
User Data	Identity management services shall integrate with privacy controls to prevent access to data based on locally managed policies		
User Data	The access policy manager shall include local, regional and global business rules for data access		
User Data	User data shall incorporate proper encryption/decryption for identity tokens and personal data		
User Data	User data shall be resolvable between individuals and identity groups, and between multiple local identity tokens		

3.2.6 Virtualization Management

This is a back-end service required for TLA cloud based, federated operation. Most of these services are provided natively in cloud-based providers like Amazon Web Services (used in the TLA Reference Implementation) and are at the heart of the DEVOPS method. Additional edge devices may use their own approaches to managing network resources, and they must comport to the rules established for the TLA and its native hosting environment. System-level performance requirements are also located here. **Table 6** lists the detailed requirements.

Table 6. Detailed requirements for Virtualization Services.

Header	Requirement	Priority	Comments
Virtualization Management Service			
Virtualization Management Service	TLA compliant components shall utilize back-end services for dynamic endpoint management between components, data, and services.	2019	
Virtualization Management Service	TLA compliant systems shall enable federated data services between enclaves	2019	
Virtualization Management Service	TLA compliant systems shall leverage trusts between back-end identity management services	2019	
Virtualization Management Service	TLA compliant systems shall have a configuration capability that registers service and data providers that operate within the enclave, to include back-end services and data portability between adjacent ecoservices.	2019	

Header	Requirement	Priority	Comments
Virtualization Management Service	TLA compliant systems shall have a configuration capability that registers service and data providers that are federated to the enclave, to include Simulators, digital devices, and remote hosted content or learning management systems	2019	May be manual file for 2019, "content in the wild"
Virtualization Management Service	TLA compliant systems portal shall use a RESTful implementation to connect to enclave and federated data services	2019	Intent to use Open API and REST as part of TLA interface spec and federation development process
Virtualization Management Service	TLA compliant systems shall provide a registration service for all enclave and federated data sources to manage URI blocks, permission holders, and path name/URL/IP for resources	2019	Works with governance system above to provide physical registry
Virtualization Management Service	TLA compliant systems shall utilize mechanisms to dynamically track and update network and physical hosting of virtual private networks, computational resources and containers in a contracted Platform as a service (cloud) environment	2019	AWS back-end
Virtualization Management Service	TLA compliant systems shall verify core data and services (competency and learner profile, LRS/Learning event, management, experience catalog, Competency Management Service, competency framework, learner profile) are available to conduct training session		System health diagnostics
Virtualization Management Service	TLA compliant systems shall have sufficient load balancing, failover, and redundancy to maintain Ao >98%		AWS back-end
Virtualization Management Service	TLA compliant systems shall have data backups to prevent loss of data even in event of core data or service failure		AWS back-end
Virtualization Management Service	TLA compliant systems shall have sufficient memory and storage resources to maintain 10 years of credential trust audit trail (i.e. preservation of reviews and awards)		Server sizing
Virtualization Management Service	TLA compliant systems shall have sufficient memory and storage resources to maintain evidentiary records for competency in accordance with local regulations		Server sizing
Virtualization Management Service	TLA compliant systems shall have sufficient memory and computational power for 90% peak duty cycle for 120% of projected user base	2019	Rough sizing for experiments as well as deployed systems
Virtualization Management Service	TLA compliant systems shall have a security audit system that logs server down time, VM load shifting, attempted communication time outs, unauthorized users or devices, and rejected xAPI statements		AWS back-end
Virtualization Management Service	TLA compliant systems shall implement NIST 800 controls for identity, access, zero trust device management, behavioral controls and authentication.		
Interfaces			
Interfaces	The portal shall enable single sign on for all subordinate services accessed through the portal	2019	Keycloak
Interfaces	TLA compliant systems shall use existing back-end services (e.g. LDAP/Active Directory) for identity management		2019 Objective

Header	Requirement	Priority	Comments
Interfaces	TLA compliant systems shall provide an access point to Virtual Private Cloud resources for client devices in the federation	2019	
Interfaces	TLA compliant systems shall comply with cybersecurity policies for the installed enclave		

3.2.7 Edge Devices

TLA edge devices include all learning record providers that create learning or assessment opportunities. The TLA supports any edge system topology as long as the boundary is compliant with the TLA internal interfaces and business rules. External topologies within the ecosystem may include fully TLA compliant devices, server-based systems that manage their own client communications and report compliant xAPI from the server, or systems with their own LRS and profiles, with gateway systems on the boundary to convert internal data to TLA compliant data. Detailed Requirements are listed in **Table 7.**

Table 7. Edge Device Requirements.

Header	Requirement	Priority	Comments
Learning Device Requirements			
Learning Device Requirements	Learning devices shall have a boundary to the TLA core that conforms to the MOM profile for xAPI messages	2019	
Learning Device Requirements	Learning device content packaging shall use the same lowest level grain size for independent "bookmarks", performance reporting, and catalog registration metadata		For single SCO content with complex courses, or ITS or self-regulated devices where some of the device manages activity sequencing independent of core
Learning Device Requirements	Learning device boundaries shall synchronize user identity with core identity management		As required for 2019
Learning Device Requirements	Learning devices shall be registered with the Experience Index as activities and resources	2019	
Learning Device Requirements	Learning devices shall comply with cybersecurity requirements for the local enclave		
Learning Device Requirements	"Bring Your Own" learning devices shall comply with zero trust risk architectures		In-the-wild devices
Learning Device Requirements	Learning devices shall be deployed as LTI Tools in conjunction with the launch features of the LEM		Investigate for 2020
Learning Device Requirements	Learning devices with locally installed content shall synchronize that content identification with the Experience Index	2019	
Learning Device Requirements	Learning devices shall use noisy LRS if they generate xAPI that does not conform to the MOM profile	2019	
Learning Device Requirements	Learning devices with their own profile shall register that profile IAW IEEE P9274.2.1		
Learning Device Requirements	Learning device boundaries shall register endpoints to transactional LRS as part of device registration		As required for 2019
Learning Device Requirements	All performance adjudication shall be performed outside of the core boundary	2019	
Learning Device Requirements	Learning devices that perform fine grained performance adaptation shall be registered at the highest level and report lower level results as required		Investigating competency object "ownership"

3.3 External Interface Requirements

The TLA ecosystem relies on several DoD level data repositories to work and can leverage non-education and training databases to provide additional capabilities for education and training.

3.3.1 Enterprise Learner Record Repository (ELRR) Registry

Each instance (i.e. “enclave”) of TLA compliant computational assets will have its own learner profile with learner records. Organizations will have equities in their own data but will lack visibility to users outside of their own purview. Learners will move from organization to organization throughout a career. The approach taken with the ELRR Registry is to keep authoritative data with the owners of the systems where these data are generated. Therefore, not every record associated with a learner is in the same database. This requires a federated approach to managing trusted, authoritative data where this information is pulled as needed from the authoritative data stores.

A central mechanism to aggregate and reconcile these disparate data is needed to provide a complete portrait of learner performance. Currently, all records are copied and centralized, with error correction being an infrequent manual process. The TLA architecture conceives of a centralized registry that lists locations for all users where any records would be located, enabling discovery, but where the actual records would be served up from the individual providers. Service requests will come as encrypted Representational State Transfer (REST) calls using the UUID for each learner.

3.3.2 Enterprise Course Catalog (ECC) Registry

Like the ELRR registry, multiple sites may have activity and content registered as an available course. Not every site will own course content, but actual assignments of course ownership (e.g. curriculum control managers) will probably change slowly. The ECC registry aids in the discovery of all locations that report course content -- to include integration with existing systems such as the Catalog of Naval Training Courses (CANTRAC).

3.3.3 DoD Schema Control

The JavaScript Object Notation (JSON) provides for the use of linked data, which must trace back to the schema.org repository. Schema.org is not globally accessible from .mil or protected network assets, so a DoD unique repository is required at each security enclave to replicate the functionality. Schema control and linked data is essential to preserving the chains of custody and evidence without performance degradation that comes from retransmitting the entire list every time. Linked data provides for data integrity, and disaster resiliency, and the schema repository anchors the linked data strategy

3.3.4 Universal Unique Identification (UUID)

The UUID provides a globally unique way of referencing all DoD personnel without resorting to PPI such as name, social security number, etc. The UUID and third-party logins provide a federated way to acknowledge user identity as they move through the ecosystem, while still preserving the local anonymization protocols for PII segmentation. The UUID are foundational to non-repudiation and data integrity to provide enterprise-level data analytics and complete portraits of performance. For the DoD, a potential unclassified enclave UUID is the Electronic Data Interchange Personal Identifier (EDIPI) or Common Access Card (CAC) token that traces back to the Defense Enrollment Eligibility Reporting System (DEERS), an authoritative data source for DoD personnel identity. The UUID is used to support Federated Identity, Credential, and Access Management (FICAM).

TOTAL LEARNING ARCHITECTURE

2019 Report - Appendix B - Draft MOM Specification

Prepared by
The ADL Initiative

IEEE Draft Standard for Learning Technology — JavaScript Object Notation (JSON) Binding of Experience API (xAPI) Data for the Total Learning Architecture (TLA)

Sponsor

Learning Technology Standards Committee
of the
IEEE Computer Society

This document is a **draft** of a proposed IEEE Standard and is intended to facilitate discussion, understanding, and improvements in how learner data are communicated between activities, devices, systems, platforms, and institutional boundaries. While this document follows the IEEE format for a specification, it has *not* been formally submitted into a standards working group. As such, this document is subject to change. USE AT YOUR OWN RISK!

IEEE Standards Department
445 Hoes Lane
Piscataway, NJ 08854, USA

Abstract: This Standard defines a controlled vocabulary and key processes to be followed when communicating learner data between activities, content, devices, systems, platforms, and organizational/institutional boundaries. It uses the IEEE Standard xAPI (9274.1.1) and the associated xAPI Profile standard (9274.3.1) to define how components of the Total Learning Architecture (TLA) communicate, store, and propagate learning information between computational and data assets located throughout the Future Learning Ecosystem. It provides a JavaScript Object Notation (JSON) binding of such data that is also conformant to the IEEE xAPI Profile Standard.

Keywords: 9274.1.1, 9274.3.1, JavaScript Object Notation, JSON, Experience API, xAPI, Total Learning Architecture, TLA, Profile, xAPI Profile

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Participants

At the time this Standard was completed, the JavaScript Object Notation (JSON) Binding of Experience API (xAPI) Data for the Total Learning Architecture (TLA) Working Group had the following membership:

TBD, *Chair* **Jerry Gordon, Andy Johnson, and Florian Tolk, *Technical Editors***		

The following individual members of the balloting committee voted on this Standard. Balloters may have voted for approval, disapproval, or abstention.

Also included are the following nonvoting IEEE–SA Standards Board liaisons:

Introduction

(This introduction is not part of IEEE Std 9274.3.2, JavaScript Object Notation (JSON) Binding of Experience API (xAPI) Data for the Total Learning Architecture (TLA).

This Standard defines a set of controlled vocabulary and processes to be followed when the IEEE Standard xAPI (9274.1.1) is used in an environment categorized as conformant to the Total Learning Architecture. It provides a JSON binding of such data that is also conformant to the IEEE xAPI Profile Standard (9274.3.1). This standard defines the structure and constraints of JSON data in this environment.

The purpose of this Standard is to allow the creation of semantically interoperable instances of learning data services exchanging xAPI across learning environments that adopt the TLA. This Standard uses a JSON encoding that is also conformant to the xAPI and xAPI Profile standards, which allows for interoperability and the exchange of xAPI data between all components of the TLA.

Table of Contents

IEEE Standard for Learning Technology—JavaScript Object Notation (JSON) Binding of Experience API (xAPI) Data for the Total Learning Architecture (TLA)

1.0 Overview

The scope and purpose of this Standard are discussed in sections 1.1 and 1.2.

1.1 Scope

This Standard defines a set of controlled vocabulary and processes to be followed when the IEEE Standard xAPI (9274.1.1) is used in an environment categorized as conformant to the Total Learning Architecture. It provides a JSON binding of such data that is also conformant to the IEEE xAPI Profile Standard (9274.3.1). This standard defines the structure and constraints of JSON data in this environment. This standard may be used as an xAPI profile in that elements of this standard may be extracted and used in other profiles, or independent of a TLA-conformant technology.

1.2 Purpose

The purpose of this Standard is to allow the creation of interoperable xAPI instances across learning environments that adopt the TLA. This Standard uses a JSON encoding that is also conformant to the xAPI and xAPI Profile standards, which allows for interoperability and the exchange of xAPI data between all components of the TLA.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).[1,2]

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2.0 Normative references

The following referenced documents are indispensable for the application of this Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

[1] The use of the word *must* is deprecated and shall not be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

[2] The use of *will* is deprecated and shall not be used when stating mandatory requirements, *will* is only used in statements of fact.

- IEEE Std 9274.1.1, Experience API (xAPI) Standard.[3]
- IEEE Std 9274.3.1, Experience API (xAPI) Profile Standard.[4]
- Cmi5 Specification [5]
- RFC 8256: The JavaScript Object Notation (JSON) Data Interchange Format[6]

3.0 Definitions, acronyms, and abbreviations

Definitions and acronyms are defined in sections 3.1 and 3.2, respectively.

3.1 Definitions

For the purposes of this Standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B7][7] should be referenced for terms not defined in this clause.

Actor: An individual, organization, technology, or other provider of data within a learning experience or acting within the TLA. In an xAPI statement, the "doer" of the statement.

Authoritative LRS: A classification of LRS that stores a record of learner proficiency that is aligned with an individual's associated competency frameworks. It has the purpose of disallowing certain persons access to certain types of data. Only an Observer, Instructor, Controller, Supervisor (OICS) can access an authoritative LRS. The Authoritative LRS stores digitally signed xAPI records of conferred credentials and other competency assertions.

Competency: Formally defined, organized, and structured description of knowledge, skills, attributes, and other (KSAOs) characteristics that can be used to manage human capital. Each competency can have a wide range of associated metadata (e.g. description, type, scope, level, and context) and associated resources (e.g. assessments, operations manuals, and training content).

Competency Framework: A data model for describing, referencing, and sharing competency definitions, primarily in the context of learning and development. It provides a formal representation of the key characteristics of a competency, independently of its use in any particular context. It enables interoperability among learning systems that deal with competency information by providing a means for them to refer to common definitions with common meanings.

Experience API (xAPI): An IEEE Standard (9274.1.1) that establishes data formats and protocols for learning experience data. Most of the requirements around the creation, storage, and retrieval of JSON data.

JavaScript Object Notation (JSON): A format of JavaScript that has specific structure and properties. These include use of structured name/value pairs and an ordered list of values.

Learning Record Provider (LRP): A system/service that creates xAPI data and sends it to an LRS. An LRP is responsible for the quality and structure of xAPI data.

Learning Record Store (LRS): The basic storage and retrieval web service, often implemented as a system, for xAPI data.

Master Object Model (MOM): The TLA policy framework includes a Master Object Model (TLA MOM) that specifies event triggers between TLA core components. The TLA MOM is an xAPI profile that defines the activity streams that create the events to manage the TLA federation execution.

Noisy LRS: An LRS without additional data restrictions seen in an Authoritative LRS. This LRS is typically associated with a specific learning activity, device, or system and is used to house all xAPI statements generated by that system. These

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[3] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

[4] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

[5] https://github.com/AICC/CMI-5_Spec_Current/blob/quartz/cmi5_spec.md

[6] https://tools.ietf.org/html/rfc8259

[7] The numbers in brackets correspond to those of the bibliography in Annex A.

statements are used to drive additional interventions or functionality within that system but only the TLA MOM verbs are communicated to other TLA components or activities.

Observer/Instructor/Controller/Supervisor (OICS): An actor with increased permission to access learner data. The only allowable user of an authoritative LRS.

Profile: Additional rules to be applied from a base specification. This document is a profile of xAPI, meaning that to be conformant to the profile, the technology shall also be conformant to xAPI.

Statement: A basic unit of learning experience data as defined in the xAPI standard. A statement is formatted using JSON and has among its properties, actor, verb, and object.

Total Learning Architecture (TLA): A research and development activity sponsored by the ADL Initiative and conducted in collaboration with stakeholders from across the defense community, professional standards organizations, and commercial industry. The TLA project will result in a collection of policy, specifications (including this document), and standards for connecting "any device, anywhere, any time" to generate learning-related data enabling next-generation learning that is integrated, personalized, and data-driven.

Transactional LRS: An LRS without additional data restrictions seen in an authoritative LRS. While the noisy LRS collects all xAPI statements, the transactional LRS only collects learner data that is conformant to the TLA Master Object Model (MOM). This allows learner performance information to be normalized as it is processed by a Competency Management System. A transactional LRS is trusted within TLA.

Verb: The most defining property in an xAPI statement – the "action" of the statement. A verb is an IRI, often shortened when being described, that uniquely identifies a tracked interaction.

3.2 Acronyms and abbreviations

The following acronyms and abbreviations are commonly used in this document.

- JSON – JavaScript Object Notation
- LRP: Learning Record Provider
- LRS: Learning Record Store
- OICS: Observer/Instructor/Controller/Supervisor
- TLA: Total Learning Architecture
- xAPI: Experience API

4.0 Conformance

Conformance to this Standard is discussed in sections 4.1 through 4.5. Please see Section 1.3, Word Usage, to determine the nature of requirements found in this section. The TLA proscribes multiple levels of conformance. There are requirements for conformance that are both in-scope and out of the scope of this document. The requirements for xAPI data are listed in sections 4.1 through 4.5. It is expected that all TLA systems, such as LRS and LRP, follow the requirements appropriate to their function in a TLA environment.

4.1 TLA conformance level 1

An instance of TLA level 1…

- Shall conform to the xAPI Standard
- Shall conform to the xAPI Profile Standard
- Should conform to the cmi5 Specification (regarding xAPI statements)
- Shall implement general requirements as found in section 5.1
- Shall implement statements using the "certified" verb with all requirements fulfilled from section 5.1.36
- Should implement statements using the "completed" verb. If implemented, shall be done so with all requirements fulfilled from section 5.1.3

- Should implement statements using the "passed" verb. If implemented, shall be done so with all requirements fulfilled from section 5.1.4
- Should implement statements using the "failed" verb. If implemented, shall be done so with all requirements fulfilled from section 5.1.5
- Shall implement statements using the "success" result in at least one of the statements that use the "completed," "passed," or "failed" verbs
- May implement statements with verbs found in section 5.1. If implemented, shall be done so with all requirements fulfilled from the corresponding section in 5.1
- May implement statements with verbs not found in this specification
- Shall send statements to their appropriate LRS as defined in section 5.2
- Should generate statements in appropriate systems as defined in section 5.3

4.2 TLA conformance level 2

An instance of TLA level 2…

- Shall follow requirements of all TLA level 1
- Shall conform to the cmi5 Specification (regarding xAPI statements)
- Shall implement statements using the "completed" verb with all requirements fulfilled from section 5.1.3
- Shall implement statements using the "passed" verb with all requirements fulfilled from section 5.1.4
- Shall implement statements using the "passed" verb using the "success" result property if the object type is "assessment"
- Shall implement statements using the "failed" verb with all requirements fulfilled from section 5.1.5
- Shall implement statements using the "failed" verb using the "success" result property if the object type is "assessment"
- Shall implement statements using the "launched" verb with all requirements fulfilled from section 5.1.2
- Shall implement statements using the "initialized" verb with all requirements fulfilled from section 5.1.9
- Shall implement statements using the "waived" verb with all requirements fulfilled from section 5.1.1
- Shall implement statements using the "satisfied" verb with all requirements fulfilled from section 5.1.6
- Shall implement statements using the "abandoned" verb with all requirements fulfilled from section 5.1.7
- Shall implement statements using the "terminated" verb with all requirements fulfilled from section 5.1.8

4.3 TLA conformance level 3

An instance of TLA level 3…

- Shall follow requirements of all TLA level 1-2
- Shall implement authority in xAPI statements that use verbs that require an authoritative source, as defined in section 5.1
- Shall implement statements using the "assessed" verb with all requirements fulfilled from section 5.1.26
- Shall implement statements using the "contextualized" verb with all requirements fulfilled from section 5.1.27
- Shall implement statements using the "located" verb with all requirements fulfilled from section 5.1.28
- Shall implement statements using the "socialized" verb with all requirements fulfilled from section 5.1.29
- Shall implement statements using the "captured" verb with all requirements fulfilled from section 5.1.30
- Shall implement statements using the "asserted" verb with all requirements fulfilled from section 5.1.31
- Shall implement statements using the "validated" verb with all requirements fulfilled from section 5.1.32
- Shall implement statements using the "inferred" verb with all requirements fulfilled from section 5.1.33
- Shall implement statements using the "qualified" verb with all requirements fulfilled from section 5.1.34
- Shall implement statements using the "certified" verb with all requirements fulfilled from section 5.1.35
- Shall implement statements using the "verified" verb with all requirements fulfilled from section 5.1.36
- Shall implement statements using the "conferred" verb with all requirements fulfilled from section 5.1.37

4.4 TLA conformance level 4

An instance of TLA level 4…

- Shall follow requirements of all TLA level 1-3
- Shall implement statements using the "organized" verb with all requirements fulfilled from section 5.1.11
- Shall implement statements using the "prioritized" verb with all requirements fulfilled from section 5.1.12
- Shall implement statements using the "curated" verb with all requirements fulfilled from section 5.1.13
- Shall implement statements using the "projected" verb with all requirements fulfilled from section 5.1.14
- Shall implement statements using the "recommended" verb with all requirements fulfilled from section 5.1.10
- Shall implement statements using the "planned" verb with all requirements fulfilled from section 5.1.15
- Shall implement statements using the "requested" verb with all requirements fulfilled from section 5.1.16
- Shall implement statements using the "approved" verb with all requirements fulfilled from section 5.1.17
- Shall implement statements using the "augmented" verb with all requirements fulfilled from section 5.1.18
- Shall implement statements using the "explored" verb with all requirements fulfilled from section 5.1.19
- Shall implement statements using the "clarified" verb with all requirements fulfilled from section 5.1.20
- Shall implement statements using the "directed" verb with all requirements fulfilled from section 5.1.21
- Shall implement statements using the "scheduled" verb with all requirements fulfilled from section 5.1.22
- Shall implement statements using the "evaluated" verb with all requirements fulfilled from section 5.1.23
- Shall implement statements using the "tracked" verb with all requirements fulfilled from section 5.1.24
- Shall implement statements using the "surveyed" verb with all requirements fulfilled from section 5.1.25

4.5 TLA conformance level 5

An instance of TLA level 5…

- Shall follow requirements of all TLA level 1-4
- Shall implement statements using the "recruited" verb with all requirements fulfilled from section 5.1.38
- Shall implement statements using the "appraised" verb with all requirements fulfilled from section 5.1.39
- Shall implement statements using the "detailed" verb with all requirements fulfilled from section 5.1.40
- Shall implement statements using the "mobilized" verb with all requirements fulfilled from section 5.1.41
- Shall implement statements using the "employed" verb with all requirements fulfilled from section 5.1.42
- Shall implement statements using the "schooled" verb with all requirements fulfilled from section 5.1.43
- Shall implement statements using the "promoted" verb with all requirements fulfilled from section 5.1.44
- Shall implement statements using the "screened" verb with all requirements fulfilled from section 5.1.45
- Shall implement statements using the "selected" verb with all requirements fulfilled from section 5.1.46
- Shall implement statements using the "reclassified" verb with all requirements fulfilled from section 5.1.47
- Shall implement statements using the "released" verb with all requirements fulfilled from section 5.1.48
- Shall implement statements using the "restricted" verb with all requirements fulfilled from section 5.1.49

5.0 TLA xAPI JSON-binding definition

A TLA solution is "learner-centric." This means all learner activity should be retrievable from any LRS (e.g., even those with minimally conformant behavior) through the querying mechanism in the xAPI standard. This standard describes the reporting portion of a TLA solution, which decentralizes state management within the systems. Most of this management is done through the use of xAPI statements. Any TLA data reporting that is not xAPI is beyond the scope of this specification. Sections 5.1-5.3 describe the data requirements of xAPI statements within the TLA. A comprehensive description of the use of TLA data can be found in Annex E.

5.1 Statement data requirements

This section describes requirements for xAPI statements within the TLA. An xAPI statement has an actor, verb, and object, and other properties. A statement is from an authoritative source if and only if the authority property is traceable back to the statement provider.

- xAPI statements shall be conformant to the xAPI Standard

- xAPI statements using verbs in this document shall implement properties as described (see Note below) in the templates in sections 5.1.1-5.1.49
- xAPI statements using verbs in this document may implement properties that are not represented in the templates in sections 5.1.1-5.1.49
- xAPI statements shall be constructed such that the learner is represented by the actor, object, a specific context extension as represented by the templates in sections 5.1.1-5.1.49
- The actor in any xAPI statement shall be of object type "Agent"
- The actor in any xAPI statement shall contain an "account, even if the actor is not the learner"

Each verb in an xAPI statement determines which template to follow, corresponding to a specific piece of learning evidence that is tracked. The naming convention of these verbs indicates an active model, where the actor is the "doer" of the verb. The learner is an integral part of every xAPI statement. When an xAPI statement is sent directly as a result of the learner's action, such as a user requesting to take a course, the actor of that statement is the learner. When something is happening to the learner as a result of another actor, such as an instructor or system, the learner is represented in a context extension, such that the activity may remain in the object portion of the statement. The rationale for this design is to minimize the number of necessary extensions within this profile, instead of relying on Activity types that the LRS can keep definitions of more easily. All other necessary requirements for xAPI statement properties, in addition to those in the xAPI Standard, are listed in the xAPI Profile templates listed in sections 5.1.1-5.1.49. Among these properties are objects with type "activity," which often represent the learning construct of the statement. More information about each type of object can be found in Annex D.

Note: Any property listed in a template with a specific value (including booleans) shall retain that value in a statement created that follows the template. In properties where there is not a specific value, these templates contain in capital letters requirements that shall be followed. These requirements are not "shall" "should" or "shall not" but should be translated as such. The use of "RECOMMENDED" in the template indicates a "should" requirement. The use of "EXCLUDED" in the template indicates a "shall not" requirement. The use of "REQUIRED" in the template indicates a "shall" requirement. These requirements may be accompanied by an explanatory text and/or other requirements on the data. The use of brackets indicates a choice of one or more of the elements within the bracket.

5.1.1 Waived

Verb:

id: "https://w3id.org/xapi/adl/verbs/waived",

display: "waived",

definition: "Indicates that the learning activity requirements were met by means other than completing the activity. A waived statement indicates the actor may skip the activity."

Object:

id: "",

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity",

"https://w3id.org/xapi/tla/activity-types/assessment",

"https://w3id.org/xapi/tla/activity-types/competency"]

5.1.2 Launched

Verb:

id: "http://adlnet.gov/expapi/verbs/launched",

display: "launched",

definition: “Indicates the user started a service. This does not always need to be a specific activity but can be a service provider as well.”

Object:

id: “”,

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/competency"]

Context:

Context Activities: EXCLUDED

5.1.3 Completed

Verb:

id: “http://adlnet.gov/expapi/verbs/completed”,

display: “completed”,

definition: “Indicates the actor finished or concluded the activity normally”

Object:

id: “”,

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/assessment"]

Result:

Success: RECOMMENDED

Duration: RECOMMENDED

5.1.4 Passed

Verb:

id: “http://adlnet.gov/expapi/verbs/passed”,

display: “passed”,

definition: “Indicates the actor completed an activity to the standard”

Object:

id: “”,

objectType: Activity

definition:

type: “https://w3id.org/xapi/tla/activity-types/assessment"

Result:

Score:

Scaled: RECOMMENDED

Success: TRUE

Completion: TRUE

5.1.5 Failed

Verb:

id: “http://adlnet.gov/expapi/verbs/failed”,

display: “failed”,

definition: “Indicates the actor did not complete an activity to standard”

Object:

id: “”,

objectType: Activity

definition:

type: “https://w3id.org/xapi/tla/activity-types/assessment"

Result:

Score:

Scaled: RECOMMENDED

Success: FALSE

Completion: TRUE

5.1.6 Satisfied

Verb:

id: “https://w3id.org/xapi/adl/verbs/satisfied”,

display: “satisfied”,

definition: “Indicates that the authority or activity provider determined the actor has fulfilled the criteria of the object or activity by means other than completing the activity”

Object:

id: “”,

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/assessment"]

5.1.7 Abandoned

Verb:

id: “https://w3id.org/xapi/adl/verbs/abandoned”,

display: “abandoned”,

definition: “Indicates that the activity or session was abnormally terminated by a learner's action (or due to a system failure)”

Object:

id: “”,

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/assessment"]

Result:

Duration: RECOMMENDED

The duration property should, at a minimum, be set as the total session time, calculated as the time between the 'launched' statement and the last statement (of any kind) issued by the exercise. Implementers should also use other (software specific) methods (if available) to determine if the total session time was longer.

Completed: FALSE

5.1.8 Terminated

Verb:

id: “http://adlnet.gov/expapi/verbs/terminated”,

display: “terminated”,

definition: “Indicates the actor has completed their session normally”

Object:

id: “”,

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/assessment"]

Result:

Duration: RECOMMENDED

The duration property should, at a minimum, be set as the total session time, calculated as the time between the 'launched' statement and the last statement (of any kind) issued by the exercise. Implementers should also use other (software-specific) methods (if available) to determine if the total session time was longer.

Completed: FALSE

5.1.9 Initialized

Verb:

id: “http://adlnet.gov/expapi/verbs/initialized”,

display: “initialized”,

definition: “Indicates that the activity was started.”

Object:

id: “”,

objectType: Activity

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/assessment"]

Result: EXCLUDED

5.1.10 Recommended

Verb:

id: “http://w3id.org/xapi/tla/verbs/recommended”,

display: “recommended”,

definition: “Indicates the learner was given the recommendation to follow a career path, work toward a learning objective, or perform a learning activity by the actor”

Object:

id: “”,

objectType: REQUIRED

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.11 Prioritized

Verb:

id: “http://w3id.org/xapi/tla/verbs/prioritized”,

display: “prioritized”,

definition: “Indicates the actor filtered goals associated with select content, usually listing what competencies are demonstrated in recently viewed content”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

This will be an array of activities that were used in the query.

5.1.12 Organized

Verb:

id: “http://w3id.org/xapi/tla/verbs/organized”,

display: “organized”,

definition: “Indicates the actor filtered content that aligns to specific goal”

Object:

id: “”,

objectType: REQUIRED

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

This will be an array of the viewed or completed Competencies

5.1.13 Curated

Verb:

id: “http://w3id.org/xapi/tla/verbs/curated”,

display: “curated”,

definition: “Indicates the actor was presented a list of activity recommendations over time, based on selected goal with recursive depth, and learner preferences, what set of content will achieve mastery in the ordered sub-goals”

Object:

id: “”,

definition:

type: RECOMMENDED

Result:

Extensions:

https://w3id.org/xapi/tla/extensions/recommendation_order: REQUIRED

This is an array of just activity recommendations statement references, in the order they were provided

5.1.14 Projected

Verb:

id: “http://w3id.org/xapi/tla/verbs/projected”,

display: “projected”,

definition: “Indicates the actor was presented a list of goal recommendations over time, based on selected goal with recursive depth, what set of content can achieve mastery in the ordered sub-goals”

Object:

id: “”,

definition:

type: RECOMMENDED

Result:

Extensions:

https://w3id.org/xapi/tla/extensions/recommendation_order: REQUIRED

This is an array of just activity recommendations statement references in the order they were provided

5.1.15 Planned

Verb:

id: “http://w3id.org/xapi/tla/verbs/planned”,

display: “planned”,

definition: “Indicates that the actor assigned themselves a new learning goal, without needing approval”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

5.1.16 Requested

Verb:

id: “https://w3id.org/xapi/adb/verbs/requested”,

display: “requested”,

definition: “Indicates the actor needed or demanded an object or another actor. Requested indicates a comment that is shared with peers as a group or Coach as a trainer. The request to coach or help prompts users to respond by giving them coaching credit.”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

5.1.17 Approved

Verb:

id: “http://w3id.org/xapi/tla/verbs/approved”,

display: “approved”,

definition: “Indicates an OICS approved a requested activity for the given learner.”

Object:

id: “”,

SHOULD be the ID of the “Requested” Statement being approved

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

Context:

Extensions:
https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.18 Augmented

Verb:

id: “http://w3id.org/xapi/tla/verbs/augmented”,

display: “augmented”,

definition: “Indicates the actor searched content on an active learning goal, viewing what other goals/branches can be related based on an active goal tree”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

This should be a resolvable identifier to the learning goal(s) used for this augmented event, but is open-ended to allow future mechanisms

5.1.19 Explored

Verb:

id: “http://w3id.org/xapi/tla/verbs/explored”,

display: “explored”,

definition: “Indicates the actor searched active learning goals related to specific content, viewing what other content may trigger related goals, based on the active goal and recently completed content”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

It should be a resolvable identifier to the learning goal(s) used for this explored event but is open-ended to allow future mechanisms

5.1.20 Clarified

Verb:

id: “http://w3id.org/xapi/tla/verbs/clarified”,

display: “clarified”,

definition: “Indicates the actor queried what other content may also reinforce the current learning goal, after completing content”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

It should be a resolvable identifier to the content and goal(s) used for this clarified event but is open-ended to allow future mechanisms

5.1.21 Directed

Verb:

id: “http://w3id.org/xapi/tla/verbs/directed”,

display: “directed”,

definition: “Indicates the actor was assigned a learning goal by another party”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

It shall be the learner to whom this data applies

5.1.22 Scheduled

Verb:

id: “http://w3id.org/xapi/tla/verbs/scheduled”,

display: “scheduled”,

definition: “Indicates the actor scheduled an activity or lesson”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/due_date: REQUIRED[8] https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.23 Evaluated

Verb:

id: “http://w3id.org/xapi/tla/verbs/evaluated”,

display: “evaluated”,

definition: “Indicates the learner(s) appeared in a Measure of Effectiveness (MOE) search”

Object

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.24 Tracked

Verb:

id: “http://w3id.org/xapi/tla/verbs/tracked”,

display: “tracked”,

definition: “Indicates the learner(s) appeared in a competency search”

Object:

id: “”,

definition:

type: "https://w3id.org/xapi/tla/activity-types/competency"

Result: EXCLUDED

Context:

---

[8] Prior to IEEE Standardization of xAPI, the following requirement existed: *This shall be in the same time zone and format as the rest of the timestamps in this statement*

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.25 Surveyed

Verb:

id: “http://w3id.org/xapi/tla/verbs/surveyed”,

display: “surveyed”,

definition: “Indicates the learner(s) appeared in a Measure of Performance (MOP) search”

id: “”,

shall point to a node in the Competency Management System with type of MOP

definition:

type:

["https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.26 Assessed

Verb:

id: “http://w3id.org/xapi/tla/verbs/assessed”

display: “assessed”,

definition: “Indicates the actor completed assessments in a way that will cause a change in their authoritative learner state”

Object:

id: “”,

definition:

type: "https://w3id.org/xapi/tla/activity-types/competency"

Result:

Duration: RECOMMENDED

Completed: EXCLUDED

Score:

Scaled: RECOMMENDED

Success: REQUIRED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the assessed competency, -1 being sure they have not, and 1 being certain they have

5.1.27 Contextualized

Verb:

id: “http://w3id.org/xapi/tla/verbs/contextualized”

display: “contextualized”,

definition: “Indicates the user performed several connected learning activities that should result in a change in their authoritative learner state”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/competency

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the assessed competency, -1 being sure they have not, and 1 being certain they have

5.1.28 Located

Verb:

id: “http://w3id.org/xapi/tla/verbs/located”

display: “located”,

definition: “Indicates the actor's competency state needs to be updated based on completed content changes in the Competency Framework”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/competency

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the located competency, -1 being sure they have not, and 1 being certain they have

5.1.29 Socialized

Verb:

id: “http://w3id.org/xapi/tla/verbs/socialized”,

display: “socialized”,

definition: “Indicates the learner interacted with \"Wild\" (unscheduled) content in a social environment”

Object

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

5.1.30 Captured

Verb:

id: “http://w3id.org/xapi/tla/verbs/captured”,

display: “captured”,

definition: “Indicates the learner interacted with \"Wild\" (unscheduled) content in a social environment”

Object

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/activity_cluster”,

"https://w3id.org/xapi/tla/activity-types/assessment”,

"https://w3id.org/xapi/tla/activity-types/activity"]

Result: EXCLUDED

5.1.31 Asserted

Verb:

id: “http://w3id.org/xapi/tla/verbs/asserted”

display: “asserted”,

definition: “Indicates the learner has provided sufficient evidence to update the learner's measure of competence in a given competency”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/competency

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the competency, -1 being sure they have not, and 1 being certain they have

5.1.32 Validated

Verb:

id: “http://w3id.org/xapi/tla/verbs/validated”

display: “validated”,

definition: “Indicates an OICS approved a change to a competency framework within the TLA that will affect the learners’ states”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/competency

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI asserted statement was just validated

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the competency, -1 being sure they have not, and 1 being certain they have

5.1.33 Inferred

Verb:

id: “http://w3id.org/xapi/tla/verbs/inferred”

display: “inferred”,

definition: “Indicates an authoritative source changed a learner's competency assertions based on a valid competency framework change”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/competency

Result: EXCLUDED

Context:

Extensions:
https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the competency, -1 being sure they have not, and 1 being certain they have

5.1.34 Qualified

Verb:

id: “http://w3id.org/xapi/tla/verbs/qualified”

display: “qualified”,

definition: “Indicates the learner meets all the requirements for a badge, but hasn't been awarded the badge yet”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/badge

Result: EXCLUDED

Context:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

5.1.35 Certified

Verb:

id: “http://w3id.org/xapi/tla/verbs/certified”

display: “certified”,

definition: “Indicates the learner received an accreditation by an authoritative source to perform a given job or task”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/job

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

5.1.36 Verified

Verb:

id: “http://w3id.org/xapi/tla/verbs/verified”

display: “verified”,

definition: “Indicates the authoritative source verified evidence of learning from a non-authoritative source as reliable data”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/competency

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the competency, -1 being sure they have not, and 1 being certain they have

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.37 Conferred

Verb:

id: “http://w3id.org/xapi/tla/verbs/conferred”

display: “conferred”,

definition: “Indicates the OICS conferred a badge to the learner in the learner context extension”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/badge

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/evidence: REQUIRED

shall be a resolvable identifier to the xAPI statement(s) that resulted in this statement

https://w3id.org/xapi/tla/extensions/confidence: REQUIRED

shall be a number between -1 and 1 displaying how likely the learner is to have mastered the competency, -1 being sure they have not, and 1 being certain they have

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this statement applies to

5.1.38 Recruited

Verb:

id: “http://w3id.org/xapi/tla/verbs/recruited”

display: “recruited”,

definition: “Indicates the actor recruited the learner to join the ecosystem”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.39 Appraised

Verb:

id: “http://w3id.org/xapi/tla/verbs/appraised”

display: “appraised”,

definition: “OICS indicates the learner met entry criteria for jobs and assigned a career trajectory”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career

Result: EXCLUDED

5.1.40 Detailed

Verb:

id: “http://w3id.org/xapi/tla/verbs/detailed”

display: “detailed”,

definition: “OICS detailed the learner to a specific job”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/location: RECOMMENDED

shall be the physical location the learner has been detailed to

https://w3id.org/xapi/tla/extensions/permanent_change_of_station: RECOMMENDED

shall be a boolean marking if this is a PCS or a different detail event

https://w3id.org/xapi/tla/extensions/unit_identification_code: RECOMMENDED

shall be a unique code for the learner's unit

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.41 Mobilized

Verb:

id: “http://w3id.org/xapi/tla/verbs/mobilized”

display: “mobilized”,

definition: “OICS mobilized the learner to a state of on duty”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career_state

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/location: RECOMMENDED

shall be the physical location the learner has been mobilized to

https://w3id.org/xapi/tla/extensions/unit_identification_code: RECOMMENDED

shall be a unique code for the learner's unit

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.42 Employed

Verb:

id: “http://w3id.org/xapi/tla/verbs/employed”

display: “employed”,

definition: “OICS employs the actor such that they started work doing their job”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career_state

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/location: RECOMMENDED

shall be The physical location the learner has been employed at

https://w3id.org/xapi/tla/extensions/unit_identification_code: RECOMMENDED

shall be a unique code for the learner's unit

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.43 Schooled

Verb:

id: “http://w3id.org/xapi/tla/verbs/schooled”

display: “schooled”,

definition: “OICS has enrolled the learner in a schooling system”

Object:

id: “”,

definition:

type:

["https://w3id.org/xapi/tla/activity-types/competency”,

"https://w3id.org/xapi/tla/activity-types/career”,

"https://w3id.org/xapi/tla/activity-types/badge”,

"https://w3id.org/xapi/tla/activity-types/job"]

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/location: RECOMMENDED

shall be the physical location the learner has been employed at

https://w3id.org/xapi/tla/extensions/unit_identification_code: RECOMMENDED

shall be a unique code for the learner's unit

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.44 Promoted

Verb:

id: “http://w3id.org/xapi/tla/verbs/promoted”

display: “promoted”,

definition: “OICS has changed a learner’s rank, either up or down”

Object:

id: “”,

definition:

type: "https://w3id.org/xapi/tla/activity-types/rank"

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.45 Screened

Verb:

id: “http://w3id.org/xapi/tla/verbs/screened”

display: “screened”,

definition: “OICS screened learner for a potentially narrower career trajectory, and passed through a \"gate\" within their career trajectory”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/evidence: RECOMMENDED

The reason the learner screened for a career path should be a resolvable identifier to xAPI data

https://w3id.org/xapi/tla/extensions/epiration: RECOMMENDED

shall be a timestamp of the time the screening expires

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.46 Selected

Verb:

id: “http://w3id.org/xapi/tla/verbs/selected”

display: “selected”,

definition: “OICS selected learner based on criteria for a potentially wider career trajectory, opening up new career possibilities”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career

Result: EXCLUDED

Context

Extensions

https://w3id.org/xapi/tla/extensions/evidence: RECOMMENDED

The reason the learner was selected for a career path should be a resolvable identifier to xAPI data

https://w3id.org/xapi/tla/extensions/epiration: RECOMMENDED

shall be a timestamp of the time the screening expires

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.47 Reclassified

Verb:

id: “http://w3id.org/xapi/tla/verbs/reclassified”

display: “reclassified”,

definition: “Indicates the actor changed career paths, putting them on a completely different or brand new career trajectory”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career_state

Result: EXCLUDED

5.1.48 Released

Verb:

id: “http://w3id.org/xapi/tla/verbs/released”

display: “released”,

definition: “Indicates OICS released the learner from the learning environment”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career_state

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/reason: REQUIRED

shall be text/String that describes the reason the learner has left the learning environment

Context:

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.1.49 Restricted

Verb:

id: “http://w3id.org/xapi/tla/verbs/restricted”

display: “restricted”,

definition: “Indicates OICS temporarily restricted the learner from some (possibly all) participation within the learning environment”

Object:

id: “”,

definition:

type: https://w3id.org/xapi/tla/activity-types/career_state

Result: EXCLUDED

Context:

Extensions:

https://w3id.org/xapi/tla/extensions/restriction: REQUIRED

shall be text/String that describes the reason the learner has been restricted

https://w3id.org/xapi/tla/extensions/reason: REQUIRED

shall be the timestamp corresponding to when the restriction is lifted. May be NULL(e.g. if the restriction will not expire)

https://w3id.org/xapi/tla/extensions/learner REQUIRED

shall be the learner to whom this data applies to

5.2 LRS storage requirements

Within a TLA environment, there are different levels of trust and access for different types of LRSs. The level of trust, user roles within those systems, and transfer of data between LRSs are out of scope of this document. Brief definitions of the types of LRSs can be found in the section 3.1.

- The following requirements exist for all LRSs within a TLA environment:
- All LRSs shall conform to the xAPI Standard
- All LRSs may use the voided verb as found in the xAPI Standard. This requirement supercedes other requirements below.
- Noisy LRSs may allow statements that use any verb
- Transactional LRSs should allow all statements with verbs in section 5.1 that authoritative LRSs do not allow
    - Note: depending on the conformance level, recommended practices change. For example, at conformance levels 1 and 2, there is no expected authoritative LRS, so all data is stored in the transactional LRS.
- Transactional LRSs shall not allow statements that use any verb not in section 5.1.
- Authoritative LRSs shall not allow statements that use any verb except for the following verbs in section 5.1:

➢ qualified	➢ conferred	➢ certified
➢ validated	➢ inferred	➢ asserted
➢ verified	➢ recruited	➢ appraised
➢ detailed	➢ mobilized	➢ employed
➢ schooled	➢ screened	➢ selected
➢ promoted	➢ reclassified	➢ released

- Authoritative LRSs should allow statements that use any verb in the list above.

5.3 TLA environment reporting requirements

A TLA compliant learning environment is composed of various functional groups. Each TLA functional group serves a different role with different requirements for reporting data (sending statements to an LRS). The functional groups may exist in any number of configurations of software and hardware, as part of distinct from devices used as "learning activities" to conduct learning. It is for this reason that the following are only recommended practices, as defining what a system is or is not simply by what is reported is not sufficient.

For a description of each of the TLA systems, please refer to Annex E.

Only a competency management system shall send statements with the "certified" verb, unless the TLA environment is level 1 or 2.

5.3.1 Competency management function

A level 1 or 2 TLA environment does not have a competency management system; rather other undefined systems shall send the required statements.

A competency management system should send statements with the following verbs, as appropriate, and in accordance with the TLA conformance level as defined in section 4.1-4.5:

- surveyed
- evaluated
- tracked
- located
- assessed
- asserted
- validated
- inferred
- qualified
- verified
- conferred
- certified

A competency management system should not send statements that do not contain the verbs stated in the previous requirement.

An OICS may send statements on behalf of a competency management system.

5.3.2 Learning event management function

A learning event management system should send statements with the following verbs, as appropriate, and in accordance with the TLA conformance level as defined in sections 4.1-4.5:

- launched
- waived
- satisfied
- abandoned
- recommended
- organized
- curated
- requested
- approved
- augmented
- clarified
- directed
- prioritized
- projected
- planned
- explored
- captured

A learning event management system should not send statements that do not contain the verbs stated in the previous requirement. Learning event management may be performed by multiple systems, by manual interfaces, wholly or in part by attached learning devices as activity providers that have contextual or adaptive features, or any combination thereof. The learning event management function may exist as part of, in conjunction with, or in addition to the mechanism used to catalog representative learning experiences (e.g. an activity index, content catalog, or experience index).

An OICS may send statements on behalf of a learning experience event system.

5.3.3 Activity provider function

Activity providers are the devices that generate the learning records (i.e. LRP) in response to learners conducting learning events. Traditional Learning Management Systems (LMS) serving Shareable Courseware Object Reference Model (SCORM) compliant courseware is an example of an activity provider, although simulators, observation tools, and any number of modern mobile learning devices may also be activity providers. Advanced providers like intelligent tutoring systems may include activity provider functions as well as some learning event management functions.

An activity provider should send statements with the following verbs, as appropriate, and in accordance with the TLA conformance level as defined in sections 4.1-4.5:

- completed
- passed
- failed
- satisfied
- terminated
- initialized

An activity provider should not send statements that do not contain the verbs stated in the previous requirement.

An OICS may send statements on behalf of an activity provider.

5.3.4 Human capital management function

A human capital management system should send statements with the following verbs, as appropriate, and in accordance with the TLA conformance level as defined in sections 4.1-4.5:

- launched
- waived
- satisfied
- abandoned
- recommended
- organized
- curated
- requested
- approved
- augmented
- clarified
- directed
- scheduled

A human capital management system should not send statements that do not contain the verbs stated in the previous requirement.

An OICS may send statements on behalf of a human capital management system.

Annex A

(informative)

Bibliography

[B1] IEEE 100, The Authoritative Dictionary of IEEE Standards Terms.

[B2] IETF RFC 2425:1998, MIME Content-Type for Directory Information.

[B3] ISO 8601:2000, Data Elements and Interchange Formats—Information Interchange—Representation of Dates and Times.

[B4] ISO/IEC 11404:1996, Information Technology—Programming Languages, Their Environments and System Software Interfaces—Language-Independent Datatypes.

[B5] W3C Recommendation (04 February 2004), Extensible Markup Language (XML) 1.1.

[B6] W3C Recommendation (04 February 2004), XML Information Set, Second Edition.

Annex B

(informative)

Intended use of verbs

A learner-centric view of all verbs. Verbs here may appear to be passive to provide context to the intended effect on the learner but will be proper (active) xAPI statements when implemented. The term experience refers to a combination of learning activities (the electronic device or format that is used to conduct the learning -e.g. a kindle) and content (the file or resource that is experienced, (e.g. an electronic publication)

TLA Level 1:

- **Certified:** Indicates the learner received an accreditation by an authoritative source (OICS) to perform a given job or task.
- **Completed:** Indicates the learner finished or concluded an experience normally. Should include the success result field.
- **Passed:** Indicates the learner completed an experience to standard. Used in assessment.
- **Failed:** Indicates the learner failed to complete an experience to standard. Used in assessment.
- **Initialized:** Indicates that the learner successfully loaded an experience. This is different from "launched", as it relates to a specific experience (such as a chapter in a book instead of just opening the book).

TLA Level 2:

- **Launched:** Indicates the learner started a service. This does not always need to be a specific experience but can be a service provider as well.
- **Waived**: Indicates that the learning experience requirements were met by means other than completing the experience. A waived statement is used to indicate that the experience may be skipped by the learner.
- **Satisfied**: Indicates that the authority or experience provider determined the learner has fulfilled the criteria of the object or experience by means other than completing the experience.
- **Abandoned**: Indicates that the AU session was abnormally terminated by a learner's action (or due to a system failure).
- **Terminated**: Indicates the learner has completed their session normally.
- **Planned**: Indicates that the learner assigned themselves a new learning goal, without needing approval from an OICS.
- **Requested**: Indicates the learner needed or demanded an object or another OICS or learner. Requested indicates a comment that is shared with peers as a group or a coach as a trainer. The request for coaching or help prompts users to respond giving them coaching credit. Can also include a request to take a class or do a course.
- **Directed**: Indicates the learner was assigned a learning goal by an OICS.
- **Approved**: Indicates an OICS approved for a requested experience for the given learner.

TLA Level 3:

- **Assessed**: Indicates the learner completed assessments in a way that will cause a change in their authoritative learner state.
- **Contextualized**: Indicates the learner performed several connected learning activities that should result in a change in their authoritative learner state.
- **Located**: Indicates the learner's competency state needs to be updated based on completed experiences and changes in the Competency Framework.

- **Socialized**: Indicates the learner interacted with "wild" (unscheduled) experience in a social environment.
- **Captured**: Indicates the learner interacted with "wild" (out of network) or unplanned experience.
- **Asserted**: Indicates the learner has provided sufficient evidence to update the learner's measure of competence in a given competency.
- **Validated**: Indicates an OICS approved a change to a competency framework within the TLA that will affect learners' states.
- **Inferred**: Indicates an OICS changed a learner's competency assertions based on a valid competency framework change.
- **Qualified**: Indicates the learner meets all the requirements for a badge but hasn't been awarded the badge yet.
- **Conferred**: Indicates the learner was given a badge by an OICS.
- **Verified**: Indicates the learner had evidence of learning from a non-authoritative source verified as reliable data by an authoritative source.

TLA Level 4:

- **Organized**: Indicates the learner filtered experience that aligns to a specific goal.
- **Prioritized**: Indicates the learner filtered goals associated with select experience, usually listing what competencies are demonstrated in recently viewed experience.
- **Curated**: Indicates the learner was presented a list of experience recommendations over time, based on a selected goal with recursive depth, and on learner preferences, what set of experience will achieve mastery in the ordered sub-goals.
- **Projected**: Indicates the learner was presented a list of goal recommendations over time, based on a selected goal with recursive depth, what set of experience can achieve mastery in the ordered sub-goals.
- **Recommended**: Indicates the learner was given the recommendation to follow a career path, work towards a learning objective, or perform a learning experience by the actor.
- **Augmented**: Indicates the learner searched for experiences on an active learning goal, viewing what other goals/branches can be related based on an active goal tree.
- **Explored**: Indicates the learner searched active learning goals related to specific experience, viewing what other experience may trigger related goals, based on active goal and recently completed experience.
- **Clarified**: Indicates the learner queried what other experience may also reinforce the current learning goal, after completing experience.
- **Scheduled**: Indicates the learner scheduled an experience or lesson.
- **Evaluated**: Indicates the learner(s) appeared in a Measure of Effectiveness (MOE) search.
- **Tracked**: Indicates the learner(s) appeared in a competency search.
- **Surveyed**: Indicates the learner(s) appeared in a Measure of Performance (MOP) search.

TLA Level 5:

- **Recruited**: Indicates an OICS recruited the learner to join the ecosystem.
- **Appraised**: Indicates the learner met entry criteria for jobs and was assigned (by an OICS) a career trajectory.
- **Detailed**: Indicates the learner detailed to a specific job.
- **Mobilized**: Indicates the learner mobilized or deployed (i.e. data will be time late) on duty.
- **Employed**: Indicates OICS employs the learner such that they started work doing their job.

- **Schooled**: Indicates OICS has enrolled the learner in a schooling system.
- **Promoted**: Indicates the OICS has changed a learner's rank, either up or down.
- **Screened**: Indicates the OICS screened learner as passed through a "gate" within their career trajectory to open up restricted opportunities.
- **Selected**: Indicates the learner met the criteria for a potentially wider career trajectory, opening new career possibilities.
- **Transition**: Indicates the learner changed career paths, putting them on a completely different and brand-new career trajectory.
- **Released**: Indicates OICS released the learner from the learning environment.
- **Restricted**: Indicates OICS temporarily restricted the learner from some (possibly all) participation within the learning environment.

Annex C

(informative)

Expected data flow for formal and informal learning

Within TLA enabled systems, there is an expected flow of learner state as depicted in ***Figure 1***. The flow may include a deliberate or casual configuration of the learner's environment. In deliberate learning, the sequence begins with the learner setting goals, planning (or being assigned plans) tasks to achieve these goals, scheduling learning events, and then launching learning exercises. Each is represented by a verb within this specification, and the data generated by learning exercise is then stored in the transactional LRS describing the order and context under which the learner, or the learner's mentor (OICS) configured their own learning environment. The relationship between the goals, tasks, events, records of completion, evaluated assertions and conferral chain provides a discoverable audit trail or trusted chain of evidence.

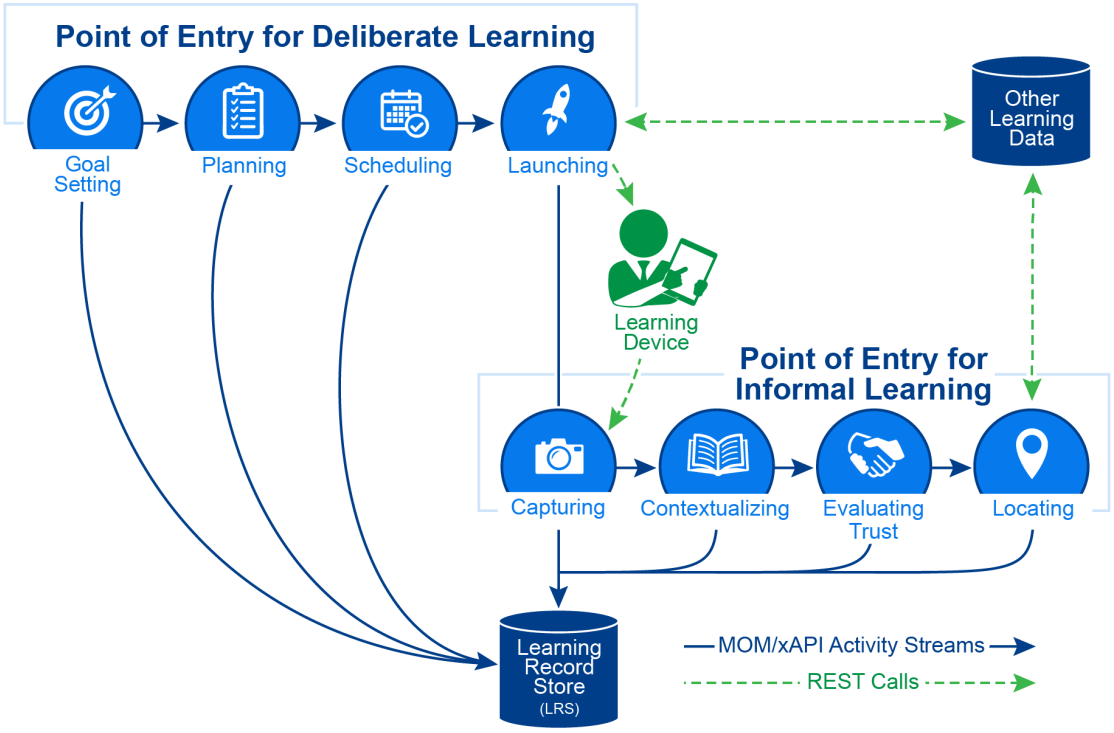

Figure 1: Data Flow for Formal and Informal Learning.

Once the learner completes the exercise, the newly generated data is contextualized and a trusted source (OICS or trusted system) takes this new information and generates a trusted record of the learner state using verification, conferral, qualification and assertion statements. These statements are stored in an authoritative LRS, that only OICSs and trusted systems have access to.

This standard uses a learner-centric vocabulary, which enables the entire TLA compliant environment to run as a stateless system of systems. This means that the learner could interface with TLA data at any stage in the expected object life cycle, and the services comprising the TLA instance can execute without knowing previous or follow on learner states. This arrangement not only allows for a true ecosystem, since the origin of the statement doesn't matter, it is resilient to configuration changes with devices or services being added or subtracted over time.

Annex D

(informative)

Object types

Object types, also known as activity types (as the object is usually of type "activity"), as found in the statement templates in sections 5.1.1-5.1.49, are used to populate the "object" field of an xAPI statement. Activity types are the various types of learning constructs present in the TLA. A summary of each activity type can be found below in **Table 1**.

Table 1. Object Types.

Name	Identifier	Definition
Activity	https://w3id.org/xapi/tla/activity-types/activity	Any generic activity an actor can interact with, that is not an assessment
Assessment	https://w3id.org/xapi/tla/activity-types/assessment	Any generic exercise that formally assesses the user's level of competence
Competency	https://w3id.org/xapi/tla/activity-types/competency	A collection of knowledge, skills, abilities, or other behaviors needed to perform in a given task
Activity Cluster	https://w3id.org/xapi/tla/activity-types/activity_cluster	Any generic collection of activities and/or assessment activities
Career	https://w3id.org/xapi/tla/activity-types/career	An outline of jobs and their competency and credential requirements in a career, usually used to outline the expected learning path as series of verifiable milestones.
Badge	https://w3id.org/xapi/tla/activity-types/badge	An online badge that is earned after achieving multiple related competencies. In this sense badge is any kind of credential, a badge, a certificate, a degree, a license, etc.
Job	https://w3id.org/xapi/tla/activity-types/job	A formal job, duty, legal obligation, permanent or temporary employment that requires a learner to possess some set of competencies and/or credentials

Annex E

(informative)

Description of TLA data and systems

The learner object life cycle is divided into 3 "levels" of data or perspectives about the learner's learning path: Learner Career states (LC states), depicted in Figure 2; Learner Activity states (LA states), depicted in Figure 3; and Learner Record Provider states (LRP states), depicted in Figure 4. All verbs are divided into Authoritative Data (depicted below in green), Evidence statements (depicted below in blue), and Activity Planning (depicted below in red).

The TLA has many functional requirements for each of the component systems within a TLA environment. Those requirements are beyond the scope of this document, as are some of the components in their entirety. The following limited explanations provide a description of how the system functions within a TLA environment from the standpoint of learning experience data.

Competency Management System – is used to CRUD the concept and relationships that define jobs, credentials and competencies, as part of overarching competency frameworks, and calculates based on trust and evidence, the impact of learning events on the competencies and credentials of learners

Learning Event Management System – is used to track the completion of the learner data flow. Learning events are conducted as a sequence of launching and completing an experience. The conduct of a learning event exists in context, however, with the preparation and analysis of the learning environment, and includes goal setting, planning, scheduling, capturing, contextualizing, evaluating and locating exercises.

Activity Provider – is a creator of xAPI data (a type of LRP in xAPI) that generates a learning event (statement) on its own (on-the-job activity) or provides the context (reader, simulator) under which learning content is experienced.

Learning Experience – the combination of learning activities (context for the experience) and content (the resources for the experience) aligned for some educational purpose.

Learner State – the hierarchy of learning goals and sequenced subgoals, the tasks defined to satisfy those goals and the events that address the tasks. These link to the assertions of competency and conferral of credentials for which they provide a discoverable audit trail of evidence.

Human Capital Management System – is an end to end technical system used to track the recruiting, accession training, detailing, training, certification, promotions, screening and selections of capable manpower according to personnel jobsite definitions throughout the enterprise and over the entire career of personnel.

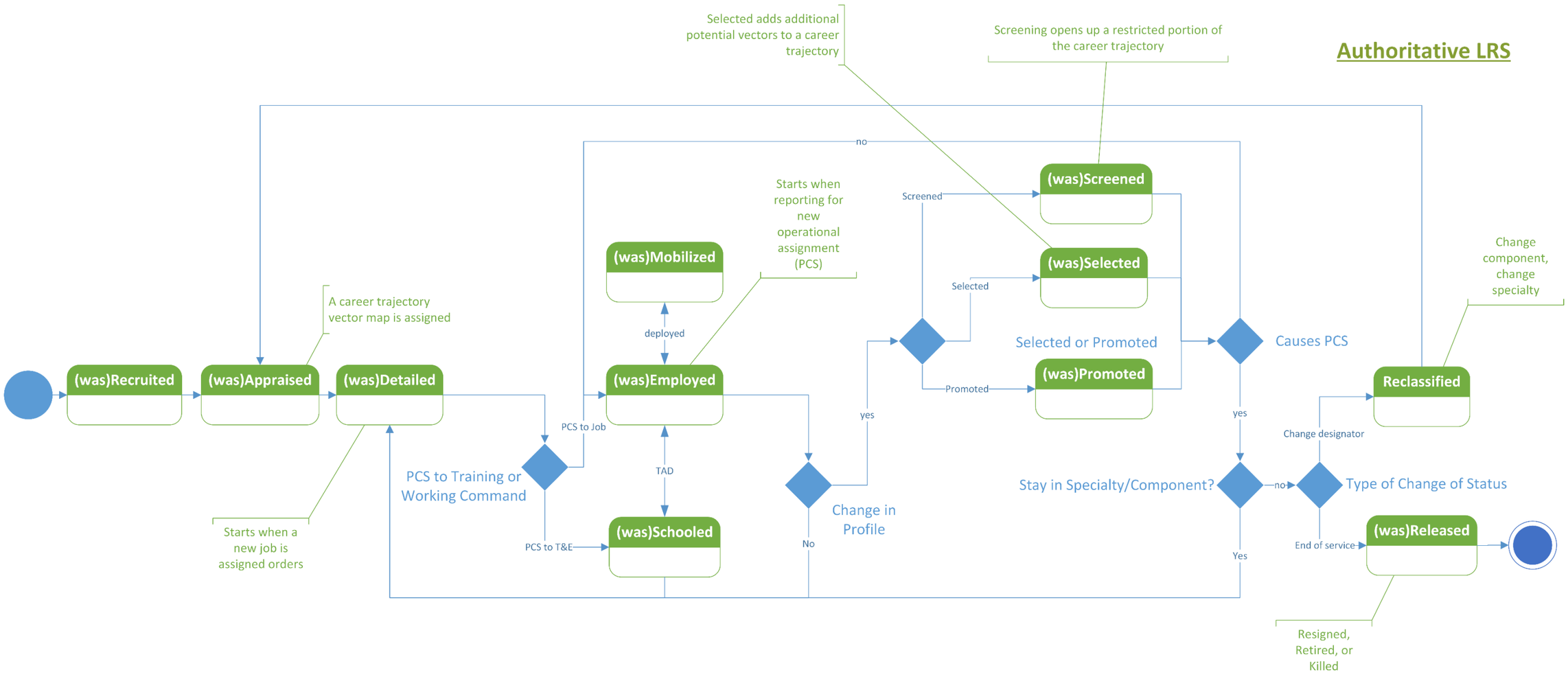

Figure 2. Learner Career States.

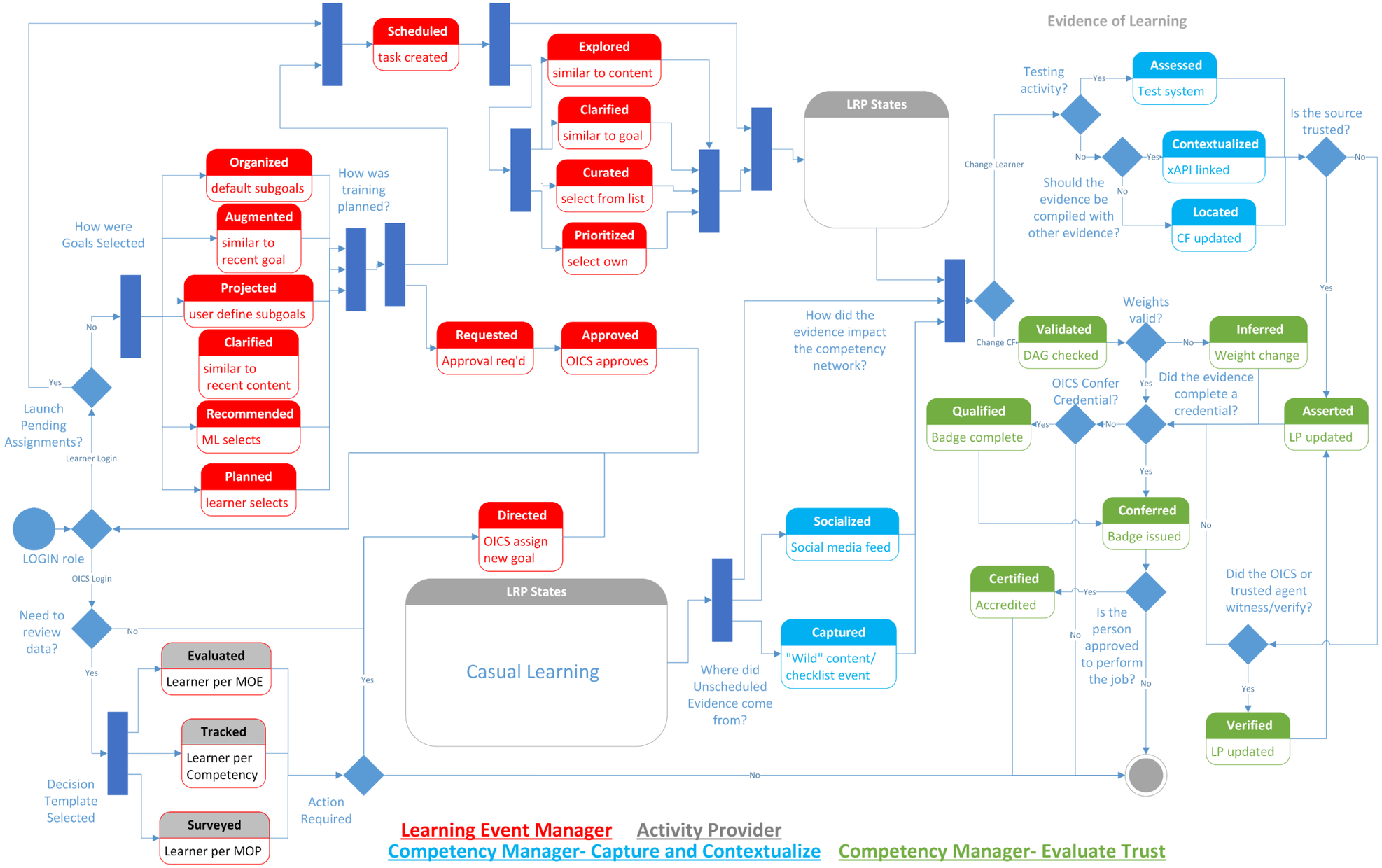

Figure 3. Learner Activity States.

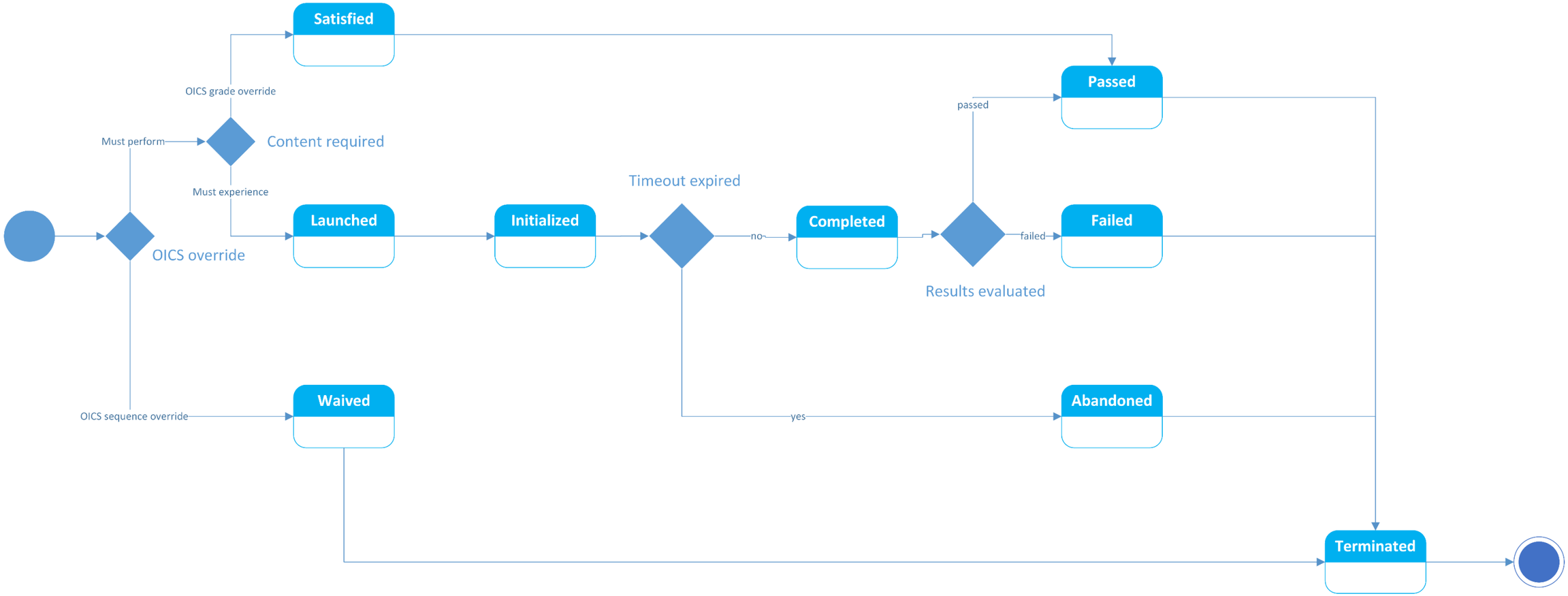

Figure 4. Leaning Record Provider States.

TOTAL LEARNING ARCHITECTURE

2019 Report - Appendix C - DoDAF

Prepared by
The ADL Initiative

Table of Contents

1. DoDAF All Views (AV)

The Department of Defense (DoD) Architectural Framework (DoDAF) is a modeling convention used to convey the multilayered elements of complex systems of systems. The DoDAF mitigates the complexity of the ADL Initiative's Total Learning Architecture (TLA) project for specific stakeholders by creating "views" that describe how requirements are implemented, and the impacts or benefits afforded to each stakeholder. **Table 1** shows the different views and their purpose.

Table 1. List of DoDAF Views Included With the TLA.

View	Description	Purpose
AV-1	Overview and Summary	Describes the overall mission, vision, and resources.
AV-2	Integrated Dictionary	Describes the terms currently in use in education and training, as well as new TLA terms.
CV-1	Capability Vision	Alignment of the end-state TLA policy framework to lines of effort, current and projected projects to inform those lines of effort, and potential transition jump-off points.
CV-2	Capability Taxonomy	Three-level hierarchical decomposition of capabilities enabled through TLA.
CV-3	Capability Phasing	The TLA capability maturity model used to scope future migration efforts.
CV-6	Capability to Operational Activities Mapping	Cross references the TLA use cases required to support each capability. Cells marked with an 'x' require the feature, those marked with an 'o' are enhanced by the feature.
CV-7	Capability to Services Mapping	Cross references the technical services required to support each capability.
DIV-1	Conceptual Data Model	The list of governance structures and organizational information exchanges defining the TLA ecology.
DIV-2	Logical Data Model	Logical class diagram of data elements used in TLA data structures.

DIV-3	Physical Data Schema	Metamodels for
		• Enterprise Learner Profiles
		• Commercial
		  ○ xAPI/cmi5 IEEE P9274
		  ○ OpenBadge3.0/CTDL
		  ○ RCD
		  ○ LTI/OpenAPI/REST
		  ○ LRMI modified to LRMI++
		  ○ OAuth/OICD

OV-1	High Level Operational Concept	The concept of TLA compliant enclaves, federations, and ecosystem and engagement with stakeholders.
OV-2	Operational Resource Flow	Ecology of operational nodes and information need lines (per DIV-1) in the total learning ecosystem organized by engagement.
OV-4	Organizational Relationships	Stakeholders in the Total Learning Ecosystem organized by reporting structure.
OV-6a	Operational Rules Model: Business Rules	Business rules for TLA governance structures.
OV-6b	Operational Rules Model: State Transition	Sequence of activities for roles and operational nodes.
SV-1	Systems Context Diagram	Connections between technical elements within enclaves as nodes and federations between nodes.
SvcV-1	Services Context Diagram	Context of ecologies, enclaves, and federations within the TLA as data service contracts.
SvcV-4	Services Functionality	High-level functions of each service and system component of the TLA.
SvcV-5	Operational Activity to Services	Mapping of services to supporting use cases used to help migration strategies.

View	Description	Purpose
SvcV-10a	Services Business Rules	Business rules for TLA technical compliance.
SvcV-10b	Services State Transition Diagram	Sequence of learner states that satisfy the continuum of andragogical, pedagogical, and heutagogical/self-regulated learning use cases for the TLA.
SvcV-10c	Services Event Trace Diagram	Objective systems concept of execution showing five control loops for human performance.
StdV-1	Standards Profile	2018/19 specifications and standards.
StdV-2	Standards Forecast	Objective system policy, specifications, and standards alignment, including the proposed TLA standard.
PV-1	Project Portfolio Relationships	Timelines current horizon projects and efforts.
PV-3	Project to Capability	High-level alignment of projects to specification, and standard versions to enable Initial, Interim, and Final Operational Capability.

1.1 AV-1 - Overview and Summary

1.1.1 Architectural Description Identification

This is an Architectural Description Document describing the TLA, an ecology of policy, specifications, and standards being developed by the ADL Initiative within the Force Education and Training (FE&T) component of the Office of the Undersecretary of Defense for Personnel and Readiness – OUSD(P&R). These documents are being developed for eventual inclusion in DoD Instruction (DODI) 1322.26[1].

This ecology describes the constraints and enabling protocols, processes, and data contracts to create the future learning ecosystem, which is comprised of interoperable learning technologies that enable a concept for *individual lifelong learning* that enhances the human capital supply chain management process for human resources.

The TLA represents a culmination of the ADL Initiative's mission of modernization, policy development, and community outreach. The TLA Initial Operating Capability (IOC) is expected in Fiscal Year (FY) 2021, starting with mandatory inclusion of the *Experience Application Program Interface* (xAPI) specification in all new and legacy-upgrade training media, with a Final Operational Capability (FOC) in 2025. FOC will include a transition to Competency Based Learning (CBL), multi-level security (MLS), and digital badging. This initial architectural description is expected to be a living document that will be continually updated based on feedback and input from the ADL Initiative's DoD stakeholders.

1.1.2 Scope

Among the "views" listed in **Table 1**, some are applicable to the objective state and some to the current 2019 research effort as described. All are applicable to education- and training-focused elements of the DoD and the uniformed services. The views also identify DoD stakeholders outside of education and training organizations that may be interested in the TLA-generated data, or that may generate data that could be used to improve or enhance education and training, such as Manpower and Personnel (M&P), system acquisition, and unit operational readiness reporting agencies. The TLA does not prescribe how these external organizations structure, store or communicate their data.

[1] *https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/132226_dodi_2017.pdf?ver=2017-10-05-073235-400*

1.1.3 Purpose and Perspective

The ability to create, retain, and manage *capable manpower* is a *critical national capability*. It is in the interest of the DoD to maximize the available pool of trained soldiers, sailors, marines, and airmen, and to optimize their training and professional development throughout their careers. In addition to benefiting DoD stakeholders, this maximizes options for these personnel when they transition to non-DoD careers, serving to continually market DoD service as a rewarding and valuable career path. Thus, the TLA vision serves three complimentary functions:

- **Support for Lifelong Learning** – provides rich, rewarding career experiences for service members to improve retention, accession, and self-actualization throughout their entire lives.
- **Human Capital Supply Chain Management** – maintains a force structure and level of readiness that supports the National Defense Strategy as it evolves over time.
- **Alignment of DoD Learning Experiences** – harmonizes DoD experience with the skills and competencies required in the civilian marketplace, preparing service members for transition to the civilian workforce.

These high-level missions for the DoD's education and training enterprise support the goals of the National Defense Strategy to improve lethality (by ensuring optimally qualified people in deploying units) and improve management functions (by reducing inefficiencies in the education and training pipeline). TLA-enabled enterprise analytics will improve the efficacy of training throughout the workforce pipeline and increase lethality with data-driven approaches to readiness. TLA compliant systems using competency-based learning will lower costs for training and reduce the size of the total force required to maintain the same operational posture.

The TLA combines new learning tools, systems, activities, and content to establish a loosely coupled ecosystem made interoperable through common specifications, standards, and policy. The TLA includes models within this architecture that decompose to lower level capabilities and functions, and ultimately technical services, data, and interfaces. These enhance, optimize, or improve upon existing learning solutions, especially in reducing the time and labor overhead to provide education and training capabilities. In the future, it is envisioned that all learning experiences will interoperate within the future learning ecosystem. This includes traditional classroom activities, field trips, and digital learning, as well as simulators and on-the-job training experiences that make up a sizable portion of human learning.

The TLA data strategy results in enhanced enterprise analytics that validate the efficacy of the education and training personnel receive. This data strategy was developed to accommodate future interfaces with other DoD systems (e.g., Manpower & Personnel, HR, Readiness) and key performance indicators in the operational environment. The TLA ecosystem will streamline the delivery and management of learning for four million uniformed and civilian members of the DoD, optimizing the supply of capable manpower to perform missions.

This will be accomplished through DODI 1322.26 and its "fungible references" that define TLA specific and related commercial standards to aid in the adoption and migration of TLA functionality. Central to the TLA are the xAPI standard and the cmi5 specification. xAPI is an evolving IEEE standard designed to replace the legacy Shareable Content Object Reference Model (SCORM). The cmi5 specification builds upon the xAPI to provide an alternative way of packaging, delivering, and managing web-based instructional content using Learning Management Systems (LMS).

The xAPI and cmi5 specifications expose important learner data using a Learning Record Store (LRS), the server component of the xAPI. These learner data can be combined with other learner data to build a more comprehensive snapshot of learner proficiencies and what they should be focusing on next in support of both their career trajectory and DoD mission needs. The new TLA policy ecology will include:

- Migrating legacy education and training solutions to leverage ubiquitous learning opportunities afforded by mobile technology, cloud computing, data analytics and other sensors.
- Assessment and reporting of personnel *knowledge, skill, ability, and other* (KSAO) capabilities as competencies and credentials reportable to DoD *manpower and personnel* systems.
- Developing standardized labeling for Government owned performance data for new system acquisitions related to human performance, education, and training.
- Developing standardized labeling and curating of new and existing content used to provide future learning opportunities.
- Forecasting of the personnel components of "system readiness" for fielded DoD units based on the status of their education and training.
- Leveraging cloud-based computing and centralized IT as a service for network and server virtualization, as well as cybersecurity in multi-level security environments, to mitigate education and training technology obsolescence.
- Providing operational security of the "capable manpower" critical national capability, implied by the potentially aggregated nature of learning data in context.
- Providing governance of data, technical, and organizational policy and standards for critical education and training systems operating on the Global Information Grid.
- Transitioning to a curation model from a content development model to enable significant reuse in the development of training events and opportunities.
- Enhancing education and training product review cycles by integrating data related to learning content, activities, and competencies with readiness data.
- Improving the throughput of learning resources by focusing only on gaps in a personal competency model instead of a standardized curriculum in the classroom model.
- Providing feedback to developmental systems on human performance issues and populating finer grained personnel demand signals during the acquisition process.

1.1.4 Context

This Architectural Description Document serves to reduce the complexity of the TLA system of systems approach, decomposing the purpose, composition, operation, and maintenance of TLA components through the TLA policy framework. The figures below depict the logical, physical, functional, and operational characteristics of the objective end-state. They also identify near-term research objectives, associated test beds, and their impact on defining policy and informing technology investments.

Each document is prepared from the viewpoint of stakeholders within the DoD education and training enterprise. While these views are prepared for specific stakeholders, they include potential linkages to other DoD functional areas such as M&P, system acquisition, logistics, and readiness reporting.

The TLA enables a learning ecosystem by defining commercial standards, technical specifications, and business rules that must be supported by learning tools, technologies, activities and content to conform with the TLA data strategy. These views should be considered as part of any education and training modernization effort. By exposing education and training data and providing the functions of learning as a series of microservices, the DoD can leverage the cost-effective models provided by cloud-based computing as the foundation for greater integration of systems over time to enable new capabilities.

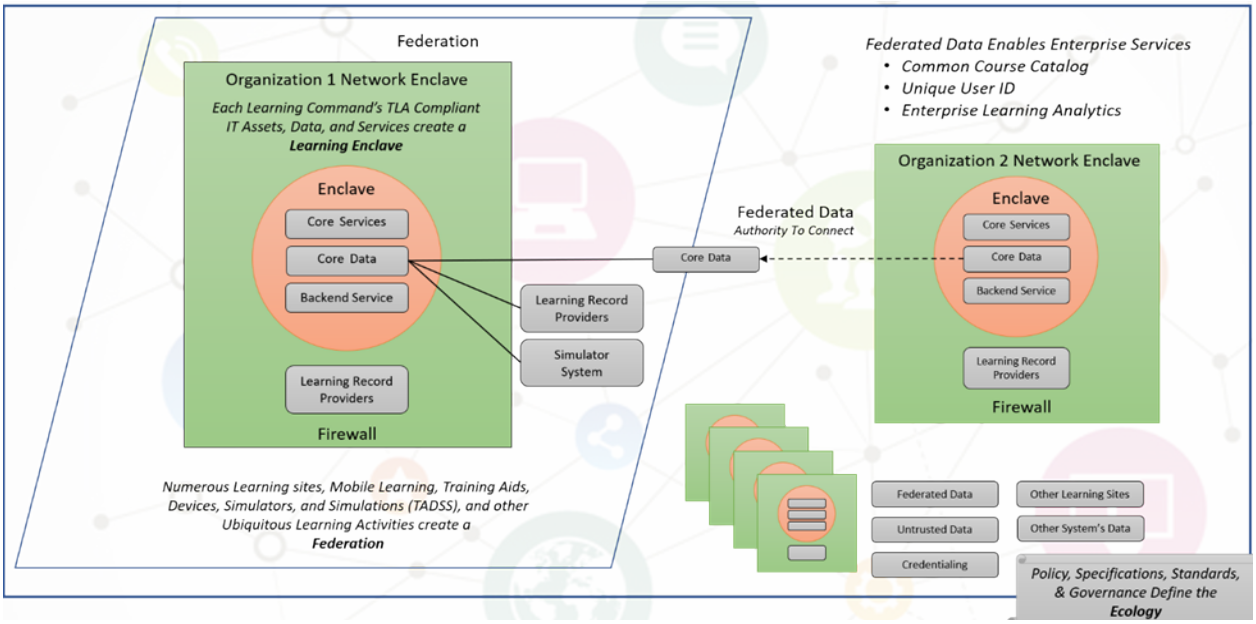

Figure 1. Future Learning Ecosystem. *The entirety of enclaves and federations, and interfaces to ancillary systems and data, create the ecosystem. An enclave is a network boundary that encapsulates core data and systems for an organization related to education and training. Enclaves may federate their data with other enclaves through Authorities to Connect. Data ownership and authoritative systems are controlled by the parent organization.*

The FLE's "ecology" includes the DODI 1322.26 policy document and its fungible references of specifications and standards and related policies (e.g. cybersecurity) that create the overall framework, as shown in **Figure 1**. The ecology is defined by three high-level concepts:

- ***The Enclave*** – is a set of computation and data assets for a DoD organization used to deliver and manage education and training opportunities. The enclave contains the core data, services, and technologies such as installed LMS solutions, learning devices, simulators, and back-end systems developed according to the TLA specifications and standards. An enclave will require a cybersecurity Authority to Operate (ATO) and will include all assets procured, installed, and managed at a particular "learning organization" within the DoD.
- ***The Federation*** – combines data from multiple enclaves, as well as truly mobile or ubiquitous learning devices that may follow a person through their career and connect as federates through a defined federation negotiation process. Federation creation requires a Memorandum of Agreement (MOA) and Authority to Connect (ATC) between enclaves. Federation negotiation allows for horizontal scaling of data lakes, and requires governance for managing data labeling, identity management, and metadata schemas and attribution. Cybersecurity requirements for "Zero Trust Networks" enable "bring your own device."

- ***The Ecosystem*** – encompasses all enclaves or potential federations, as well as interfaces from systems outside of education and training that consume or produce data useful for learning (such as credentials reported to *manpower and personnel* systems). These external systems require additional MOAs and ATCs. The TLA policy framework includes the organizational processes for governance that manages interoperability and semantic consistency between TLA compliant elements within education and training. These external connections allow for complete human capital supply chain management, using federated users to maintain their own data standards and interface specifications.

1.1.5 Status

The draft TLA architecture baseline 0.5 version was developed in 2019. The 2018 Reference Implementation SV-1, SV-10, and Svc-4 views were previously published in the 2018 TLA report[2]. The CV-3, DIV-2, OV-1, and Svc-V1 were developed for the OUSD(I) Talent Development Toolkit (TDT) delivered in 2019. These draft architectural views included in the TLA DoDAF are being presented to solicit feedback and facilitate discussion for improvement before being submitted for consideration to the Defense ADL Advisory Committee (DADLAC) for inclusion among the DoDI 1322.26 fungible references.

1.1.6 Tools and File Formats Used

TLA DoDAF source documents are developed in Microsoft Word, Excel, PowerPoint, and Visio. The technical models are developed according to the semantics and notation of the Unified Modeling Language or System Modeling Language (UML/SYSML) using the Visio template. Schedules are developed in Microsoft Project or summarized in PowerPoint. Cross reference tables and matrices are developed in Microsoft Excel. The entire architecture is maintained on the ADL Initiative's internal SharePoint site and will be transitioned to the ADL GitHub[3] as appropriate.

1.1.7 Assumptions and Constraints

The TLA assumes a requirement for data federations because of the horizontal scale of data[4] and because security enclave and access constraints across DoD components preclude a single "walled garden" solution. The TLA approach must also adhere to cybersecurity requirements and comply with the Defense Information Security Administration (DISA) policy and processes.

It must provide normative guidance for program offices to establish, contract, and maintain its requirements through governance and provide a recapitalization strategy that enables the departments to plan, budget and transition without a negative impact to ongoing operations and mission. Initial fielding will be through pilot programs that field site-specific capabilities. Programs will expand and interconnect organically over time.

1.1.8 Schedule

FY 2019

- September 2018 – Kickoff for OUSDI Talent Development Toolkit (TDT) requirements and architecture project

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[2] https://apps.dtic.mil/dtic/tr/fulltext/u2/1077398.pdf

[3] https://github.com/adlnet/

[4] ~4 million uniform and civilian personnel spending 2000+ hours a year training or in performance of their duties.

- December 2018 – Interviews of IC stakeholders
- February 2019 – Commencement of the Navigator for Interoperable Learning Experiences (NILE), DATASIM, Data Analytics and Visualization Environment (DAVE), and the Privacy and Security for TLA (PS4TLA) projects
- March 2019 – Submission of OUSDI TDT requirements and Architecture Report
- August 2019 – Commencement of CASS authoring tools and CaSS requirements hardening projects, and Competency Framework Development (CFD) process documentation
- August 2019 – Commencement of the xAPI Profile Server and xAPI profiles for DoD use projects, and acceptance of the TLA portal software submission
- July-September 2019 – Integration of the 2019 TLA Reference Implementation

FY 2020

- January 2020 – Commencement of the Competency and Skills System (CaSS) integration effort with the US Air Force Learning Services Ecosystem (AFLSE) project
- DRAFT DoDAF released to community for review and to solicit feedback
- xAPI as an approved IEEE standard
- RCD as an approved IEEE standard
- Commencement of LOM 2.0 Standards working group
- Finalize TLA specifications (interface specification, metamodels, business, rules, federation negotiation)
- NILE established as a TLA enclave – facilitate federated data testing and evaluation
- Advance metadata and data labeling
- Integrate Privacy & Security of Learner Information into Federated Identity, Credential, and Access Management (FICAM) approach defined by DISA/DoDCIO
- Establish Enterprise Course Catalog (sometimes referred to as *Universal Course Catalog*)
- Establish Universal Unique Identifier
- Establish accredited Learning Record Store (LRS)
- Establish cmi5 conformance testing and viewer capability
- CaSS IATT / IATO for Air Force, Army, and Navy

FY 2021

- Initial Operational Capability (IOC)
- xAPI profile server operational
- cmi5 conformance test operational
- Federated activity and resource management services
- Enterprise Course Catalog operational

FY 2025

- Final Operational Capability (FOC)

1.2 AV-2 Integrated Dictionary

See **Table 2.**

Table 2. AV-2 Integrated Dictionary.

Lexicon Term	Definition	Citation/Reference/Attribution
Accreditation	1. (M&S - V.V & A) The official certification that a model, simulation, or federation of models and simulations and its associated data is acceptable for use for a specific purpose. 2. (RMF - ATO) The signed approval of a cybersecurity package under the Risk Management Framework (RMF) within DoD.	https://csrc.nist.gov/projects/risk-management/risk-management-framework-(RMF)-Overview
Activity and Resource Registry	Manages the relationship between activities, competencies, Enabling and Terminal Learning Objectives, and other relevant information about each activity. Contains access information and permission to allow access to activities.	https://apps.dtic.mil/dtic/tr/fulltext/u2/1077398.pdf
Activity Statement	A single xAPI record entry.	https://in.nau.edu/its-lpd/xapi/
Activity Streams	Time-stamped data ledger about learner experiences tracked across learning activities encountered by an individual or team. The Experience API (xAPI) communicates information about each learning experience through a series of xAPI statements that encapsulate a learner's experience with different learning activities.	https://apps.dtic.mil/dtic/tr/fulltext/u2/1077398.pdf
Alignment	1. The positioning of the human capital system's policies, practices, and strategies in relationship to the agency's strategic plan and performance plan, so what is done in the system is in direct support of the agency's mission, goals, and objectives. 2. In Competency-based learning, it refers to the mapping of learning activities and other evidence of learner proficiency to a specific competency. A competency is encapsulated in a framework where each competency has a unique identifier, as well as its own variables and conditions that need to be satisfied to achieve different mastery levels.	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
Aptitude	1. A natural ability. 2. A component of a competency that relates to performing certain kind of work at a certain level.	https://www.merriam-webster.com/dictionary/aptitude https://en.wikipedia.org/wiki/Aptitude
Assertion	1. A statement of fact or belief. 2. In competency-based learning, it is a claim about a learner's mastery over a specific competency, or the elements that a competency is comprised of (e.g., behaviors, knowledge, skills, abilities, aptitudes, or other information).	https://www.edglossary.org/competency-based-learning/
Assessment	Wide variety of methods or tools that are used to evaluate, measure, and document the academic readiness, learning progress, skill acquisition, demonstrated proficiency, or educational needs of an individual or team.	https://www.edglossary.org/assessment/
Attitude	A psychological construct, a mental and emotional entity that inheres in, or characterizes a person.	https://en.wikipedia.org/wiki/Attitude_(psychology)
Authoritative Data Source	A recognized or official data-production source which publishes reliable and accurate data for subsequent use by customers. The authoritative data may be the functional combination of multiple, separate data sources.	https://definedterm.com/authoritative_data_source

Lexicon Term	Definition	Citation/Reference/Attribution
Bloom's Taxonomy	A set of three hierarchical models used to classify educational learning objectives into levels of complexity and specificity.	https://en.wikipedia.org/wiki/Bloom%27s_taxonomy
Communities of Practice	A group of people bound by a shared interest, purpose, or practice where people share ideas and knowledge in many different ways, including real-time collaborative sessions, newsletters, chat forums, social groups, and links to websites.	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
Competencies	The set of demonstrable characteristics and skills that are required by an individual or team for performance of a job. Characteristics include knowledge, skills, abilities, and other (KSAO) - such as attitudes, aptitudes, motivations and social elements.	https://en.wikipedia.org/wiki/Competence_(human_resources)
Competency Based Learning	An instructional strategy that allows students to progress as they demonstrate mastery of academic content, regardless of time, place, or pace of learning. Competency-based strategies provide flexibility in the way that credit can be earned or awarded and provide students with personalized learning opportunities.	https://www.ed.gov/oii-news/competency-based-learning-or-personalized-learning
Competency Framework	A model that broadly defines the blueprint for 'excellent' performance within an organization or sector. Generally, the framework will consist of numerous competencies, which can be applied to a broad number of roles within the organization or sector.	https://participatoryartslearning.wordpress.com/the-framework/what-is-a-competency-framework/
Reusable Competency Definitions	A framework that describes the full range of competencies required to be successful in a specific occupation. It provides a formal representation of the key characteristics of a competency, independently of its use in any specific context. It enables interoperability among learning systems that deal with competency information by providing a means for them to refer to common definitions with common meanings.	https://ieeexplore.ieee.org/document/4445693
Competency Management System	The system or platform that aligns evidence from education, training, or operational learning experiences to Competency Frameworks and asserts a predicted level of proficiency for individuals and teams.	https://en.wikipedia.org/wiki/Competency_management_system
Competency Model	A data model for describing, referencing, and sharing competency definitions, primarily in the context of learning and development. Competency models are used to support key human capital programs such as selection, career development, training, and performance management. These models usually describe the required occupation-specific, or technical, competencies and general cross-occupational competencies (e.g., analytical competencies).	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
Competency Object	An encapsulated set of related knowledge, skills, and abilities required to successfully perform "critical work functions" in a defined work setting. Competencies often serve as the basis for skill standards that specify the level of knowledge, skills, and abilities required for success in the workplace.	https://sph.uth.edu/content/uploads/2012/01/Competencies-and-Learning-Objectives.pdf
Computer Assisted Instruction (CAI)	Learning presented, managed, and controlled by an instructor that is in a different classroom than the learner. The instructor is assisted by technologies that support communication and passing documents between the instructor and the learner. The instructor still scores the course and determines if the learner has mastered the TLOs.	https://adminpubs.tradoc.army.mil/pamphlets/TP350-70-3.pdf

Lexicon Term	Definition	Citation/Reference/Attribution
Computer Managed Instruction (CMI)	Learning presented, managed, and controlled by software (e.g., LMS). There is no travel. There is no instructor. There is no classroom. The computer software manages all course activities and their interactions with the learner. The computer software measures mastery by automated evaluation and reports learner scores to the student registration system or other learning system.	https://adminpubs.tradoc.army.mil/pamphlets/TP350-70-3.pdf
Content Object	An instance of a content class. While the class only defines the data structure, it is the content objects themselves that contain actual data. Once a content class is defined, several content objects / instances of that class can be created.	https://doc.ez.no/eZ-Publish/Technical-manual/3.6/Concepts-and-basics/Content-management/The-content-object
Content and Resource Management	A set of processes and technologies that supports the collection, managing, and publishing of information in any form or medium. When stored and accessed via computers, this information may be more specifically referred to as digital content, or simply as content. In the TLA, content management registers, selects, reports and validates resources required for all learning opportunities.	https://en.wikipedia.org/wiki/Content_management
Context	Refers to those objects or entities which surround a focal event, in these disciplines typically a communicative event, of some kind.	https://en.wikipedia.org/wiki/Context_(language_use)
Core Service	Logic “wrappers” that provide services by managing requests in and out of data stores that can also federate to additional segments on multiple edge system.	https://www.adlnet.gov/assets/uploads/TDT%20Report.pdf
Course	A series of learning activities about a specific subject that are sequenced together into a program of instruction (POI) or (Navy- Course of Instruction - COI). Each activity may include different types of instructional content.	https://adminpubs.tradoc.army.mil/regulations/TR350-70.pdf
Course Management System (CMS)	A collection of software tools providing an online environment for course interactions. A CMS typically includes a variety of online tools and environments.	https://cft.vanderbilt.edu/guides-sub-pages/course-management-systems/
Credential	An attestation of qualification, competence, or authority issued to an individual by a third party with a relevant or de facto authority or assumed competence to do so.	https://en.wikipedia.org/wiki/Credential
Credential Portability	Portability means the credential has value locally, nationally or internationally in labor markets, education systems, or other trust-based systems. The learner or consumer uses the credential for a variety of purposes but the context and competencies the credential represents remain intact. A portable credential enables earners to move vertically and horizontally within and across the credentialing ecosystem for attainment of other credentials.	https://connectingcredentials.org/wp-content/uploads/2016/06/Glossary-of-Credentialing-Terms.pdf
Credentialing	Formally grouped competencies and experiences used to define a capability or level of knowledge recognized across systems. Credentials in the TLA also refer to portable, digital badges that preserve the provenance of the conferrer and possess an evidentiary audit trail of assertions.	https://www.accredible.com/credentials/

Lexicon Term	Definition	Citation/Reference/Attribution
Curriculum	A set of courses constituting an area of specialization. All training conducted within a school, outlined into specific topics with detailed training objectives. Curricula are maintained as "programs of Instruction" (POI) or Courses of Instruction (COI).	MIL-HDBK-29612
Data Contract	A formal agreement between a service and a client that abstractly describes the data to be exchanged. That is, to communicate, the client and the service do not have to share the same data types, only the same data contracts. A data contract precisely defines, for each parameter or return type, what data is serialized (turned into XML) to be exchanged.	https://docs.microsoft.com/en-us/dotnet/framework/wcf/feature-details/using-data-contracts
Data Dashboards and Analytics	An information management tool that visually tracks, analyzes and displays key performance indicators (KPI), metrics and key data points to monitor the health of a business, department or specific process.	https://www.klipfolio.com/resources/articles/what-is-data-dashboard
Data Model for Content Object Communication (IEEE Std 1484.11.1-2004)	This standard describes the Computer Managed Instruction (CMI) data model that the DoD uses to support the interchange of agreed upon data elements and their values between a learning-related content object and a runtime service (RTS) used to support learning management.	https://standards.ieee.org/standard/1484_11_1-2004.html
Data Validation	The process of ensuring data have undergone data cleansing to ensure they have data quality that is correct and useful.	https://en.wikipedia.org/wiki/Data_validation
Data Visualization	Translating data from aggregated experiences and/or systems in order to provide a pictorial representation of the data analysis information collected to drive informed decisions.	https://www.academia.edu/40046943/_2_TDT_Report
Data-driven	1. Decision making philosophy determined by or dependent on the collection or analysis of data. 2. An organizational culture where data and information are the basis of all actions and gathering and analyzing of data is the core motivator.	https://www.techopedia.com/definition/18687/data-driven
Decision Support System (DSS)	An information system that supports decision-making activities. DSSs serve the management, operations and planning levels of an organization and help people make decisions about problems that may be rapidly changing and not easily specified in advance.	https://en.wikipedia.org/wiki/Decision_support_system
Digital Badge	A validated token of accomplishment, skill, quality, or interest that can be earned in many learning environments. Digital badging allows a learner to display badges across the web.	https://openbadges.org/
Distributed Learning (DL)	By its nature, learning is distributed. With ubiquitous availability of mobile devices and other technology advancements, Distributed Learning now includes any type of learning mediated with technology and accessed through a network or experienced via portable media.	DODI 1322.26
DoDI 1322.26	Establishes policy, assigns responsibilities, prescribes procedures, and establishes information requirements for developing, managing, providing, and evaluating Distributed Learning for DoD military and civilian personnel. Directs DoD to implement emerging interoperability specifications (e.g., xAPI) and formally charters DADLAC as oversight body.	DODI 1322.26
Ecosystem/Ecology	A distributed, adaptive, and open system with properties of self-organization, scalability and sustainability inspired from natural ecosystems.	https://en.wikipedia.org/wiki/Digital_ecosystem

Lexicon Term	Definition	Citation/Reference/Attribution
Edge System	Modern network architecture defines edge systems as independent systems that sit on the outside periphery or edge of the network. The separation between TLA core and edge systems provides layered security boundaries around core business systems.	https://itknowledgeexchange.techtarget.com/modern-network-architecture/what-is-an-edge-system/
Education	Developing general knowledge, capabilities, and character through exposure to and learning of theories, concepts, and information. Education is traditionally delivered by an accredited institution and may relate to a current or future mission-related assignment.	https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/ai/a040p.pdf?ver=2017-07-19-142854-093
Efficiency	The ratio of the outcome or output to the input of any program; the degree to which programs are executed or activities are implemented to achieve results while avoiding wasted resources, effort, time, and/or money.	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
e-learning	learning utilizing electronic technologies to access educational curriculum outside of a traditional classroom. In most cases, it refers to a course, program or degree delivered completely online.	http://www.elearningnc.gov/about_elearning/what_is_elearning/
Enabling Learning Objective (ELO)	Precise three-part statement … describing what the learner can accomplish in terms of the expected student performance under specific conditions to accepted standards.	https://adminpubs.tradoc.army.mil/pamphlets/TP350-70-3.pdf
Enclave	Within the context of the TLA, an enclave is a segregated sub-network managed by a DoD component (e.g., Defense Acquisition University, Air Education and Training Command), located behind a firewall with managed access to support education and training activities.	https://apps.dtic.mil/dtic/tr/fulltext/u2/1077398.pdf
Evidence	Anything presented in support of an assertion of competency.	https://en.wikipedia.org/wiki/Evidence
Experience Application Programming Interface (xAPI)	A software specification that provides a standardized format for communicating and tracking all types of learning experiences across the enterprise. Learning experiences are recorded in a Learning Record Store (LRS), the server-side implementation of the xAPI. The xAPI uses Statements as a communication mechanism. Statements are evidence of learner performance that include [Actor --> Verb --> Object].	https://adlnet.gov/research/performance-tracking-analysis/experience-api/
Expertise Levels	A theoretical explanation for understanding how adults acquire skill and transition from being a novice to an expert (e.g., the five stages of skill acquisition: novice, advanced beginner, competent, proficient, and expert).	https://www.bumc.bu.edu/facdev-medicine/files/2012/03/Dreyfus-skill-level.pdf
Failure Modes and Effects Analysis (FMEA)	One of the first highly structured, systematic techniques for failure analysis. It was developed by reliability engineers in the late 1950s to study problems that might arise from malfunctions of military systems. An FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects, including human performance.	https://en.wikipedia.org/wiki/Failure_mode_and_effects_analysis
Federation	A group of computing or network providers agreeing upon standards of operation in a collective fashion.	https://en.wikipedia.org/wiki/Federation_(information_technology)
Future Learning Ecosystem	A transformation away from disconnected, episodic experiences and towards a curated continuum of lifelong learning, tailored to individuals, and delivered across diverse locations, media, and periods of time.	https://www.adlnet.gov/modernizing-learning

Lexicon Term	Definition	Citation/Reference/Attribution
Governance	Establishment of policies with continuous monitoring of their proper implementation, by members of a governing body. Governance includes the mechanisms required to monitor and enforce compliance.	http://www.businessdictionary.com/definition/governance.html
Higher Order Cognition / Higher Order Thinking	1. A composition of sophisticated neurodevelopmental functions that influence decision making including concept acquisition, systematic decision making, evaluative thinking, brainstorming, and rule usage. 2. Higher-order thinking is a concept of education reform based on the concept that some types of learning require more cognitive processing than others. These include concepts that require strategic thinking, planning, or comprehending the interconnectivity of concepts, places, events, and people.	https://www.sciencedirect.com/topics/psychology/higher-order-cognition
Human Capital Supply Chain	Refers to the integration of business planning, strategic workforce planning, staffing and recruiting processes and technology to enhance organizational productivity.	https://en.wikipedia.org/wiki/Human_Capital_Supply_Chain
Identity Management	Also known as identity and access management (IAM). IAM refers to a framework of policies and technologies for ensuring that the proper people in an enterprise have the appropriate access to technology resources.	https://en.wikipedia.org/wiki/Identity_management OUSDI Final Reort-JAGFinal.docx
Inference	In the TLA and competency-based learning, an inference is a calculation of the strength of a relationship between two concepts based on statistical reduction of cause and effect data. An inference considers steps in reasoning, moving from premises to logical consequences.	https://en.wikipedia.org/wiki/Inference OUSDI Final Reort-JAGFinal.docx
Instructional Strategies	Instructional Theories provide insights about what is likely to happen and why with respect to different kinds of teaching and learning activities while helping indicate approaches for their evaluation. Strategies based on a chosen instructional theory offer explicit guidance on how to better help people learn and develop. Instructional designers focus on how to best structure material and instructional behavior to facilitate learning.	https://en.wikipedia.org/wiki/Instructional_theory
JavaScript Object Notation (JSON)	An open-standard file format that uses human-readable text to transmit data objects consisting of attribute–value pairs and array data types (or any other serializable value).	https://en.wikipedia.org/wiki/JSON
Job, Duty, Task Analysis (JDTA)	A standard process for capturing pertinent data that describes work performed for a specific job. This includes the decomposition and structuring of work and the application of appropriate attributes to the work, at the task level, to more comprehensively describe the work.	https://www.public.navy.mil/netc/ile/documents/NETCResource/NAVEDTRA_137.PDF
Just-in-Time Teaching (JITT)	Providing access, anytime and anywhere, to learning and training that is the relevant information in the correct moment. Just-in-time training is not something that takes separate time from day-to-day work, instead is something that happens throughout the working day easily and quickly.	https://www.swiftelearningservices.com/improve-learning-culture-by-embracing-just-in-time-training-in-workplace/
Knowledge, Skills, and Abilities (KSAs)	The attributes required to perform a job and are generally demonstrated through qualifying experience, education, or training. Knowledge is a body of information applied directly to the performance of a function. Skill is an observable competence to perform a learned	https://www.opm.gov/policy-data-oversight/classification-qualifications/general-schedule-qualification-policies/#url=exp

Lexicon Term	Definition	Citation/Reference/Attribution
	psychomotor act. Ability is competence to perform an observable behavior or a behavior that results in an observable product.	
Learner	The generic term for a user in a distributed learning environment that generates data while interacting with elements within that environment.	https://github.com/adlnet/xAPI-Spec/blob/master/xAPI-About.md
Learner Profile, Learner Profile Service	An adaptive data structure that tracks and stores learning and skills mastery over a lifetime of learning experiences. The information can be used to make academic or employment decisions, among other things.	https://www.armyupress.army.mil/Portals/7/journal-of-military-learning/Archives/jml-april-2017-whole-book.pdf
Learning Activity	Activities designed or deployed by the teacher to bring about or create the conditions for learning.	http://newlearningonline.com/learning-by-design/glossary/learning-activity
Learning Activity Provider	An activity provider is any tool or system that generates data about learning experiences, achievements, and job performance and sends it to the LRS.	https://xapi.com/ecosystem/
Learning Content Management System (LCMS)	An environment where developers can create, store, reuse, manage and deliver learning content from a central object repository, usually a database. LCMS generally work with content that is based on a learning object model.	http://edutechwiki.unige.ch/en/LCMS
Learning Event Management	The process of recording learning data the order that it is done and determining which learning activity a learner should experience next. In the TLA, this is the function that schedules, initiates, monitors and closes out each learning event. It provides the control logic around the LRS. Previously called “activity management.”	https://en.wikipedia.org/wiki/Activity_management OUSDI Final Reort-JAGFinal.docx
Learning Management System (LMS)	A software application that controls the administration, documentation, tracking, reporting, and delivery of educational courses, training programs, or learning and development programs.	https://en.wikipedia.org/wiki/Learning_management_system
Learning Record Store (LRS)	A server-based system capable of receiving and processing web requests, that is responsible for receiving, storing, and providing access to Learning Records.” The LRS is designed to enable systems to store and retrieve xAPI statements, store xAPI state, and store various other xAPI metadata from other systems.	https://github.com/adlnet/xAPI-Spec/blob/master/xAPI-About.md
Learning Science	An interdisciplinary field that works to further scientific, humanistic and critical theoretical understanding of learning as well as to engage in the design and implementation of learning innovations, and the improvement of instructional methodologies.	https://en.wikipedia.org/wiki/Learning_sciences
Level of Mastery	Refers to how good or proficient you have to be in an attribute, trait, or skill to use it in a job, or proceed to the next level.	https://en.wikipedia.org/wiki/Mastery_learning
Lifelong Learning	An acknowledgement that learning is pervasive. It encompasses a “continuum of learning” from birth to adulthood that connects formal and informal learning experiences into a cohesive set of competencies and credentials to drive future educational and work choices.	https://www.adlnet.gov/modernizing-learning
Linked Data	A method of publishing structured data so that it can be interlinked and become more useful through semantic queries.	https://en.wikipedia.org/wiki/Linked_data

Lexicon Term	Definition	Citation/Reference/Attribution
Live, Virtual, Constructive, Game (LVCG)	Integrates emerging simulations and technology-based exercises into unit and Soldier training and is part of the Army's Integrated Training Environment.	https://www.army.mil/standto/archive_2013-05-23
Master Scenario Events List (MSEL)	Provides a timeline and location for all expected exercise events and injects (actions that push the scenario forward).	https://emilms.fema.gov/IS130a/groups/25.html
Measures of Effectiveness (MOE)	Outcome metrics that define the level of achievement for a set of goals and the intended results. They may be expressed as probabilities or key performance indicators that a job or task has been performed to standard.	http://acqnotes.com/acqnote/tasks/measures-of-effectivenessrequirements
Measurement of Performance (MOP)	A criterion used to assess friendly actions that are tied to measuring task accomplishment.	https://www.jcs.mil/Doctrine/Joint-Doctrine-Pubs/3-0-Operations-Series/
Metadata	Data that describe other data. Metadata describes learning resources, competencies, learners, and data that is used within the TLA. It is often used for discovery and identification of resources using a search tool. Similarly, a Competency Management System will use metadata to predict proficiency levels upon receiving an assertion from a specific learning activity.	https://techterms.com/definition/metadata
Micro Credentials	Limited certifications that represent an individual's demonstration of specific skills or knowledge. They are sometimes conferred as open or digital badges as opposed to a more traditional written diploma.	http://policyatlas.org/wiki/Micro-credentials
Microlearning	A way of teaching and delivering content to learners in small, very specific bursts. The learners are in control of what and when they're learning.	https://elearningindustry.com/why-microlearning-is-huge
Microservice	A software development technique—a variant of the service-oriented architecture (SOA) architectural style that structures an application as a collection of loosely coupled services.	https://en.wikipedia.org/wiki/Microservices
Mobile Learning	Mobile Learning focuses on learning across contexts and locations by the means of mobile devices (e.g. laptops, smart phones, personal digital assistants, game devices, tablet PCs, and e-books). Mobile devices are used to access online courses and resources and can also foster collaboration among individuals, conduct assessments and evaluations, provide access to performance support, and capture evidence of a learning activity.	https://www.opm.gov/WIKI/training/Leveraging-New-Technologies-for-Employee-Development-Programs.ashx
Needs Assessment	A systematic process for determining and addressing needs, or "gaps" between current conditions and desired conditions. A needs assessment is the process of identifying the "gap" between performance required and current performance.	https://www.opm.gov/policy-data-oversight/training-and-development/planning-evaluating/
Observer, Instructor, Controller, Supervisor (OICS)	A collective identification of roles in the Total Learning Architecture which provide mentoring, guidance or approval for learning activities and evaluations of learners.	TLA DODAF
On the Job Training (OJT)	A form of training provided at the workplace. Employees also get a hands-on experience using machinery, equipment, tools, materials, and facing the challenges that occur during the performance of the job.	https://en.wikipedia.org/wiki/On-the-job_training

Lexicon Term	Definition	Citation/Reference/Attribution
Paradata	Usage data about learning resources that include quantitative metrics (e.g., how many times a piece of content was accessed) and pedagogic context, as inferred through the actions of educators and learners. Paradata may be operationalized as a specific type of metadata, however the construct differs from traditional descriptive metadata that classify the properties of the learning resource itself, and instead involves the capture—and open resharing—of in situ information about online users' interactions related to the resource.	https://en.wikipedia.org/wiki/Paradata_(learning_resource_analytics)
Performance Measurement	The process of collecting, analyzing and/or reporting information regarding the performance of an individual, group, organization, system or component.	https://en.wikipedia.org/wiki/Performance_measurement
Persona	A Persona is a component of Identity Management that expresses the context for an individual's social interactions with work, family, friends, etc. Each persona has a different set of data, associations, or other attributes. For example, an individual's Facebook account, work account, and gym membership are all separate personas of the same person.	https://github.com/adlnet/xAPI-Spec/blob/master/xAPI-About.md
Personalization	A diverse variety of educational programs, learning experiences, instructional approaches, and academic-support strategies that are intended to address the distinct learning needs, interests, aspirations, or cultural backgrounds of individual students.	https://www.edglossary.org/personalized-learning/
Personally Identifiable Information (PII)	Any representation of information that permits the identity of an individual to whom the information applies to be reasonably inferred by either direct or indirect means.	https://www.dol.gov/general/ppii
Proficiency	1. Army: Proficiency is the completeness of achievement of lower level standards to an overarching standard. 2. Navy: Proficiency is equivalent to level of mastery. 3. Joint: Proficiency is meeting standard.	ADP-7 NAVEDTRA 137 MIL-HDB-29612
Profile	A set of rules and human- and/or machine-readable documentation of application-specific vocabulary concepts, statement patterns, extensions, and statement templates used when implementing xAPI in a specific context.	https://github.com/adlnet/xapi-profiles
Readiness	The ability of US military forces to fight and meet the demands of the National Defense Strategy. Readiness is the synthesis of two distinct but interrelated levels. • *Unit Readiness* is the ability to provide capabilities required by the combatant commanders to execute their assigned missions. This is derived from the ability of each unit to deliver the outputs for which it was designed. • *Joint Readiness* is the combatant commander's ability to integrate and synchronize ready combat and support forces to execute his or her assigned missions.	https://www.militaryfactory.com/dictionary/military-terms-defined.asp?term_id=4430
Recommender Service	A subclass of information filtering system that seeks to predict which learning activity a learner should interact with to further career goals or to meet operational needs.	https://en.wikipedia.org/wiki/Recommender_system
Representational State Transfer (REST)	A software architectural style that defines a set of constraints to be used for creating Web services. Web services that conform to the REST architectural style, termed RESTful Web services (RWS), provide interoperability between computer systems on the Internet.	https://en.wikipedia.org/wiki/Representational_state_transfer

Lexicon Term	Definition	Citation/Reference/Attribution
Resident Instruction (Live)	Education or training activities that are presented, managed, and controlled by an onsite instructor or facilitator. There is an instructor, a classroom, and one or more learners in the same classroom at the same time.	https://sill-www.army.mil/DOTD/divisions/pdd/docs/Army%20Learning%20Model%202015.pdf
Return on Investment (ROI)	A performance measure that compares the monetary value of the business impacts gained from a project or a program with the actual cost of implementing the project or program.	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
Shareable Content Object Reference Model (SCORM)	A set of technical standards for eLearning software products developed in the early 2000s. Specifically, SCORM governs how online learning content and Learning Management Systems (LMSs) communicate with each other.	https://adlnet.gov/scorm
Self-Directed Learning	Learners identify potential for learning from novel experiences and determine own path (Heutagogy).	https://www.teachthought.com/pedagogy/a-primer-in-heutagogy-and-self-directed-learning/
Self-Regulated Learning	Refers to one's ability to understand and control one's learning environment. The self-regulatory processes that learners apply to transform their cognitive abilities into academic performance. Self-regulation includes goal setting, self-monitoring, self-instruction, and self-reinforcement.	https://lincs.ed.gov/sites/default/files/3_TEAL_Self%20Reg%20Learning.pdf
Skill Decay	The loss of knowledge or a skill following a period of nonuse.	https://www.researchgate.net/publication/232904872_Factors_That_Influence_Skill_Decay_and_Retention_A_Quantitative_Review_and_Analysis
Social Learning	A theory of learning process and social behavior which proposes that new behaviors can be acquired by observing and imitating others. Using technology to learn vicariously through others' experiences, benefit from their knowledge and ability to highlight important information, and to increase interest and enjoyment in learning.	https://www.psychologytoday.com/us/basics/social-learning-theory
Specifications and Standards	A set of community-accepted or normative technical rules used to coordinate interoperability of systems or interchanges of data.	https://www.dsp.dla.mil/Specs-Standards/
Stakeholder	An individual, or group of individuals, who have a significant or vested interest in the outcomes of ongoing education and training modernization efforts.	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
Subject Matter Expert	A person with bona fide expert knowledge about what it takes to do a job. First-level supervisors are normally good SMEs.	Delegated Examining Operations Handbook
Talent Development	1. Building the knowledge, skills, and abilities of others and helping them develop and achieve their potential so that the organizations they work for can succeed and grow. 2. Talent Development cultivates a continuous learning and development environment to ensure that an agencies workforce can adapt to globalization, internal restructuring, and adaptations that affect how work is performed.	1. https://www.td.org/insights/talent-development 2. https://www.opm.gov/policy-data-oversight/human-capital-management/talent-management/

Lexicon Term	Definition	Citation/Reference/Attribution
Talent Development and Training	Talent Development and Training is the creation and delivery of learning resources and opportunities increasing the employees' capacity to successfully perform in their roles and advance their careers.	https://www.opm.gov/services-for-agencies/hr-line-of-business/enterprise-architecture/brm_report_v2.pdf
Talent Development Planning	Talent Development cultivates a continuous learning and development environment to ensure that an agency's workforce can adapt to globalization, internal restructuring, and adaptations that affect how work is performed. To integrate Talent Development with Talent Management an analysis of workforce data is needed to determine how an agency will meet future needs through the development or cross-training of talent who possess the required skills.	Definition provided by Shanaz Porter (OPM)
Talent Management	1. An organization's ability to recruit, retain, and produce the most talented employees available in the job market using data to inform purposeful recruitment and personnel selection, assignment, and management. 2. A system that promotes a high-performing workforce, identifies and closes skills gaps, and implements and maintains programs to attract, acquire, develop, promote, and retain quality and diverse talent.	https://www.opm.gov/WIKI/training/Talent-Development-Glossary.ashx#T
Talent Management System	A system that addresses competency gaps, particularly in mission-critical occupations, by implementing and maintaining programs to attract, acquire, develop, promote, and retain quality talent.	https://www.opm.gov/policy-data-oversight/human-capital-management/reference-materials/
Technical Interoperability	A characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, at present or in the future, in either implementation or access, without any restrictions.	https://en.wikipedia.org/wiki/Interoperability
Terminal Learning Objective (TLO)	Specifies what learner should know or be able to do at the end of a course that they didn't know or couldn't do before taking the course. Each TLO must have at least one ELO.	https://adminpubs.tradoc.army.mil/pamphlets/TP350-70-3.pdf
Total Learning Architecture	A research and development activity sponsored by the ADL Initiative and conducted in collaboration with stakeholders from across the defense community, professional standards organizations, and commercial industry. The TLA is a collection of specifications for accessing and making use of lifelong learning-related data to enable next-generation learning.	https://www.adlnet.gov/tla/
Training	Process of placing or enrolling an employee in a planned, prepared, and coordinated program, course, curriculum, subject, system, or other education activity that improves individual and organizational performance and assists in achieving the agency's mission and performance goals.	https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/ai/a040p.pdf?ver=2017-07-19-142854-093
Universal Unique Identifier (UUID)	A 128-bit number used to identify information in computer systems.	https://en.wikipedia.org/wiki/Universally_unique_identifier
User Interface/User Experience (UI/UX)	The space where interactions between humans and machines occur.	https://en.wikipedia.org/wiki/User_interface

2.0 CAPABILITY VIEWS (CV)

Capability views describe the TLA from the perspective of measurable improvements to the education and training enterprise. It is stated in terms of value added to the national defense strategy.

2.1 CV-1 Vision

The TLA vision shows the alignment of the phased deployment of capabilities aligned with the lines of effort in the ADL Initiative research portfolio. These lines of effort and related capabilities, specifications and projects are listed in **Table 3**.

2.2 CV-2 Capability Taxonomy

Table 2 describes the hierarchy of capabilities provided, and measurements of effectiveness to determine the impact of the new TLA capability on lethality or management systems in the education and training enterprise.

2.3 CV-3 Capability Phasing

The TLA capabilities will be phased-in as a series of migration efforts. Existing systems and content can be recapitalized by exposing additional interfaces and conversion of data structures or migrating to new data repositories. Eventually the adoption of services or microservice-based systems can replace legacy systems as part of obsolescence management and provide even more capabilities as end-to-end management and optimization of the human capital supply chain is enabled. This is shown in **Figure 2** as the TLA Capability Maturity Model.

2.4 CV-6 Capabilities to Operational Activities Mapping

Table 4 presents a cross reference between the capabilities listed in **Table 2** and stakeholder processes (i.e. “operational activities”) that support or are supported by those capabilities.

Table 3. CV-1 TLA Vision and Alignment with ADL Initiative Lines of Effort.

TLA Maturity Level	Alignment with NDS	Capability Provided	ADL Project Supporting	Associated Specification	Expected Time to Complete		*LEGEND*
							Threshold for TLA IOC FY 221
1		Decouple learning solutions from Vendor	P4STLA-> *Privacy Api* ->*Accredited LRS*	xAPI, cmi5, MOM IEEE P9274.3.1, REST	Apr-20	IOC	ADL Policy or origin
			Profile Server		Sep-21		External Policy, Spec or standard
			Pub/Sub-> xAPI MOM ->Activity Management Service-> *DATASIM*		Dec-19		Improve Management Systems
			cmi5 viewer		Sep-21		
		Expansion of Instrumented Learning Activities	*PALMS*	Federation Negotiation (TLA Spec), NIST 800 (ZTN), IAM (DISA), LTI, Service Specs for TADSS and support data , LRMI	Sep-21		
			PEBL		Sep-21		
			PERLS		Sep-21		Improve Management Systems and Increase Lethality
			LVCG		Sep-23		
			Content and Resource Registration Service		Dec-19		
2		Legacy Content Recapitalization	Federated Activity Indices ->Data Labeling->Enterprise Course Catalog (ECC)	LRMI,DODI 1322.26	Apr-19		
			Flash Deprecation metadata		Sep-19		
		Enhanced Enterprise Analytics	*DAVE*	Federated Negotiation (TLA Spec), ZTN, IAM, xAPI, TLA Business Rules	Apr-20		
			OUSDI->Federated Identity Management -> UUID		Sep-21		
3		Reduced Schooltime Duty Cycle*	CaSS AFLSE-> *CaSS hardening ->NILE->* Data Labeling->CBL	IEEE P1484.20.1 RCD	Sep-23	FOC	Increase Lethality
			Enterprise Learner Record Repository (ELRR)	Airman Learner Record, ELRR metamodel	Sep-23		
		Integration with Occupational Alignment	MILGEARS Interoperability	MILGEARS API	Sep-23		
			Digital Badging-> Centralized Credential management	OPM Credential Policy	Sep-23		
		Operational Data Validation	Data Governance-> Readiness Data Integration	DRRS API, etc.	Sep-25		
			Data Governance-> M&P/HR data integration	DEERS API, etc. (e.g. HR system update TBD)	Sep-25		
		Full Integration with CDO Data Interoperability	Data Governance-> EPSS/IETM Integration	GEIR, S-1000D etc., xAPI, Federation Negotiation	Sep-25		Associated Specifications rolled out as fungible references in DODI(D) 1322.26 via DADLAC
			Data Governance-> ILS/Product Support Data Integration	Model Based Product Support, ISO 10303	Sep-25		
4		Incorporation of Learning Adaptation Support	Recommenders**	TLA Interface Spec, Business Rules	Outyear TBD		
			Internet of Learning Things **	TLA Interface Spec, Business Rules	Outyear TBD		
5		Fully Automated Human Capital Demand Signals	Meta Adaptation **	TLA Interface Spec, Business Rules	Outyear TBD		
			Machine Learning **	TLA Interface Spec, Business Rules	Outyear TBD		

	Project	Purpose
Backend Infrastructure and Outreach Support	MADLX	stakeholder engagement
	NATO CMM	stakeholder engagement
	DADLAC	stakeholder engagement
	Virtualization Management/Hosting/Sandbox	experimentation to vet concepts for inclusion in TLA policy framework
	Learning Warehouse	clearing house for product Transition
	XAWG, TLAWG, Ltech reform, xAPI std	Outreach and marketing
	Conformance Suite	Maintain existing user base
	Curated GitHub	Maintain existing user base

* Competency based learning enhances lethality by tying credential back to demonstrated work performance, and enables shortening of formal education cycles so more time is spent operational/deployable

-> Follows

Underlined are IRAD projects

Italicized are candidates for transition to separate Program of Record (PoR)

** Not currently in portfolio

Table 4. CV-2 Capability Taxonomy.

1.0 Level	1.1 Level	1.1.1 Level	Capability ID	Maturity Level	Purpose and Description	Measures of Effectiveness
Optimize the selection, retention, and assignment of capable manpower through enhanced education and training	Decouple learning systems from proprietary vendor technology	Provide central point for records from disparate CMS/LMS	**1.1.1**	**IOC (1)**	Allows disparate LMS, CMS and other instrumented activities to record xAPI in central LRS without requiring interface between internal system components or data.	Reduce overhead costs to maintain training
		Create agility with legacy LMS license management fees	**1.1.2**		Reduce financial burden of maintenance at sites by removing dependencies between content, LMS, assessment and other institutional administrative functions.	Reduce overhead costs to maintain training
	Expansion of Instrumented Learning Activities and integration with learning data	Address full range of formal and informal learning, including on the job experiences	**1.2.1**		Include the assertion of competency that comes from demonstration in work context of knowledge, skills, abilities and other characteristics (KSAOs), especially those associated with motivation and soft skills - combination of Personnel and Training data.	Demonstration of performance data capture for OJT, LVCG, traditional eLearning, and attributes typically aligned with performance evaluations
		Enable Self-Paced Learning in common system	**1.2.2**		Manage adult learning activities using same data structures as formal pedagogical setting.	Reduce overhead costs to maintain training
		Enable Self Directed Learning in common system	**1.2.3**		Manage heutogical learning activities using same data structures as formal pedagogical setting.	Reduce overhead costs to maintain training
	Legacy Content Recapitalization	Eliminate redundancy in course development	**1.3.1**		Identify courses and course elements that are redundant between agencies and remove them from sustainment to improve cost performance of courseware maintenance activities.	Improve content recapitalization ROI
		Evaluate frequency of use of activities	**1.3.2**	**IOC (2)**	Enhanced curriculum review by determining which activities are used most often.	Improve content recapitalization ROI
		Correlate user experience feedback	**1.3.3**		Enhanced curriculum review by determining which activities are most popular or yield best experiences.	Improve content recapitalization ROI
		Evaluate content efficacy	**1.3.4**		Enhanced curriculum review by determining which activities are correlated to superior performance.	Improve content recapitalization ROI
		Support recapitalization of legacy learning technology (LMS, etc.)	**1.3.5**		Allow integration of existing LMS, simulation systems, HR databases, operational data, offline assessment systems and network management systems without requiring extensive refactoring of solutions.	Improve content recapitalization ROI
	Enhanced Local/Enterprise Learning Analytics	Identify systemic performance issues	**1.4.1**	**3**	Enhanced curriculum review by determining which areas of competency, curriculum, or content are associated with system service wide performance problems.	Reduce cycle time for curricular review
		Optimize individual path for completing course/learning event	**1.4.2**		Improve student opportunity to pass class/excel at learning event.	Reduce cycle time for curricular review Reduce overhead costs to maintain training
		Optimize individual credential achievement	**1.4.3**		Improve student time required to achieve degree/certification.	Reduce cycle time for curricular review Reduced overhead costs to maintain training
		Optimize requirements of Current Job	**1.4.4**		Improve alignment of overall learner skillset and proficiency with job requirements.	Improve overall unit readiness
		Improve student performance	**1.4.5**		Maximize pass rate for students enrolled in course (pump, not filter).	Reduce overhead costs to maintain training
	Reduced Schooltime Duty Cycle	Maximize training site throughput	**1.5.1**		Maximize number of learners qualifying per period (not linked to time-based schedule but based on contention of learning resources to quickly achieve qualification).	Reduce overhead costs to maintain training
		Improve speed of qualification and proficiency	**1.5.2**		Maximize number of qualified personnel who can perform a duty by reducing time to qualify (improve "operational duty cycle").	Improve overall unit readiness
		Optimize current career trajectory	**1.5.3**		Ensure knowledge and skill acquisition aligns with future job requirements.	Improve overall unit readiness
	Integration of low-level competency data with Occupational Alignment	Support recapitalization of legacy improvement initiatives	**1.6.1**	**3**	Allow integration or synchronization with ongoing improvement initiatives to leverage ongoing capital investment.	Improve content recapitalization ROI
		Support career transition	**1.6.2**	**3**	Improve attractiveness of Military as a career option /improve retention.	Improve overall retention
		Provide single authoritative reference point for credentials and competencies	**1.6.3**	**3**	Be able to find competency and credential data on any personnel without having to manually search through multiple systems.	All DOD personnel are accessible with records >95% complete
		Select new career	**1.6.4**	**3**	Determine possible options for career change based on legacy skills inventory, motivation and aptitude aligning with other jobs' requirements	Improve overall retention
	Operational Data Validation	Tie human performance objectives to curricular requirements	**1.7.1**	**FOC (4)**	Reduce cycle time for curriculum review from 3 years to continuous improvement and relevancy.	Reduce cycle time for curricular review
		Provide reliable predictions of overall warfighting readiness based on competency state	**1.7.2**		Improve estimation of warfighting capability by increasingly granularity of human contribution to readiness.	Improve overall unit readiness
		Maximize options and fitness for detailing	**1.7.3**		Ensure demand signals for future personnel requirements are transmitted and addressed as early as possible in the supply chain.	Improve overall unit readiness

1.0 Level	1.1 Level	1.1.1 Level	Capability ID	Maturity Level	Purpose and Description	Measures of Effectiveness
	Integration with Data Interoperability (ILS/FE&T)	Provide feedback to system development for human performance issues	**1.8.1**	**5 (Future)**	Reduce high outyear life cycle cost growth from unplanned training costs to address readiness.	Reduce cycle time for curricular review Reduced overhead costs to maintain training
	Incorporation of Machine Learning Adaptation Support	Support recapitalization of adaptive learning algorithms	**1.9.1**		Allow for reuse and integration of advanced adaptation to aid in performance improvement without refactoring of existing systems.	Improve ROI for machine learning initiatives
		Integrate advanced sensors	**1.9.2**		Refine performance information with worksite context and other assessment strategies. Use biometric identity management.	Reduce cycle time for curricular review
		Full macro and meta adaptation	**1.9.3**		Aid learners with course/objective/career planning - optimize learning path	Reduce overhead costs to maintain training
	Fully Automated Human Capital Management Demand Signals	Detailing quota and incentives alerts	**1.10.1**		Support human capital supply chain management within and across agencies and commands.	Optimize cost to maintain given manpower posture

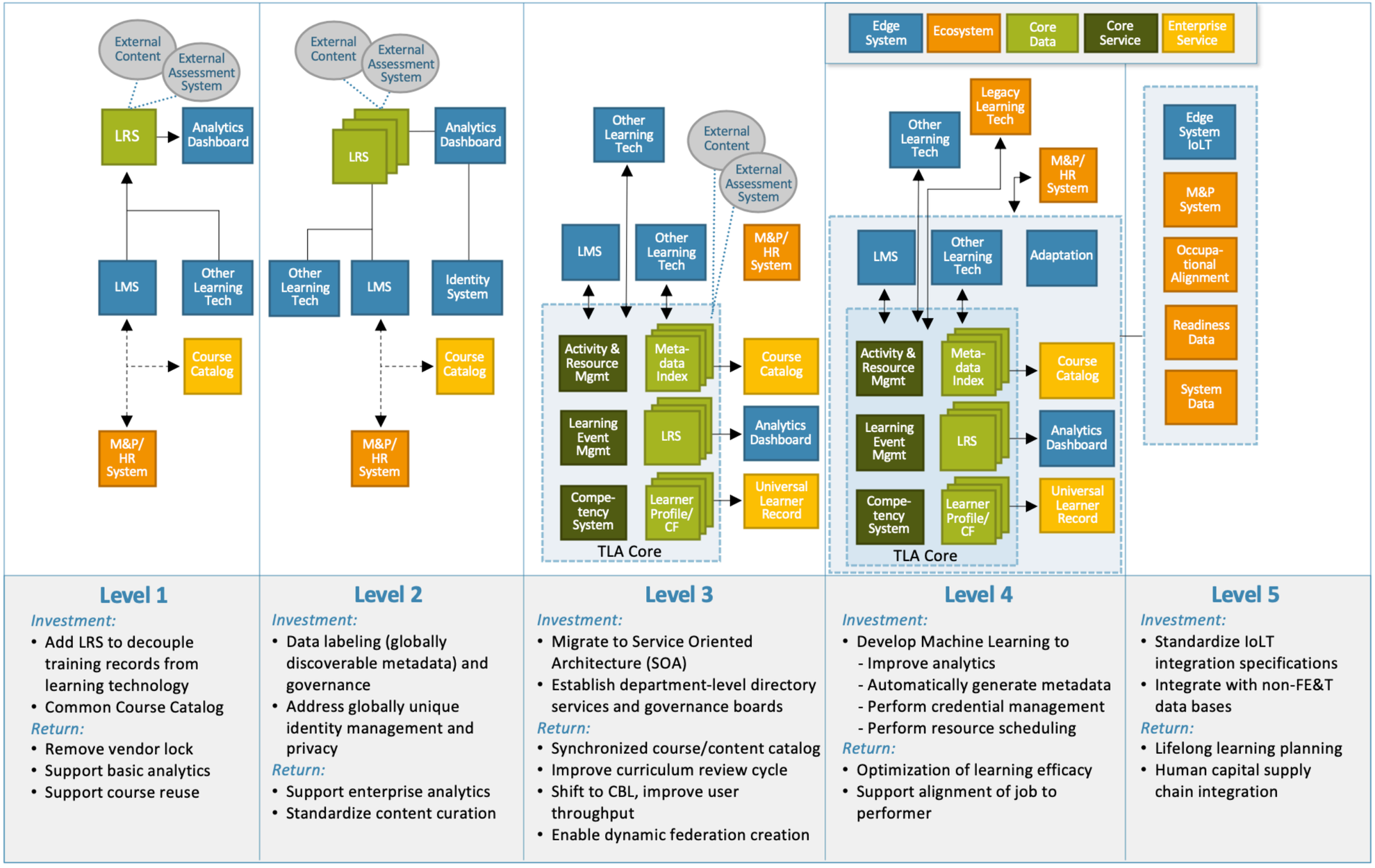

Figure 2. CV-3 Capability Phasing. *TLA Maturity Model enables phased migration of capabilities.*

Table 5. CV-6 Capability to Operational Activities Mapping. *References marked "x" are required and "o" are enhanced.*

Operational Activity Decomposition			Capability ID and Alignment																													
Stakeholder	**Operational Activity**	**Purpose**	**1.1 .1**	**1.1 .2**	**1.2 .1**	**1.2 .2**	**1.2 .3**	**1.3 .1**	**1.3 .2**	**1.3 .3**	**1.3 .4**	**1.3 .5**	**1.4 .1**	**1.4 .2**	**1.4 .3**	**1.4 .4**	**1.4 .5**	**1.5. 1**	**1.5. 2**	**1.5. 3**	**1.6. 1**	**1.6. 2**	**1.6. 3**	**1.6. 4**	**1.7. 1**	**1.7. 2**	**1.7 .3**	**1.8 .1**	**1.9 .1**	**1.9 .2**	**1.9 .3**	**1.10 .1**
Learning Command	Conduct Learning Events	Assign and collect Learning data	X	X	X	X	X	X	X	X	X	X						X	X	X					X							
Credential Owner		Update conferral of credentials based on data																X	X	X					X							
Identity manager	Synchronize Identity management	Maintains globally unique ID tokens	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X			X		X	X	X	X
Credential owner		Reconciles credential reporting and digital signatures																X	X	X					X							
Learning Command		Uses identity handle and anonymization for PII protection											O	O	O	O	O								X							
Analytics Owner		Uses identity handle and anonymization for PII protection											X	X	X	X	X	X	X									X			X	X
Analytics Owner	Sharing Learning Records	Establishes data sets for analysis	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X
Data Model Owner		Establishes data metamodels for interoperability			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Learning Command		Creates and stores learning records	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								X							
Competency owner	Creating Competency Frameworks	Identifies RCD and association DAG																X	X	X	X	X	X	X	X	X	X	X			X	
Warfighting System Owner		Identifies tasks, conditions, and standards											O	O	O	O	O								X	X	X	X			X	X
Warfighting Requirements Owner		Identifies tasks, conditions, and standards																							X	X	X	X			X	X
Warfighting System Owner	Manage Job/Duty/Gig Definitions	Validates candidate audience against warfighting tasks																							X	X	X	X			X	X
M&P Owner		Identifies jobs, duties and gigs																X	X	X	X	X	X	X	X		X	X				X
Analytics Owner	Manage Decision Support Analytics	Identify new templates and metrics	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X
Learning Command		Populate and use decision making templates for Kirkpatrick 1-2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Readiness Owner		Populate and use decision making templates for Kirkpatrick 3-4																							X	X	X	X			X	X
Policy Owner	Maintain Policy Framework	Define policy framework	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Content Owner	Curate experiences	Create, survey and register new learning content											X	X	X	X	X	X	X	X					X			X	X		X	
Learning Command	Maintain Data Federation	Obtain ATC/MOA and use federated data	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X					
DISA		Issue ATO/ATC																														
Identity manager		Enforce non-repudiation, PII protection and UUID	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X			X		X	X	X	X
Learning Command	Register New Activities	Register, use and manage configuration of content	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X				X	X	X	
Data Model Owner		Update registry metamodel			X	X	X	X	X	X	X	X																X			X	X
Warfighting Requirements Owner		Register, use, and manage configuration of content																							X	X	X	X			X	X
Content owner	Migrate legacy activities	Populate metadata and register content elements						X	X	X	X	X						X	X	X					X							
Competency owner		Establish new educational alignment updates																X	X	X					X							
DISA	Maintain Cybersecurity	Establish cybersecurity policy, Conduct 3PAO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Learning Command		Establish ATO/ATC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Learning Command	Synchronizing Enterprise Course Catalog	Provide for federation of local XI content			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X				X	X	X	
Competency owner		Federation of local educational alignment data																X	X						X							
Content owner		Populate required metadata for discovery																X	X						X							

Operational Activity Decomposition			Capability ID and Alignment																													
Stakeholder	**Operational Activity**	**Purpose**	**1.1 .1**	**1.1 .2**	**1.2 .1**	**1.2 .2**	**1.2 .3**	**1.3 .1**	**1.3 .2**	**1.3 .3**	**1.3 .4**	**1.3 .5**	**1.4 .1**	**1.4 .2**	**1.4 .3**	**1.4 .4**	**1.4 .5**	**1.5. 1**	**1.5. 2**	**1.5. 3**	**1.6. 1**	**1.6. 2**	**1.6. 3**	**1.6. 4**	**1.7. 1**	**1.7. 2**	**1.7 .3**	**1.8 .1**	**1.9 .1**	**1.9 .2**	**1.9 .3**	**1.10 .1**
Readiness Owner	Evaluate Competency Frameworks	Provide MOE to validate weights and completeness of framework																						X	X	X	X			X	X
Competency owner		Update Competency Framework (CF)																			X	X	X	X	X	X	X					X
Data Model Owner		Update CF metamodel											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Analytics Owner		Provide data templates to evaluate CF and MOE																						O	X	X	X	X	X	X	X
Competency owner	Sharing Competency Frameworks	Share CF																			X	X	X	X		X	X					X
Learning Command		Use CF											X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	
Credential Owner		Archive updates to credentials																X	X	X	X	X	X	X		X	X					
Warfighting System Owner	Maintain Data Governance	Define data development and sharing policies PDSS																									X					X
Readiness Owner		Define data development and sharing policies DRRS																						X	X	X						X
M&P Owner		Define data development and sharing policies M&P																X	X	X	X	X	X	X								X
Data Model Owner		Define data development and sharing policies CF, LP, AI formats						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DISA		Establish privacy and security requirements	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Content owner		Develop and implement content data labeling policies			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Content owner	Create Experiences	Create, survey and register new learning content			X	X	X																									
Warfighting System Owner		Create, survey and register new reference content			X	X	X																		X							
M&P Owner	Review Learner Records	Identify Detailing and Job assignments																								X						
Interoperability	Maintain Device Federations	Networking, MOA, ATC and data sharing standards		X	X													X														
Learning Command		Obtain ATC/MOA and use federated data		X	X												X	X														
DISA		Issue ATO/ATC		X	X													X														
M&P Owner	Conduct Audits	Verify credentials											X	X	X	X	X					X										O
Competency owner		Evaluate performance vs requirements											X	X	X	X	X															O
Credential Owner		Update credential requirements											X	X	X	X	X															O
Learning Command		Comply with gradebook and transcript requirements, conferral review											X	X	X	X	X															O
Learning Command	Evaluate Experiences	Determine suitability of local content for purpose			X	X	X	X	X	X	X	X																				O
Content owner		Perform technology refresh/course update											X	X	X	X	X															O
Data Model Owner		Evaluate paradata for data labeling requirements											X	X	X	X	X															O
Analytics Owner		crowdsource analytic templates to evaluators											X	X	X	X	X															O
M&P Owner	Evaluate Learners	Personnel detailing, screening, selecting, promotions											X	X	X	X	X															O
Analytics Owner		Crowdsource analytic templates to evaluators											X	X	X	X	X															O
Learning Command		Review for awarding credential, staff pick up, etc.											X	X	X	X	X															O
Learning Command	Register New Activities	Create and register on site content and activities			X	X	X																									
Content owner		Create and register globally available content			X	X	X																									
Learning Command	Manage Credentials	Review evidence and assign credential											X	X	X	X	X				X	X	X	X								O
Competency owner		Define qualification standards											X	X	X	X	X				X	X	X	X								O
Credential Owner		Archive non repudiable copy of credential											X	X	X	X	X				X	X	X	X								O

Table 6. CV-7 Capability to Services Mapping. *References marked "x" are required and "o" are enhanced.*

		Capability ID and Alignment																													
Service Function Decomposition		**1.1.1**	**1.1.2**	**1.2.1**	**1.2.2**	**1.2.3**	**1.3.1**	**1.3.2**	**1.3.3**	**1.3.4**	**1.3.5**	**1.4.1**	**1.4.2**	**1.4.3**	**1.4.4**	**1.4.5**	**1.5.1**	**1.5.2**	**1.5.3**	**1.6.1**	**1.6.2**	**1.6.3**	**1.6.4**	**1.7.1**	**1.7.2**	**1.7.3**	**1.8.1**	**1.9.1**	**1.9.2**	**1.9.3**	**1.10.1**
Event Management	Schedule event	X	X	X													X	X	X	O	O	O	O	O	O	O	O	O	O	O	O
	Capture event	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O
	Monitor learner object life cycle	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O
	Update event context xAPI messages	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O
Activity and Resource Registry	Federate experience records				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Register content and activities				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	CRUD metadata values				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Provide Enterprise Course Catalog				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Return activity search				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
Competency Management	Search competency																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Update/fetch career state																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	CRUD/Import job pool																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	CRUD/Import competency networks																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Calculate change in learner competency state																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Manage learner credentials																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Mange leaner records																X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
	Import readiness data																							X	X	X	O	O	O	O	O
Identity Management	Mange identity groups											O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	CRUD/fetch users in enclave	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	Manage user personas	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	Manage user digital records	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Virtualization Management	Manage dynamic endpoints	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Manage dynamic resources	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

3.0 DATA AND INFORMATION VIEWS (DIV)

3.1 DIV-1 Conceptual Data Model

The DIV -1 describes the types of operational information by data owner class. The headings in the following section represent classes of interfaces shown on the OV-2 in Section 3.

3.1.1 Governance Procedures

The future learning ecosystem is a living, constantly evolving enterprise of products and processes where the scope and complexity of tools and data involved require policy and procedures for governance[5]. The total scope of content, user base, and record retention requirements for the DoD is too large for a single data store or suite of tools to provide utility to all users at acceptable performance. This requires a federated systems approach, which necessitates continuous coordination, reviews and updates.

Data must be maintained at the appropriate classification level, but also be available to push from low to high enclaves for decision makers to get complete pictures of the status of personnel, curricula, materials, and readiness. Governance procedures providing data structure compatibility, message interoperability, coordination between enclaves, and continual review and update of data mappings are necessary for success in this environment.

A critical part of this solution is the configuration of data elements and service deployments over time. This requires a robust governance for federated data and the consistent migration of legacy content and data to the new stores. Governance must exist at several levels (enclave/organizational, federated integrated product team, and the broader ADL community), and the appropriate level of participation, and frequency for each governance board needs to be identified. For these purposes, organizations are asserted to own (govern) the types of information presented below.

3.1.2 Education and Training Policy Owners

The TLA policy framework defining the ecology of the objective end-state is developed by the ADL Initiative, under the Force Training and Education Branch and reporting through the Under Secretary of Defense for Personnel and Readiness - OUSD(P&R). The TLA is composed of commercial standards and technical specifications developed under the TLA research portfolio at the ADL Initiative.

3.1.3 The TLA Policy Framework

The TLA policy framework includes the experience API (xAPI), currently undergoing revision by the IEEE Learning Technology Standards Committee (LTSC) to version 2.0. It will transition to the IEEE 9274 Standard. The Reusable Competency Definition Object (RCD) is also under review, to create an update to IEEE 1484.20.1. Additional TLA specifications are being evaluated during 2019 and 2020 with a target date for Initial Operational Capability (IOC) of 2021. Other elements that require governance include:

- DODI 1322.26 (Reference A) – policy guidance managed by the ADL Initiative
- Business Logic – rules for being TLA compliant

[5] *Walcutt, J.J. & Schatz, S. (Eds.) (2019). Modernizing Learning: Building the Future Learning Ecosystem. Washington, DC: Government Publishing Office. License: Creative Commons Attribution CC BY 4.0 IGO.*

- TLA Specification – references the xAPI specification and provides a management profile for ensuring consistent state changes between TLA core systems
- The TLA Master Object Model (MOM) – composed of the reserved verbs listed in the SvcV-10b view
- Federation Negotiation Process – rules for registering components, profiles, and content and ensuring federated identity management, semantic alignment of metadata, namespace management, and alignment of activity-content-competency object handles
- Industry governing bodies for constituent specifications
  - Dublin Core™ - Learning Resource Metadata Initiative (LRMI) and LOM 2.0
  - IMS Global™ - Learning Tools Interoperability (LTI)
  - IMS Global™ - OpenBadge3.0
  - Open API Initiative™ - Open API
  - Open ID Foundation™ - Open Identification Connect (OIDC)
  - Credential Engine™ - Credential Transparency Description Language (CTDL)

3.1.4 Competency Based Talent Management

Governance considerations include:

- Assignment of competency owners and lifecycle management process
- Migration of legacy curricula and standards to populate the initial Competency Frameworks
- Governance for maintenance of the Competency Frameworks over time resulting from changes to Warfighting Systems
- Policy guidance to manage condition and time-based skill decay and de-credentialing policies
- Credential reporting

3.1.5 Social Learning Policies

- Instrumentation of social networks and tools
- Standardization of tools for operational security and stability
- Standardization of tagging and linking to align with xAPI profiles

3.1.6 Data Model Owners

- Data Metamodels
  - Configuration of Competency Framework metamodel
  - Human Performance Requirements Model
  - Content and Resource Metamodel definition
  - Enterprise Learner Profile Metamodel
  - xAPI profile development for edge systems (verbs, object life cycles, and learning technology)
- Metadata Name-Value-Pair definitions
  - Local, regional and global attributes
  - Maintenance of namespaces for semantically equivalent terms

3.1.7 Cybersecurity (DISA), Identity Management, and Data Federations Policy

A basic feature of any networked system is its cybersecurity posture, including privacy, non-repudiation, integrity, security and reliability. In the future learning ecosystem, non-repudiation requires federated ID management. Privacy and security require anonymization tokens for user data to prevent accumulation of PII or aggregation of exploitable data that can present a security risk.

In classified domains, this is complicated by the use of multiple security enclaves. Currently, the Defense Manpower Data Center and Joint Interoperability Test Center have equities in their management of tokens and protocols, as well as open industry standards and best practices, so this is likely to change and mature as the ecosystem grow.

- Universal Unique Identifier (UUID) and PII protection, including technology used and clean room server policies
- Authority to Operate (ATO) Memorandum of Agreement (MOA)/ Authority to Connect (ATC)
  - Multi-level security Cross Domain Solution
  - Network and server virtualization and dynamic endpoint management
  - Cybersecurity and Global Information Grid integration - DODI 8500 (series)
  - Maintaining integrity and searchability of federated data structures (i.e. Enterprise Course Catalog)
  - Leveraging of virtualized identity management (central logins), networking and file management services as technology changes (Federated ID)
  - Encryption, tokens, and digital signatures
- Asynchronous Data Management (for deployed units or individuals)
  - Time stamping
  - Asynchronous data updates

3.1.8 Learning Commands (Schoolhouses, Instrumented Field Activities)

Learning commands represent the fundamental building blocks of the ecosystem and have their own equities in locally relevant user data, collection and archival requirements. Moreover, they have instructional goals that are enhanced by analysis of learner data archived elsewhere in the DoD in a different part of the learner's trajectory, so they are most concerned with data federation and data labeling policies.

- Federated LRS data - Learner Experience Records and evidentiary chain supporting credentials
- Federated Experience Index data - Enterprise Course Catalog information
- Federated Learner Profile data - Learner preferences, competency and credential history
- Local Metadata, User data and data labeling procedures
- Namespace management and coordination

3.1.9 Competency Owners (Rating, MOS, NEC, AFSC, CoE, TCM)

The TLA concept recommends the decomposition of curriculum into competencies and content. The legacy curriculum owners are likely to absorb one or the other of those new roles. In the case of tradecraft, the competency owner may the Program Management Office (PMO). Competency owners define the job roles, and the nature of the KSAOs, and competency maps for the given level of mastery that define the job requirements.

- Federated Competency Framework data
  - Competency Framework information
  - Warfighting system and warfighting requirements
- DoD schema management

3.1.10 Content Owners (Acquisition Agencies, Local Education and Training Facilities)

Content owners are responsible for the creation, acquisition, search, evaluation, assessment, validation and maintenance of the activities and content used to provide learning experiences. Part of content curation process is the configuration management and status accounting of normative references for the performance standards.

- Curation versus content development acquisition policies
- Activity/content registration policies
  - Content management review, approval, and audit
  - Grain Size normalization

3.1.11 Analytics Owners (e.g. OPA)

It will be valuable to crowd source and share analytics templates and business logic amongst the various learning commands and curricula maintainers. Currently, the Office of Personnel Analysis (OPA) has some equities in analytics, but this will likely mature as the ecosystem grows.

- "Crowd sourcing" of innovative analytics /decision support templates

3.1.12 Manpower and Personnel Owners (e.g. Detailers)

Human Resources or M&P commands have interest in TLA data because they define job and manning requirements, detail personnel based on their competencies and career trajectories, and manage the evaluations which in the legacy solution are the only place competencies other than Knowledge, Skills and Abilities (KSA's) are usually maintained (i.e. in performance evaluations). Eventually M&P can be fully integrated with feedback and feedforward demand signals to the TLA stocking the human capital supply chain.

- Job/duty/gig definitions
- Configuration management
- Demand signals

3.2 DIV-2 Logical Data Model

Figures 3 & 4 show the logical relationship of concepts used throughout the TLA. The colored icons show the notional allocation of these data elements to core data services described in the main report. **Table 6** is the data dictionary for this model.

3.3 DIV-3 Physical Data Model

Figure 5 shows the class structure of the experience API (xAPI), IEEE P9274. These models will be extended as the TLA policy framework and specification tree matures.

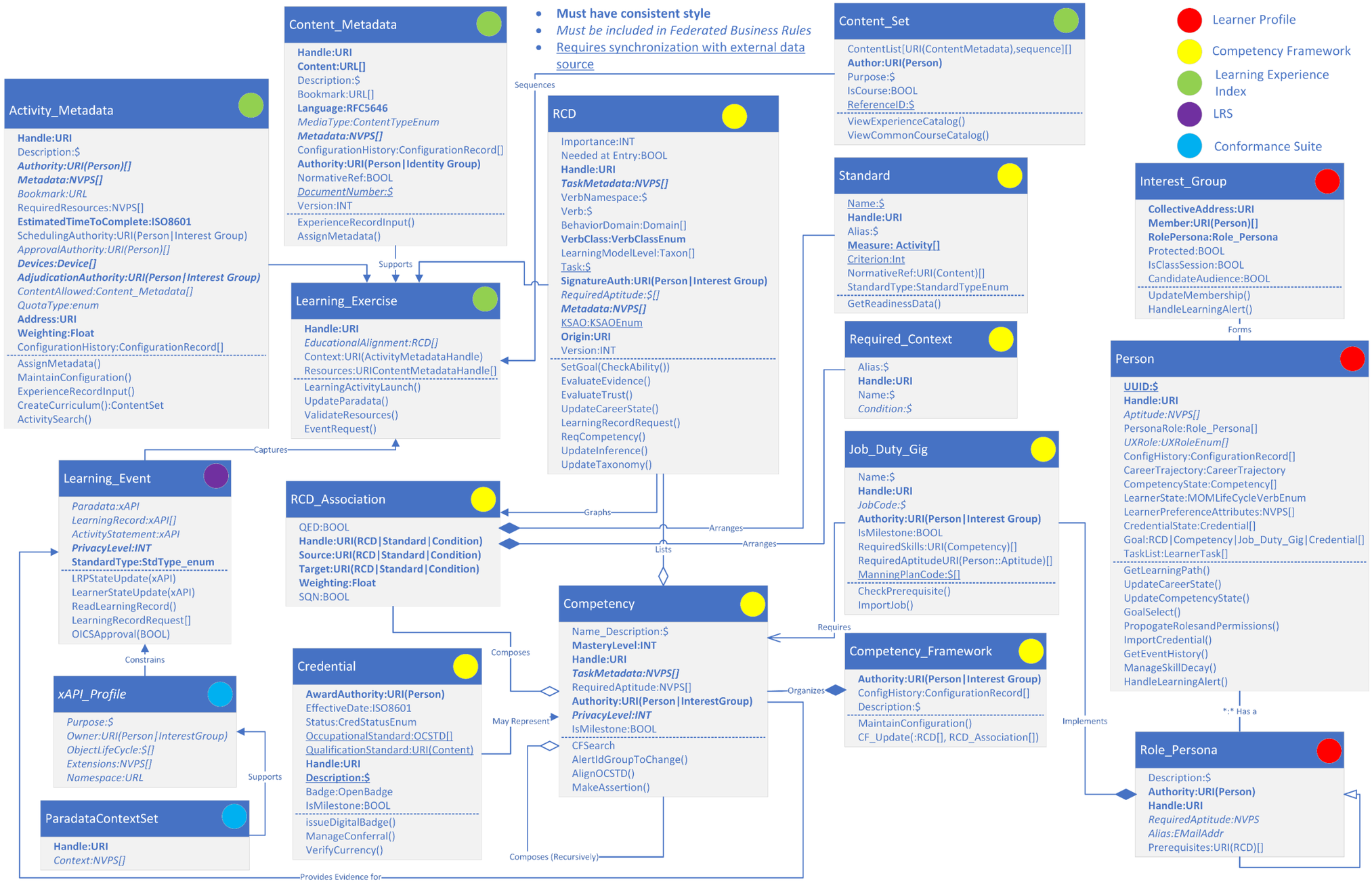

Figure 3. DIV-2 Logical Data Model.

<<Enumeration>>
UXRoleEnum

Administrator
Learner
Observer/Instructor/Controller/ Supervisor
Curriculum manager
Competency manager

<<Enumeration>>
KSAOEnum

Knowledge
Skill
Ability
Other
Behavior

<<Enumeration>>
QuotaTypeEnum

Agency Specific...

<<Enumeration>>
AttachmentEnum

Agency Specific

<<Enumeration>>
ContextEnum

Agency and Program Specific

<<Enumeration>>
ResultEnum

MediaTypeSpecific

<<ComplexType>>
Occupational Standard (OCSTD)

ReferenceDocument:URI(Content)
InDocumentReference:$

<<ComplexType>>
Domain

DomainEnum:DomainEnum
Level:INT {1-7]

<<Enumeration>>
DomainEnum

Cognitive
Affective
Psychomotor- Fine Motor
Psychomotor- Gross Motor
Environmental Constraint
Metacognitive
Social
Motivational

<<Enumeration>>
StandardTypeEnum

MOP
MOE

<<ComplexType>>
CompetencyState

SkillSet:RCD[]
Achievements:Competency[]
IsCurrent:BOOL
IsPending:BOOL
IsSuspended:BOOL
IsRevoked:BOOL
EffectiveDate:ISO8601
PendingDate:ISO8601

<<Enumeration>>
DataTypeEnum

Integer
Double
Float
IRI
ISO8601
String
Char
BOOL
RFC 5646

<<ComplexType>>
Device

DeviceName:$
IPAddress:IPv4
Type:$
Interface:URL
MACAddress:$
PhysicalLocation:$
Certificate:FIPS140.2

<<Enumeration>>
MOMLifeCycleVerbEnum

Recruited
Assessed
Detailed
Mobilized
Employed
Selected/Screened
Promoted/Demoted
Transitioned
ReleasedPlanned
Augmented
Directed
Requested
Approved/Denied
Explored
Clarified
Captured
Assessed
Asserted
Verified
Validated
Located
Inferred
Conferred
Qualified
Certified
Socialized
Organized
Prioritized
Recommended
Curated
Scheduled
Regulated
Projected
Contextualized
Evaluated
Surveyed
Tracked
Projected
waived
launched
initialized
passed
failed
satisfied
completed
abandoned
terminated

<<Enumeration>>
VerbClassEnum (Cognitive/Psychomotor)

Know		Comprehend	
Count	Read	Classify	Interpret
Define	Recall	Cite	Locate
Describe	Recite	Conclude	Make sense of
Enumerate	Record	Describe	Paraphrase
Find	Reproduce	Discuss	Predict
Identify	Select	Estimate	Report
Label	Sequence	Explain	Restate
List	State	Generalize	Review
Match	View	Give examples	Summarize
Name	Write	Illustrate	Trace
Apply		**Analyze**	
Assess	Instruct	Break down	Examine
Change	Predict	Characterize	Illustrate
Chart	Prepare	Classify	Infer
Choose	Produce	Compare	Limit
Compute	Relate	Contrast	Outline
Construct	Report	Correlate	Point out
Demonstrate	Select	Diagram	Prioritize
Determine	Show	Differentiate	Relate
Develop	Solve	Discriminate	Separate
Establish	Use	Distinguish	Subdivide
Synthesize		**Evaluate**	
Adapt	Invent	Appraise	Interpret
Categorize	Modify	Argue	Judge
Compose	Organize	Assess	Justify
Construct	Perform	Choose	Predict
Create	Produce	Compare & Contrast	Prioritize
Design	Propose	Conclude	Prove
Formulate	Reinforce	Critique	Rank
Generate	Reorganize	Decide	Rate
Incorporate	Rewrite	Defend	Reframe
Integrate	Structure	Evaluate	Support

<<Enumeration>>
VerbClassEnum (Affective/Metacognitive)

ACH-Achievement Orientation
CO-Concern for order, quality and accuracy
INT-Initiative
INFO-information seeking
IU Interpersonal understanding
CSO- customer service orientation
IMP impact and influence
OA- organizational awareness
RB relationship building
DEV developing others
DIR directiveness, assertiveness and use of positional power
TW teamwork and cooperation
TL Team leadership
AT analytic thinking
CT conceptual thinking
EXP technical professional managerial expertise
CST self control
SCF self confidence
FLX flexibility
OC organizational commitment

<<ComplexType>>
LearnerTask

ScheduledEvent:URI(LearningExperience:Handle)
ScheduledTime:ISO8601
SuspenceTime:ISO8601
Authorized:URI(Person:Handle)
Assigner:URI(Person:Handle)

<<ComplexType>>
Taxon

Framework:$
EnumeratedLevel:Int[]
Enumerated List:$[]

<<ComplexType>>
NameValuePairSet (NVPS)

AttributeName:URI
AttributeDataType:DataTypeEnum
AttributeValue: DTC
AttributeDescription:$
Scope:$
TimeStamp:ISO8601

<<ComplexType>>
xAPI

Actor:URI (Person:Handle)
Verb:URI(Profile:Handle)
Object:URI (Profile:Handle)
Timestamp:ISO8601
Stored:ISO8601
Language: RFC5646
Result:ResultEnum
Context:ContextEnum
Authority:URI(Person(handle)|Interestgroup(Handle)|ActivityMetadata(handle)_
Attachments:AttachmentEnum[]
Version:$

<<ComplexType>>
CareerTrajectory

State:xAPI(MOMLifeCycleverbs)[]
JobList:Job_Duty_Gig[]
CareerEndpoint:Job_Duty_Gig[]
Classifier:$[]
CurrentGoals:URI(Competency)[]

<<Enumeration>>
ContentType

ePublication
Publication
Digital Video
Video
SCORM Course
LMS - Assessment
Assessment - Other
ITS
CMS Material
SocialMediaSharedFile
LVCG Simulation Scenario file
IETM/EPSS
Trainee Guide
OICS Comment Sheet/Checklist
Game Level
ERP

<<ComplexType>>
ConfigurationRecord

SequenceID:LONG
TimeOfChange:ISO 8601
AuthorityForChange:URI(IdentityGroup|Person::Handle)
RecordType:$
AttributeChange:NVPS[]

<<Enumeration>>
CredStatusEnum

Current
PendingReview
OutOfCurrency
Suspended
Revoked

<<ComplexType>>
OpenBadge

Context:JSONLD
ID:JSONLD
Type:JSONLD
Recipient:JSONLD
IssuedOn:JSONLD
Verification:JSONLD
Badge:JSONLD
Issuer:JSONLD

Figure 4. Complex Data Types and Enumerated lists for DIV-2 Data Model.

Table 7. DIV-2 Data Dictionary.

Class	Attributes	Data Type	Definition
Activity_Metadata	Address	URI	RESTful location of the content metadata mapping within an Experience Index
Activity_Metadata	AdjudicationAuthority	URI(Person) Array	Trusted agents that can positively or negatively adjudicate learner success at a scenario, exercise or activity
Activity_Metadata	Authority	URI (Person)	The author or registrant of the activity
Activity_Metadata	ApprovalAuthority	URI (Person|Identity Group) Array	Authority to select the content to satisfy a competency element or curriculum
Activity_Metadata	Bookmark	URL	Location within the content
Activity_Metadata	ConfigurationHistory	Configuration Record Array	List of content or competency attributes which have been changed over time in this association
Activity_Metadata	Description	String	Purpose of the learning activity
Activity_Metadata	EstimatedTime	ISO8601	Mean time to complete the activity
Activity_Metadata	Handle	URI	Internal reference for the learning activity
Activity_Metadata	Device	Device Array	Complex type for registered devices and clients as appropriate
Activity_Metadata	Metadata	NVPS	Data that describes the content from metadata standard
Activity_Metadata	QuotaType	Enum	How cost of attendance at the experience or content is remunerated
Activity_Metadata	Required Resources	NVPS	Consumables, instructors, classrooms, computational resources, laboratories or other materials necessary for the experience
Activity_Metadata	SchedulingAuthority	URI (person or interest group object handle)	Person or interest group authorized to schedule the content or act as registrar
Activity_Metadata	Weighting	Float	Contribution of the activity towards demonstrating competence
Activity_Metadata	ContentAllowed	URI (Content_Metadata) (Array)	Content that can be used with the specified activity
Competency	IsMilestone	BOOL	Signifies whether competency establishes a personnel milestone (for planning learning trajectories).
Competency	Masterylevel	INT	Level of proficiency required for a competency as defined for use in a job/duty/gig
Competency	Name_Description	String	Short reference handle for the competency (as a map of competency objects, level of mastery, associated standards and conditions or

Class	Attributes	Data Type	Definition
			contexts, and the relationships between them described as a DAG for defining the competencies
Competency	RequiredAptitude	NVPS String	List of user aptitude attributes as prerequisite to attempt achievement of the overall competency
Competency	CnCmetadata	NVPS String	Metadata associated with task (used to scrape for applicable content)
Competency	Handle	URI	Internal handle for referencing the competency network
Competency	Authority	URI (person object handle)	Person or organization that owns the competency element
Competency	PrivacyLevel	Integer	A scaled level of privacy for the evidence provided by the record.
Competency_Framework	ConfigurationHistory	ConfigurationRecord Array	The ordered list of changed attribute values, authorization and date of change from complex data type
Competency_Framework	Authority	URI (Person or Identity Group object handle)	The person or organization who “owns” the Competency Framework definition
Competency_Framework	Description	String	A short title for describing the Competency Framework (may tie to organization, MOS, Rating, or some subset)
Content_Metadata	Handle	URI	Internal object handle for referencing the standard
Content_Metadata	Content	URL Array	An array of possible locations the content can be located at
Content_Metadata	Description	String	A description of the piece of content
Content_Metadata	Bookmark	URL Array	A pointer to the content’s location on the internet
Content_Metadata	Language	RFC5646	The language(s) needed to use the content
Content_Metadata	MediaType	ContentTypeEnum	An enumeration of the kind of content the content is, such as ebook, pdf, or movie
Content_Metadata	Metadata	NVPS	Data that describe the content, according to the LRMI, TLA, and local extensions for metadata
Content_Metadata	ConfigurationHistory	ConfigurationRecord Array	List of content or competency attributes which have been changed over time in this association
Content_Metadata	Authority	URI (Person | Identity Group)	The person(s) allowed to assign and edit the content
Content_Metadata	NormativeRef	BOOL	Whether the content is a normative reference for the listed competencies (i.e. tech manual describing a skill)

Class	Attributes	Data Type	Definition
Content_Metadata	DocumentNumber	String	The record number used to reference the document, especially if a normative reference (e.g. AFM65-10, MCWP 5.0. NATOPS 80R14)
Content_Metadata	Version	Integer	x.x.x version number of the piece of content
Content_Set	Author	URI (Person object handle)	Instructor or course manager who approved course
Content_Set	Purpose	String	Catalog entry or description of course, or other purpose for the set
Content_Set	IsCourse	BOOL	Used to index records for Enterprise Course Catalog searches
Content_Set	ReferenceID	String	The agency specific record number for the course listing
Content_Set	ContentList	URI (Array)	An array of the content object handles in the content set
Credential	IsMilestone	BOOL	Signifies whether competency establishes a personnel milestone (for planning learning trajectories).
Credential	AwardAuthority	URI(Person)	Who signs off as the issuing or updating official
Credential	EffectiveDate	ISO8601	What is the status date effective by
Credential	Status	CredStatusEnum	A status on awarding the credential
Credential	Badge	OpenBadge2	Definition of the digitally signed credential in the OpenBadge 2.x standard
Credential	QualificationStandard	URI (ActivityMetadata object handle)	The normative reference, document or instruction (e.g. Field Manual, Technical Instruction) that specifies the need
Credential	OccupationalStandard	OCSTD array	The Occupational Classification Standard (OCSTD) from O*NET that defines the framework
Credential	Handle	URI	Internal handle for referencing the competency network
Credential	Authority	URI (person object Handle)	Person or organization that owns the competency element
Interest_Group	CandidateAudience	BOOL	The group of identified users is assigned to collectively assign a training requirement (e.g., a class)
Interest_Group	Collective Address	URI	Name for referring to the collection of entities (e.g. All Pacific commands, section 12 of the 2021 fire controlman class). Typically for classes, it is class number based on year and number of classes being taught.
Interest_Group	IsClassSession	BOOL	Used to filter faster for classes and sections

Class	Attributes	Data Type	Definition
Interest_Group	Member	URI Array	Internal handle or handles used for identifying humans logged into the local instance of the system (used to protect PII)
Interest_Group	PersonaRole	URI (Persona_role)	Persona role of the learner or group of learners
Interest_Group	Protected	BOOL	Interest group membership changes must be approved by an observer, instructor, controller, or supervisor
Job_Duty_Gig	Authority	URI (Person or Interest Group object handle)	Curriculum or competency definition authority
Job_Duty_Gig	JobCode	String	Branch specific occupational code (e.g., Naval Enlisted Classification, Military Occupational Specification, Air Force Specialty Code)
Job_Duty_Gig	Name	String	Short name for referring to the job, duty or gig (e.g., imagery analyst, collections)
Job_Duty_Gig	RequiredAptitude	String array	Aptitude values (i.e. from ASVAB or AFQT) required to perform job
Job_Duty_Gig	RequiredSkills	URI (Ability object handle array)	Pre-requisite abilities to pursue the job
Job_Duty_Gig	IsMilestone	BOOL	Job establishes a personnel milestone for planning learning trajectories
Job_Duty_Gig	Handle	URI	Internal handle for referring to the job
Job_Duty_Gig	ManningPlanCode	String Array	Reference number or code in the governing M&P document that describes or justifies the position
Learning_Event	ActivityStatement	xAPI	Atomic level learning event where leaner did something, where “something” includes review of some type of content or conducting some job experience, as per xAPI standard used as evidence of competence
Learning_Event	Experience	xAPI Array	A linkage of activity statements that must be taken together to constitute “evidence”. The verb of the xAPI statement, used to explain how the user interacted with content to learn
Learning_Event	Paradata	xAPI	Proforma record of the context of the learning experience, including cognitive and environmental effects
Learning_Event	StandardType	StdType_enum	An enumerated data type of the type of evidence (MOP or MOE) that the record defines. MOP come from learning technology; MOE typically come from operational data sets

Class	Attributes	Data Type	Definition
Learning_Event	PrivacyLevel	Integer	A scaled level of privacy for the evidence provided by the record.
Learning_Experience	EducationalAlignment	RCD (Array)	List of competencies the activity can satisfy or enhance
Learning_Experience	Context	URI (ActivityMetadataHandle)	The player, reader or environment used to conduct the learning exercise
Learning_Experience	Resources	URI (ContentMetadataHandle)	The files or other resources required to conduct the exercise
Paradata_Context_Set	Handle	URI	Internal handle for referring to the paradata attribute set
Paradata_Context_Set	Context	NVPS Array	List of potential attributes that can be reported by the activity provider to define the paradata
Person	Ability	URI (ability object handle) Array	The learner's abilities (defined from ability classes)
Person	Aptitude	NVPS Array	The learner's aptitudes (defined from aptitude classes)
Person	Handle	URI	Anonymized internal reference for a person (used as "actor" in xAPI)
Person	CompetencyState	Competency Array	An array of all the competencies the person has had asserted and verified
Person	CredentialState	Credential Array	An array of all of the competencies the person has had certified and conferred
Person	LearnerState	MOMLifeCycleVerbEnum	The current learner state as managed by the learning event manager
Person	LearnerPreferenceAttributes	NVPS Array	Attributes of the learner used for adaptation decisions or algorithms (reference installation specific)
Person	PersonaRole	URI (Role_Persona object handle) Array	Personas or roles of the person (e.g. Sailor, division officer, watch stander, analyst)
Person	UUID	String	Externally valid reference for person (CAC or other UUID)
Person	Goal	Job_duty_gig, RCD, Credential or Competency Array	Lists the fully recursive array of competency objects that are currently pursued by the learner. May be arbitrarily deep and broad
Person	Career Trajectory	CareerTrajectory	An array of jobs that define the past, present and candidate future jobs for the learner on their current trajectory
Person	ConfigurationHistory	ConfigurationRecord Array	The ordered list of changed attribute values, authorization and date of change from complex data type
Person	TaskList	Learner Task Array	The list of tasks that have been formally assigned as complex types

Class	Attributes	Data Type	Definition
RCD	BehaviorDomain	DomainEnum	Whether competency element is cognitive, psychomotor, affective, metacognitive, social or motivational
RCD	Importance	INT	Weighted requirement for career progression
RCD	KSAO	KSAOEnum	Identifies whether competency element is Knowledge, Skills, Ability, Behavior, or other
RCD	Metadata	NVPS string	An array of one or more metadata elements that describes the competency object
RCD	Needed at Entry	BOOL	Is competency needed at entry for the job/gig trajectory (part of learning validation logic for pre-requisite skills or experiences)
RCD	RequiredAptitude	String Array	List of user aptitude attributes as prerequisite to attempt achievement of the competency
RCD	SignatureAuth	URI (Person or Interest Group object handle)	Trusted agents that can assert competence from evidence
RCD	Task	String	Task, behavior, or measurable elements (in the case of knowledge competencies) that are demonstrated by the competency
RCD	TaskMetadata	NVPS	An array of one or more metadata elements about the tasks that are included as part of a competency
RCD	Handle	URI	A Uniform Resource Identifier (URI), a string of characters that unambiguously identifies a resource
RCD	Origin	URI	The URI of the normative reference (content metadata) that specifies the competency requirement
RCD	Verb	String	The verb that defines the task statement for the RCD if it is sourced from an existing learning objective or stated as a task.
RCD	VerbClass	VerbClassEnum	Generic category of the task (e.g., operate equipment is “perform”)
RCD	VerbNamespace	String	Community of practice whose definition of the verb applies
RCD	LearningModelLevel	Taxon Array	Defines which learning model framework and level the verb applies (e.g. Bloom, Merrill)
RCD	BehaviorDomain	Domain array	The skill component and level from 1-7 of the behavior
RCD	Version	INT	Version of the competency object definition

Class	Attributes	Data Type	Definition
RCD_association	Handle	URI	A reference for the vector map represented by the sequence of associations
RCD_association	QED	BOOL	*Quod Erat Demonstrandum*; Association that cascades positively downwards (if high level competency is asserted, lower level is automatically asserted)
RCD_association	Source	URI (of RCD, Standard, or Condition)	Source URI of competency object that is upstream on the association
RCD_association	SQN	BOOL	*Sina Qua Non;* Association that cascades negatively upwards (if low level competency is de-credentialled, the higher level is automatically de-credentialled)
RCD_association	Target	URI (of RCD, Standard, or Condition	Target URI of competency object that is downstream on the association
RCD_association	Weighting	Float	Covariance weight or contribution of the downstream competency object to the upstream object
Required_Context	Alias	String	Mapping for "condition" if specified in the associated Competency Framework more concretely or explicitly (e.g. context, environment, organizational level)
Required_Context	Condition	String	A condition under which the definition of competency is appropriate
Required_Context	Handle	URI	Internal object handle for referencing the condition (used in xAPI extensions)
Required_Context	Name	String	Screen name for describing the condition
Role_Persona	Alias	EMailAddr	Internal reference handle provides a name that cannot traced back to PII
Role_Persona	Authority	URI (person object Handle)	Curriculum or professional standardization authority
Role_Persona	Description	String	Short description of the purpose or scope of the job/duty/gig
Role_Persona	Handle	URI	Local code or nomenclature for the job/duty/gig as appropriate (e.g., billet code), which resolves to local database and handles
Role_Persona	Prerequisite	URI (RDC object handle) Array	Required competencies to perform the job
Role_Persona	RequiredAptitude	NVPS	Required Aptitude of the person to perform the job

Class	Attributes	Data Type	Definition
Standard	Alias	String	Way “standard” is specified in the associated Competency Framework (e.g. level of proficiency)
Standard	Criterion	Integer	The level of performance that defines the standard
Standard	Handle	URI	Internal object handle for referencing the standard
Standard	Measure	Activity Array	The objective measurement for establishing the standard
Standard	Name	String	Screen name for describing the standard
Standard	NormativeRef	URI (ActivityMetadata) Array	Identifies the normative reference defining the standard within the content library (e.g., tech manual that describes a procedural skill)
Standard	Standard Type	Standard TypeEnum	Whether the standard is a MOP for a competency object (means of asserting competency) or an MOE for an entire competency or range of competencies (i.e. organizational or outcome-based performance metric against which to validate individual performance and instructional efficacy)
xAPI Profile	Purpose	String	Type of learning activity or data sources that would use this profile (e.g. eReader, Personnel Database)
xAPI Profile	Owner	URI (Person or Interest group object handle)	Creator of the profile
xAPI Profile	ObjectLifeCycle	String Array	List of allowable xAPI verbs within the Profile
xAPI Profile	Extensions	NVPS Array	List of attribute and enumerations or string masks for extensions, results and attachments
xAPI Profile	Namespace	URL	Globally unique way of referring to elements within the profile
Complex Data Types (depicted in Figure 4)			
Class	**Attributes**	**Data Type**	**Definition**
BehaviorDomain	DomainEnum	DomainEnum	Cognitive components
BehaviorDomain	Level	Integer	Level of cognitive components from 1-7
CareerTrajectory	State	xAPI Array	Used manpower verbs from enumerated data type LearningEventLifeCycleVerb
CareerTrajectory	Job List	JobDutyGig Array	List of jobs the learner has held

Class	Attributes	Data Type	Definition
CareerTrajectory	CareerEndpoint	JobDutyGig Array	The list of jobs that the learner wants to hold on their current career trajectory – with branches and options
CareerTrajectory	Classifier	String Array	The learner's current career classification (e.g., MOS/NEC/specialty code)
CareerTrajectory	CurrentGoals	Competency Array or RCD Object Array	Competency objects the learner is currently pursuing or has been assigned by the observer, instructor, controller, or supervisor
CompetencyState	Skillset	RCD Array	All the lower level items, especially those not belonging to core framework, that the individual has demonstrated competency
CompetencyState	Achievements	Competency Array	All the complete competencies, at a given level of mastery, that represent a graph of RCD, that the learner has mastered
CompetencyState	IsCurrent	BOOL	For those competencies that require periodic demonstration observed by a designated person that the learner has maintained currency in the task
CompetencyState	IsPending	BOOL	A Boolean depicting if the competency state needs OICS approval before becoming official
CompetencyState	IsSuspsended	BOOL	The learner has been administratively removed from being considered competent (e.g., medical hold, out of currency)
CompetencyState	IsRevoked	BOOL	The learner has been punitively removed from being considered competent (i.e. revocation of credential)
CompetencyState	EffectiveDate	ISO8601	When was the competency *asserted* or credential *conferred* (see Figure 14 for states)
CompetencyState	PendingDate	ISO8601	For Credentials, when does a currency requirement need to be evaluated
ConfigurationRecord	SequenceID	Long	Record entry ID for changes
ConfigurationRecord	TimeOfChange	ISO 8601	Time at which data was updated
ConfigurationRecord	AuthorityForChange	URI (Identity Group or Person Handle)	Who or what agency authorized the change
ConfigurationRecord	RecordType	String	Class name or record ID where change occurred
ConfigurationRecord	AttributeChange	NVPS Array	List of attribute/field, datatypes and values of change
Device	DeviceName	String	A common name for referring to the device on the screen

Class	Attributes	Data Type	Definition
Device	IPAddress	IPv4 array	IP or IP range of device connected to the federation
Device	Type	String	Common name for type of device, e.g. mobile device, desktop client, simulation IOS, Player Unit, Exercise Control, etc.
Device	Interface	URL	Endpoint universal Resource Locator for REST communication
Device	MACAddress	Formatted String	As required for cybersecurity (i.e. sticky-MAC), the physical hardware address of the device
Device	PhysicalLocation	String	May be updated in future iterations with GPS information, otherwise a way of locating the device, building, room, work site, etc.
Device	Certificate	FIPS140.2	As applicable for cybersecurity, the digital certificate authorizing the device for operation on the network
LearnerTask	ScheduledEvent	URI (Learning_Experience Handle)	Reference for the activity/content/competency tuple that the task represents
LearnerTask	ScheduledTime	ISO8601	DTG of when the task was assigned
LearnerTask	SuspenseTime	ISO8601	DTG of when the task must be completed by
LearnerTask	Authorized	URI(Person:handle)	Reference of the person who authorized the training even to occur
LearnerTask	Assigner	URI(Person:handle)	Reference of the person who assigned the learner to the event (may be the learner if it was requested)
NVPS	UserDefinedAttribute	String	Name of the locally defined data element
NVPS	UserDefineDataType	DataTypeEnum	List of possible data types
NVPS	Value	Data Type Array	Value placed in the field constrained by data type
NVPS	Scope	String	The level or command designation at which the specific attribute list is managed through governance (e.g. agency, ODNI, USAF, JICPAC)
OCSTD	ReferenceDocument	URI(Content)	The volume or reference ID of the occupational standard reference ID
OCSTD	InDocumentReference	String	Internal section or subsection number
Taxon	Framework	String	The name of taxonomy or learning model (e.g. Bloom, Merrill)
Taxon	Enumerated Level	Int Array	Preserves a hierarchical structure or tensor (array index>1) for the taxonomy
Taxon	Enumerated List	String Array	The concepts filling a given level or cell for the taxonomic model

Class	Attributes	Data Type	Definition
xAPI	Actor	URI (Person: object Handle)	The person or system that had the experience; refers to object from user and group management
xAPI	Verb	URI (Profile: object handle)	The action taken by the actor; refers to concept in Profile
xAPI	Object	URI (Profile: object handle)	The activity in which the action was taken; refers to concept in profile
xAPI	Timestamp	ISO8601	When the action was taken
xAPI	Stored	ISO8601	When the LRS stored the xAPI activity statement
xAPI	Language	RFC5646	The language code for the activity
xAPI	Result	ResultEnum	The grade or success of the activity
xAPI	Context	ContextEnum	The caveats explaining the activity (as defined in the index to support the competency object in the educational alignment)
xAPI	Authority	URI (Person object handle, interest group object handle or activity metadata object handle)	The person or system which authorized the creation of the experience record
xAPI	Attachments	AttachmentsEnum	Any allowable files which are included with the activity
xAPI	Version	String	The xAPI version used (automatically populated by LRS)

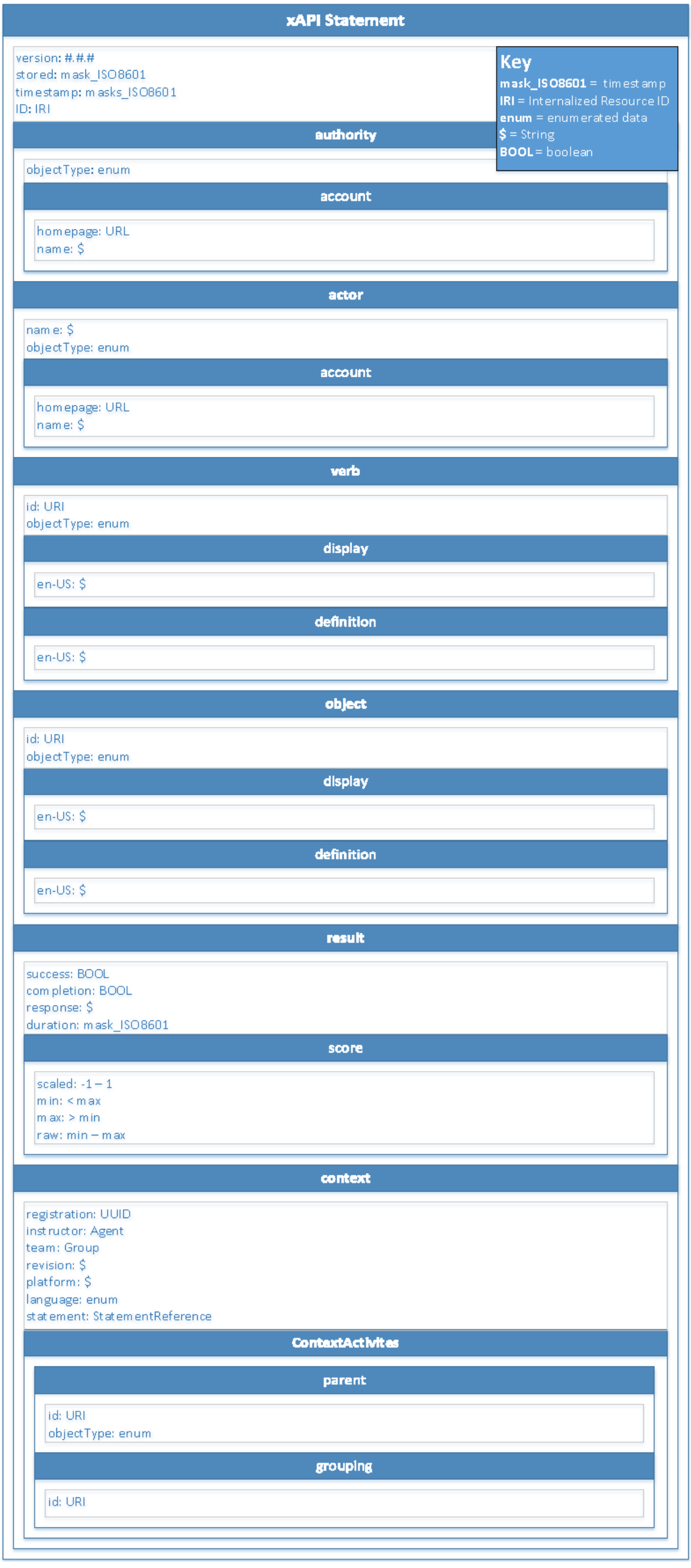

Figure 5. DIV-3 Physical Data Schema.

3.0 OPERATIONAL VIEWS (OV)

3.1 OV-1 Operational Overview

The graphic shown in **Figure 6,** depicts the relationship between the building blocks of the future learning ecosystem, its enclaves and federations, and the stakeholders that provide value to or receive value from deploying, integrating or using the data and computational resources within those enclaves and federations. The figure is organized to start with Initial Operational Capability (IOC) capabilities in the lower left hand and progressively field or migrate data and services to achieve the Final Operational Capability (FOC) in the upper right corner.

3.2 OV-2 Operational Resource Flow Description

The graphic in **Figure 7** shows the various stakeholder types and the data (system digital communications) and information (process generated organizational data, managed through governance structures) exchanged between them. The elements on the right are the initial targets for migration, and as the capabilities mature, more and more stakeholders will be defined and integrated with processes and digital interfaces. The interface icons show the governance relationships, which are detailed in the DIV-1, Section 2.1

3.3 OV-4 Organizational Chart

The graphic in **Figure 8** shows partial agency and department organizations that are typical of the agencies who have data equities for the TLA roles that were defined in the main report. In practice, each agency will determine its own processes and it's likely that these will change over time in response to the TLA and other business realignment initiatives.

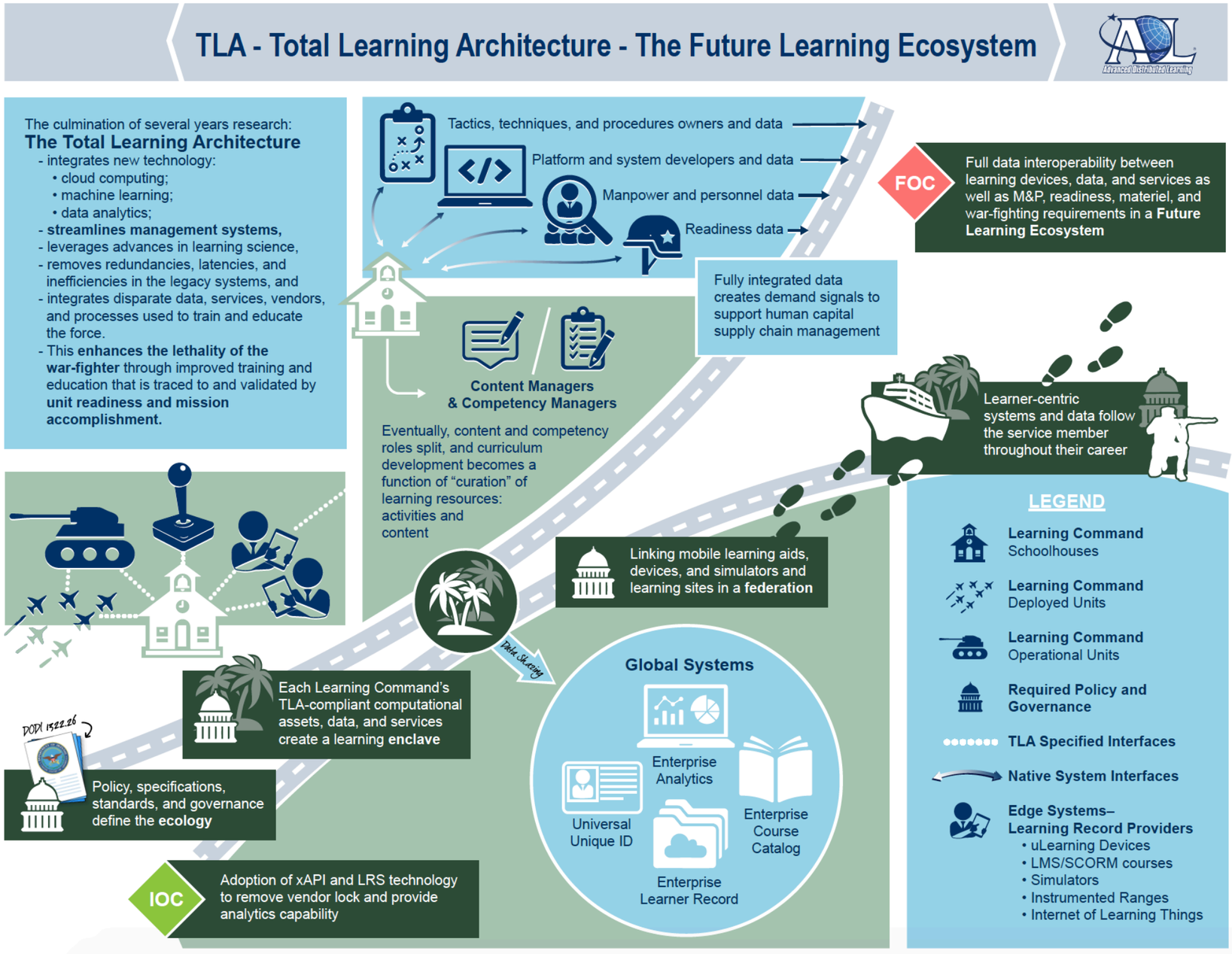

Figure 6. OV-1 High Level Operational Concept.

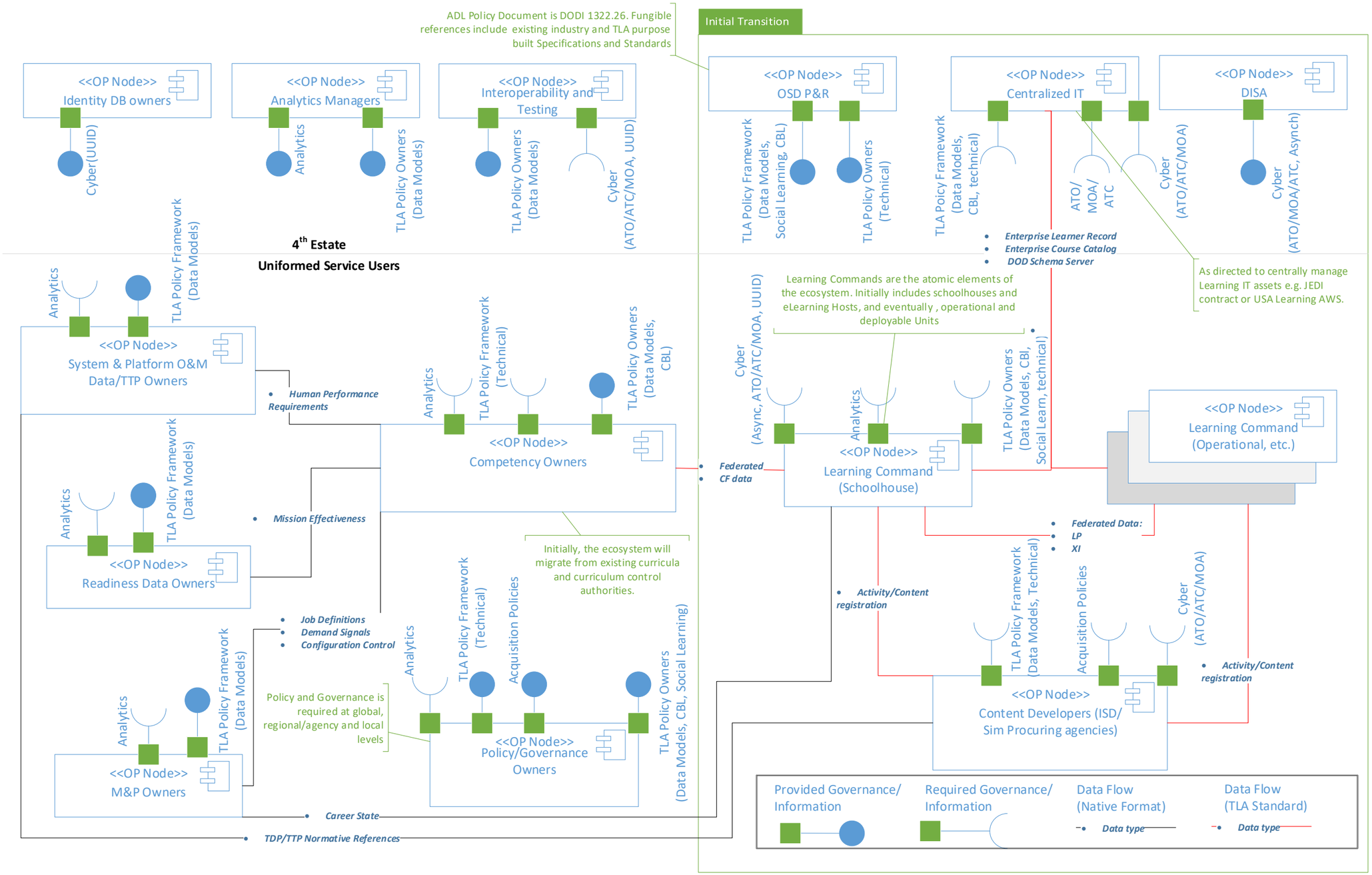

Figure 7. OV-2 Operational Resource Flow.

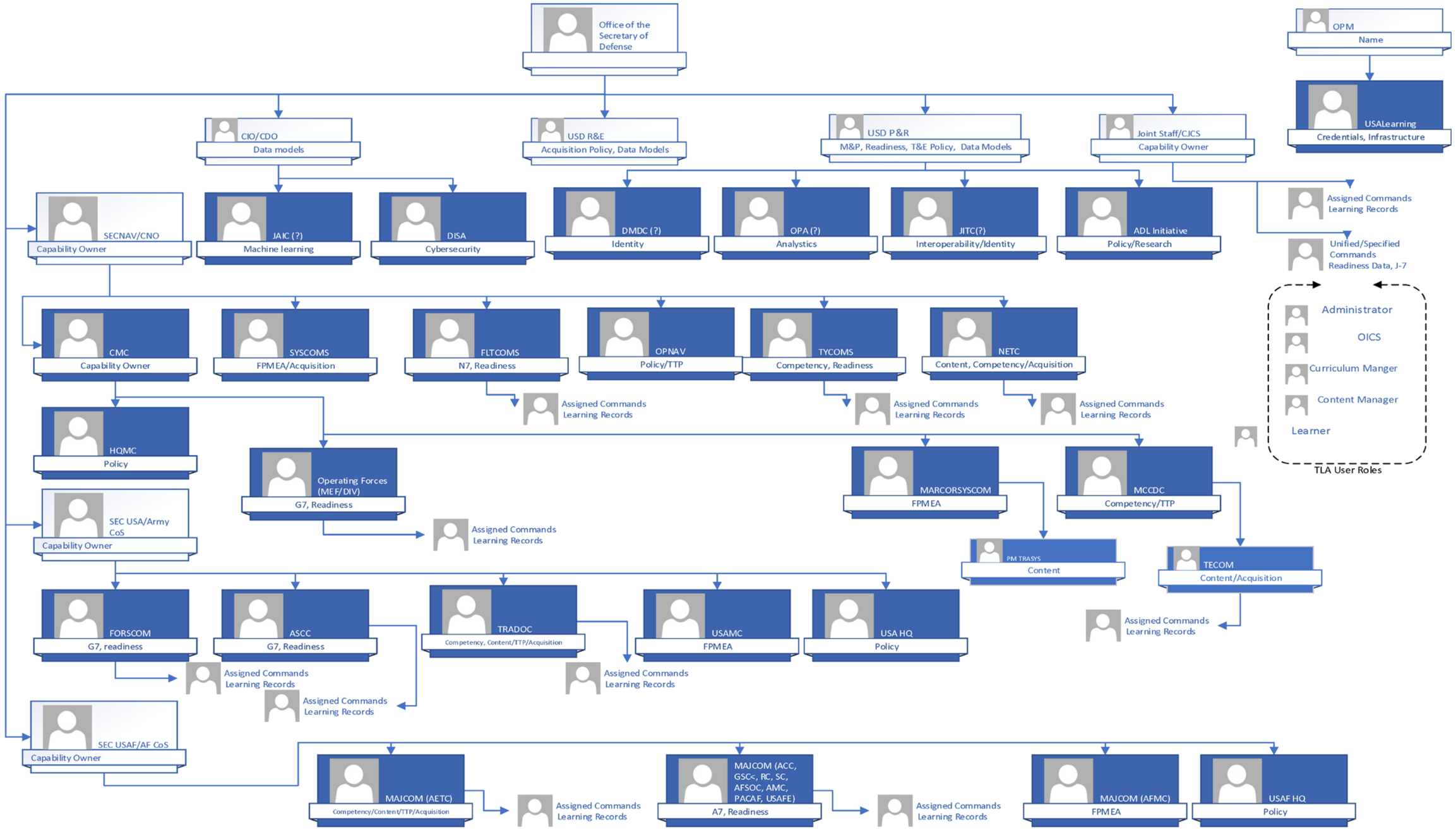

Figure 8. OV-4 Organizational Relationships.

3.4 OV-6a Operational Rules Model: Business Rules

3.4.1 Cybersecurity

- The TLA shall store local data related to a user with anonymized identity references.
- Each organization shall assign a group of individuals who are authorized to evaluate and register content and activities.
- TLA implementations shall leverage industry best practices for back-end services for authentication, virtualization and storage.
- Each learning organization shall assign a trusted group of individuals who can approves requests for event scheduling or validate observations and self-reports.
- The LRS shall be network discoverable and auditable (enforce non-repudiation of serial entries and identity resolution).
- Any organization or group of organizations shall implement a federation using the TLA federation negotiation process, including cybersecurity policies to establish ATC*s.*
- Systems shall use a globally unique UUID marker to associate PII with local records.

3.4.2 Competencies

- Each DoD Service Secretary or designate shall assign ownership of jobs and performance requirements for each job.
- Jobs shall have assigned Competency Frameworks.
- Competency Frameworks may include sub-frameworks shared from other competency owners.
- Competency Frameworks shall be network discoverable and shareable.
- The Competency System shall be able to validate frameworks against human/systems integration-system design, operational, and readiness data.
- Any organization implementing TLA standardized activity, content and competency management services shall comply with the TLA interface specification and Functional Requirements Document.

3.4.3 Data Governance

- Every data element related to education and training shall have a single authoritative source.
- Data interoperability shall be ensured using governance procedures to maintain semantic and protocol compatibility.
- Each service shall assign one or more governance bodies to develop schema for Name-Value-Pair Sets describing user settable metadata to ensure semantic interoperability. Governance bodies will be severable by community of practice as defined.
- Each category of metadata shall be assigned the proper scope and associated governance owner.
- The Enterprise Course Catalog shall be parsed from applicable content metadata across all agency activity indices.
- The activity indices shall be network discoverable and searchable.
- Each organization’s Learner Profiles shall be discoverable.
- User identity tokens shall be universally discoverable but protected.
- LP credential updates can be forwarded to a centralized HR system.
- Any organization implementing TLA standardized core data (Experience Index, Competency Frameworks, Learning Record Store, Learner Profile) shall comply with the industry-standard metamodels defined In the ADL Initiative Policy Framework (DODI 1322.26).
- Any organization implementing TLA standardized core data shall comply with all appropriately scoped data governance for the establishment of metadata sets and data labeling.

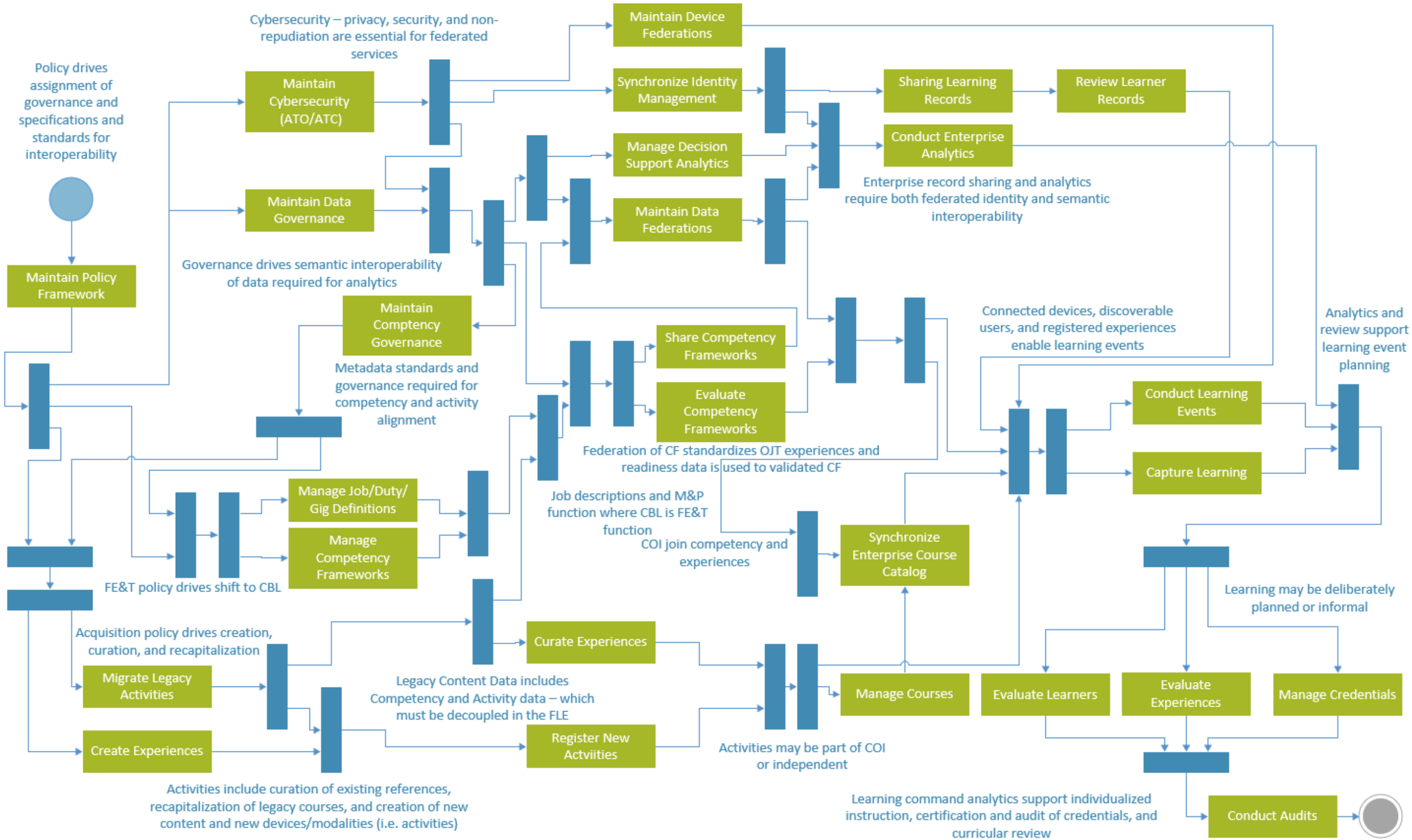

Figure 9. OV6b Operational Rules Model: State Transition.

4.0 SYSTEM AND SERVICE VIEWS (SV/SVCV)

4.1 SV-1 Notional System View of a Single Enclave and its Enterprise Asset Connections

Figure 10 shows a notional deployment of actual databases and computational assets in an enclave, connected or federated learning devices with their TLA boundary and edge communications and services, as well as connections to enterprise assets.

4.2 SvcV-1 Service Level View of Enclaves and Federations Within the Ecosystem

Figure 11 shows a service-based view of the relationship between inter and intra enclave assets within a federation and across the ecosystem.

4.3 SvcV-4 Service Functions and Interfaces Within an Enclave

Figures 12, 13, 14, 15 and **16** include diagrams that show the high-level functions allocated to each microservice group, along with function block diagrams that provide details. These functions are captured in the Functional Requirements Document.

4.4 SvcV-5 Operational Activity to Services Mapping

Table 7 shows the way deployment of specific services provide value to or require input from the various stakeholders by category. This document can be used to define the deployment, and migration plan as well as stakeholder engagement plans.

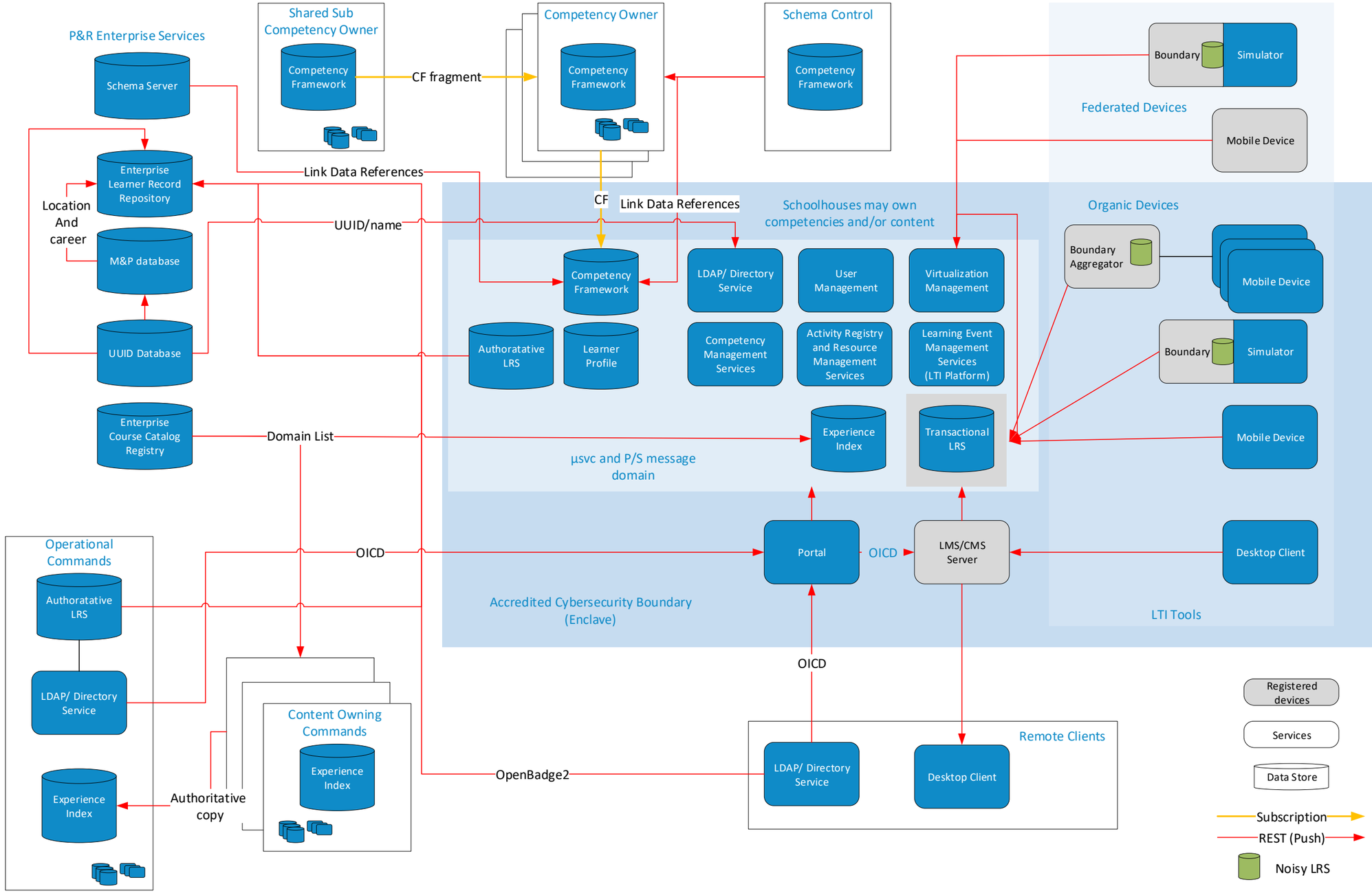

Figure 10. SV-1 System Context Diagram. *Shows internal components of notional enclave and connections to enterprise assets and notional connections across the ecosystem.*

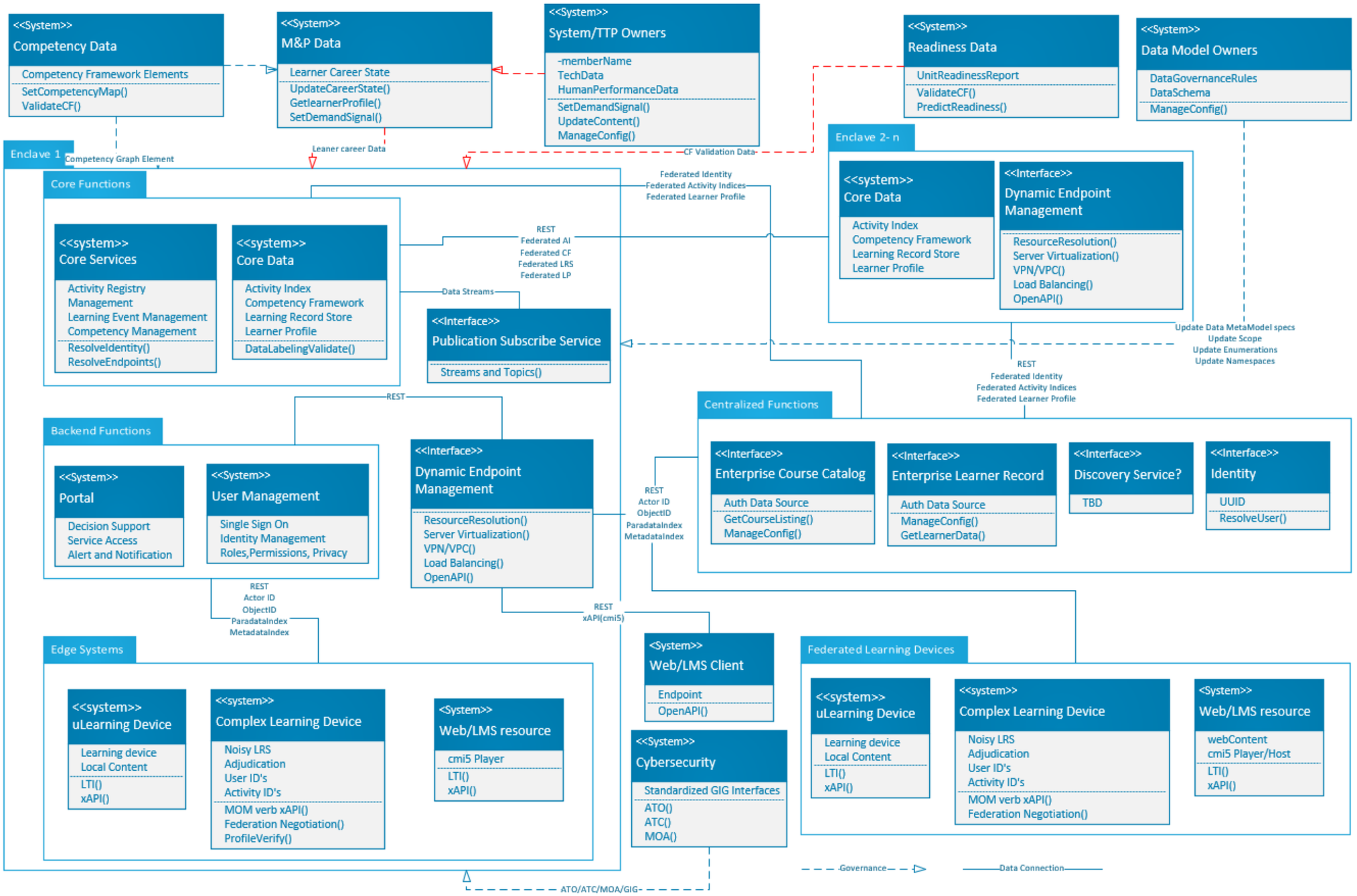

Figure 11. SvcV-1 Service Context Diagram.

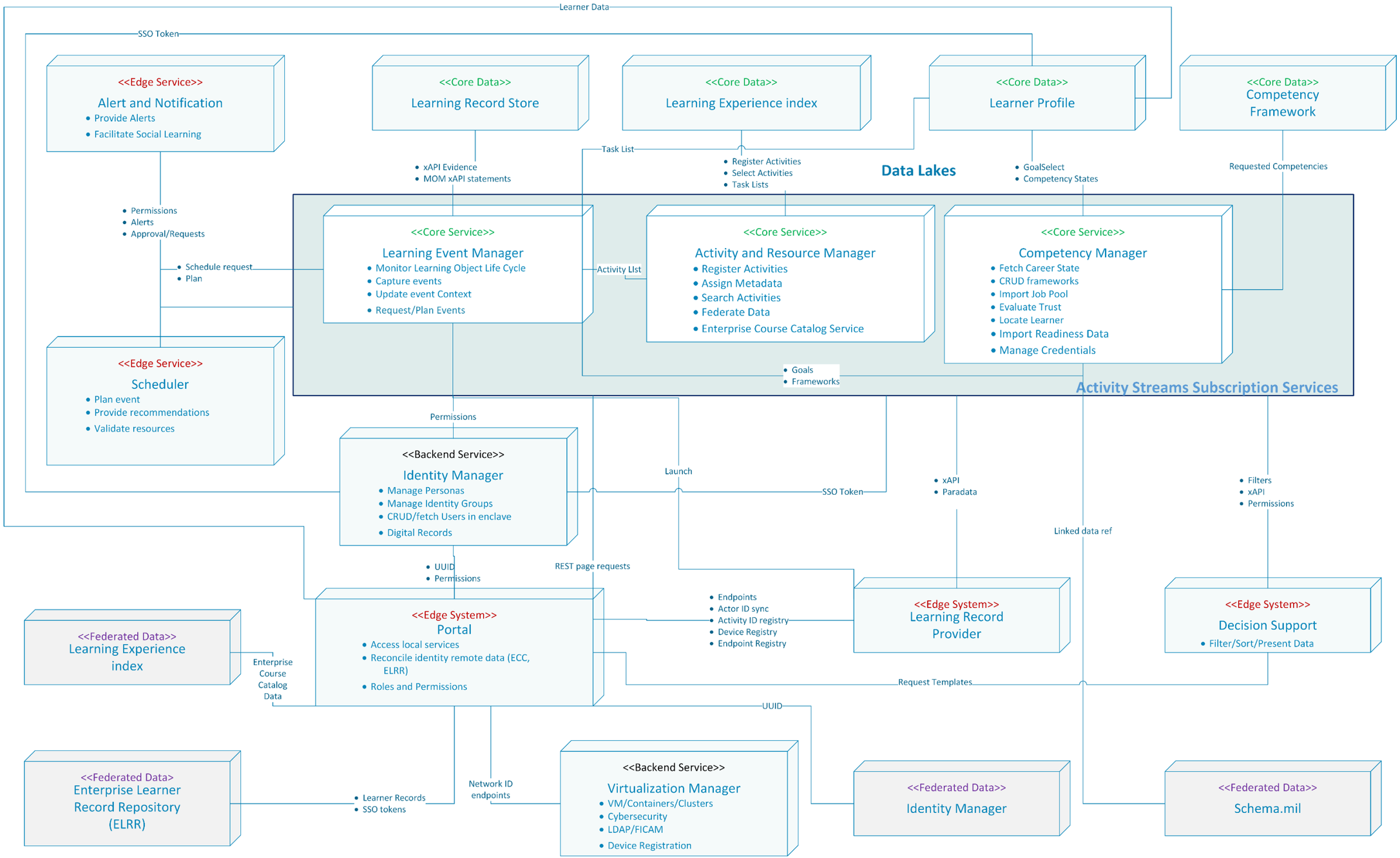

Figure 12. SvcV-4 Services Functionality (Overall Logic Arrangement).

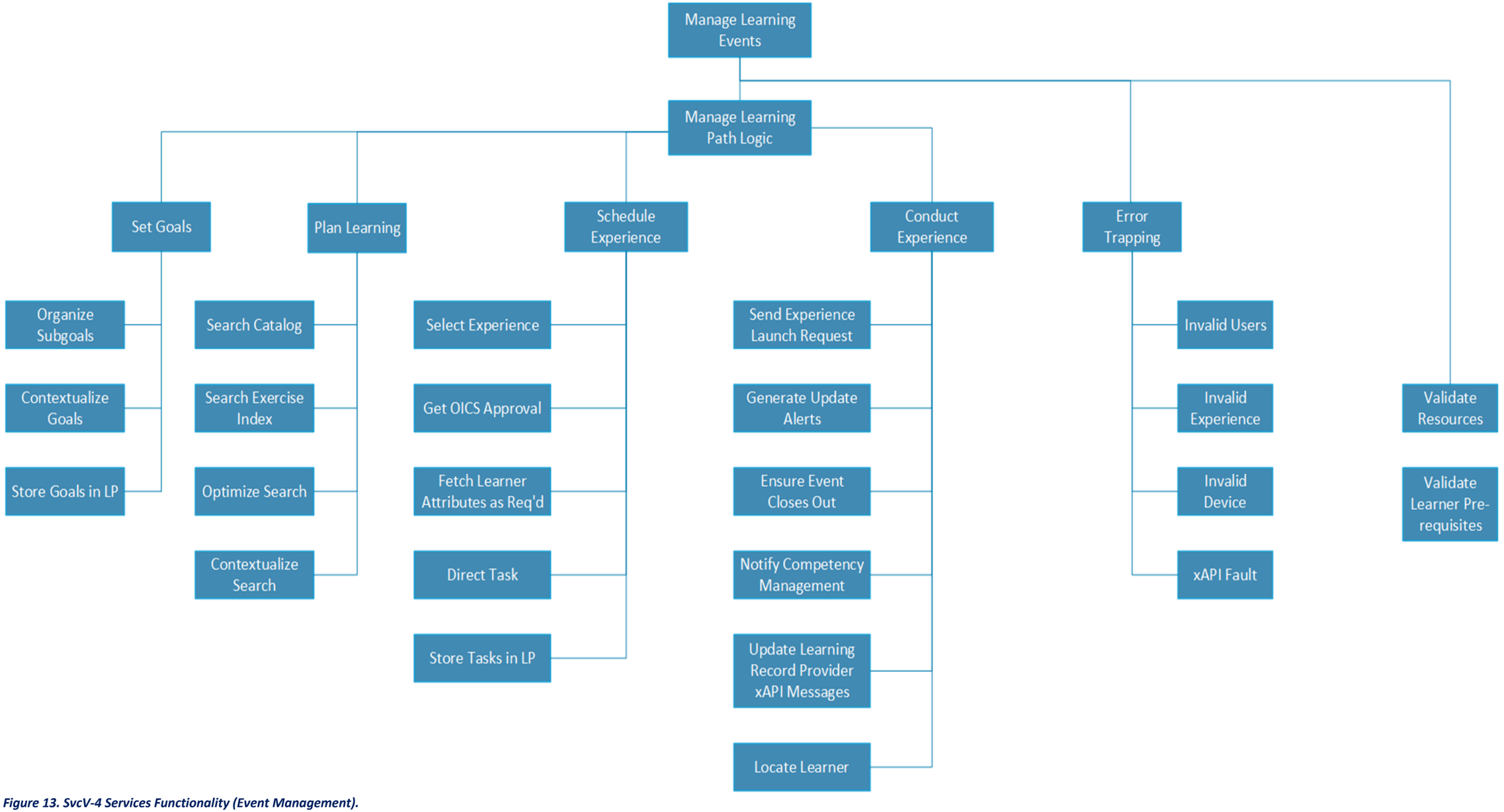

Figure 13. SvcV-4 Services Functionality (Event Management).

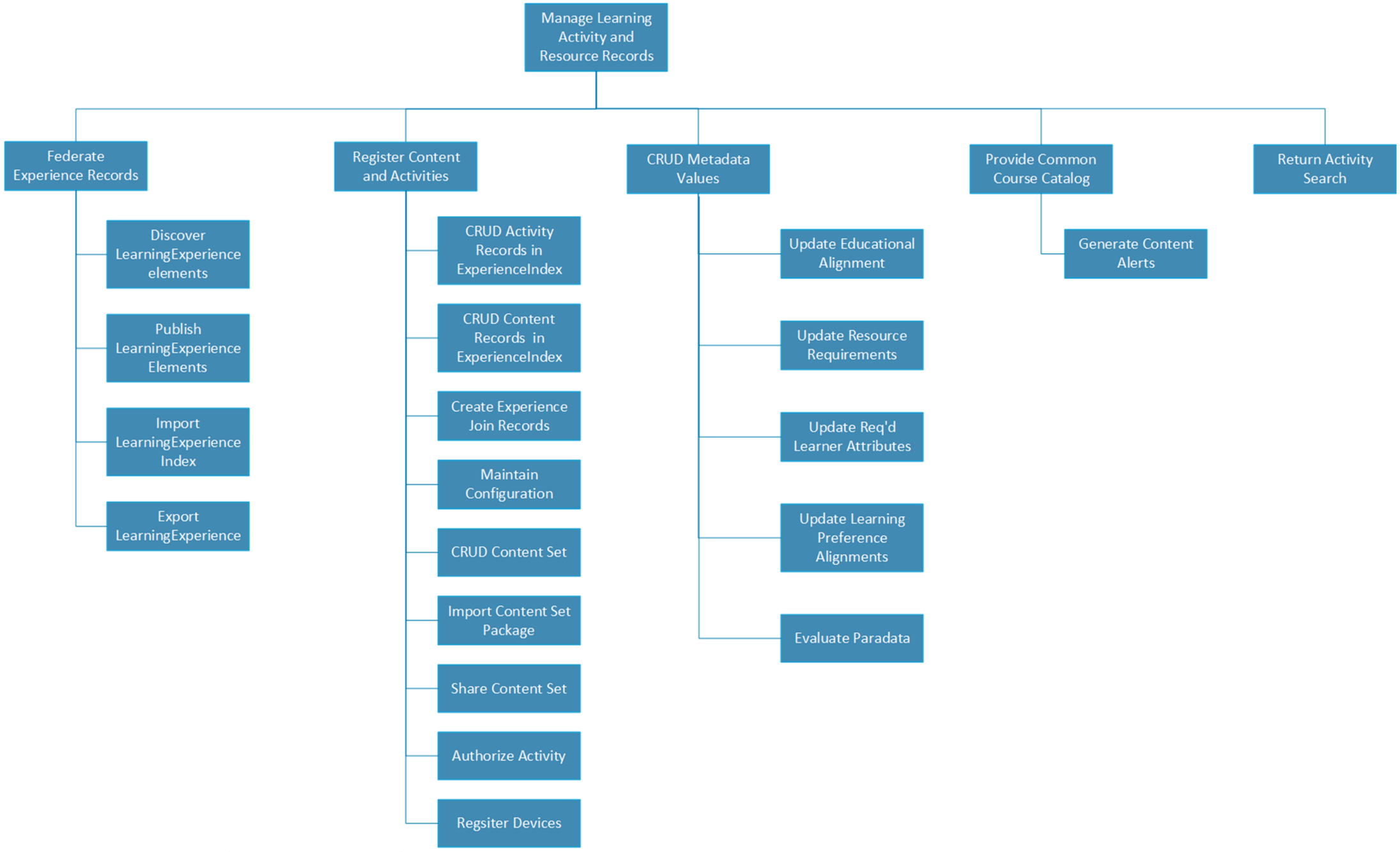

Figure 14. SvcV-4 Services Functionality (Activity and Resource Registry).

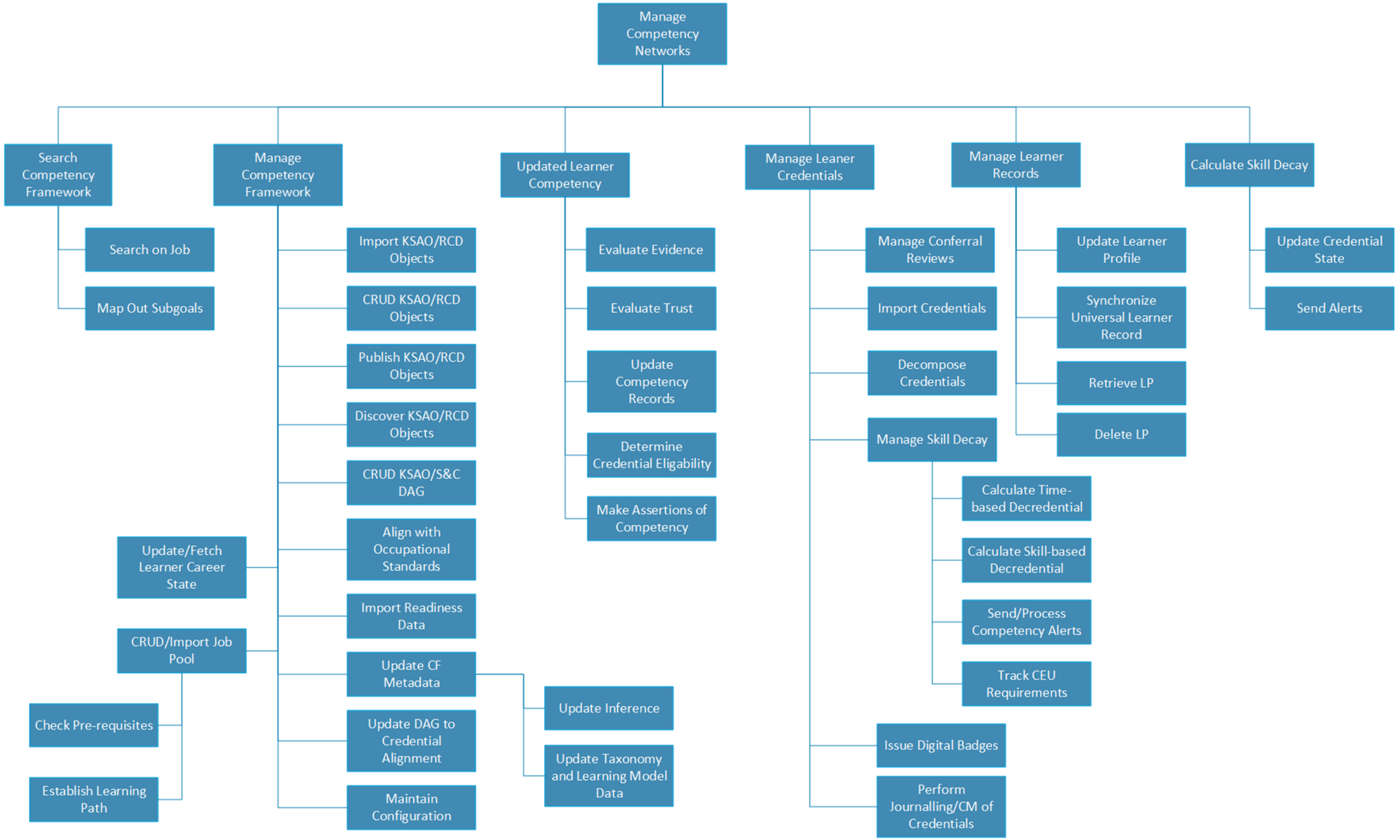

Figure 15. SvcV-4 Services Functionality (Competency Management).

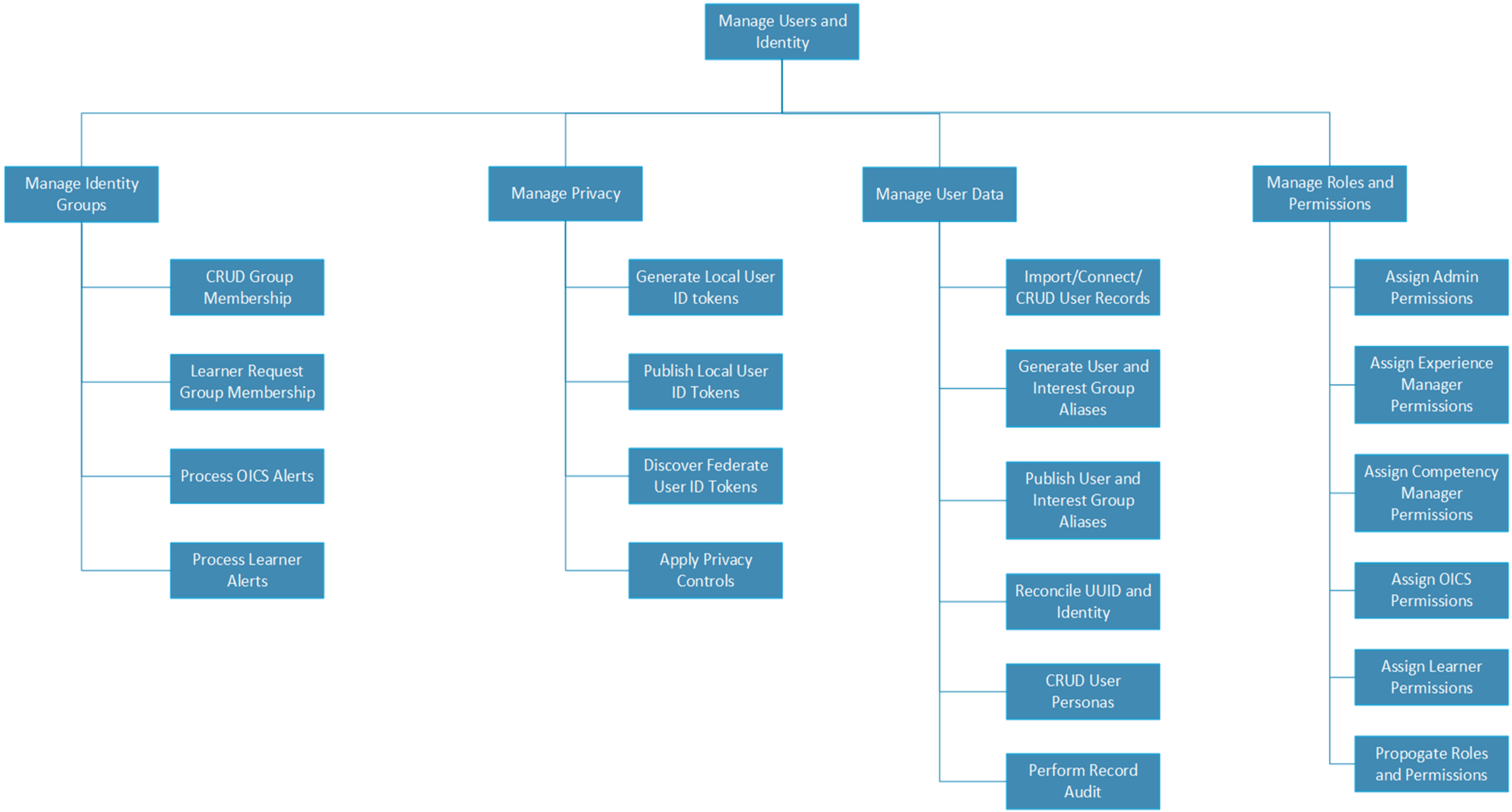

Figure 16. SvcV-4 Services Functionality (Identity Management).

Table 7. SvcV-5 Operational Activity to Services.

Service Functions	Schedule Event	Capture Event	Monitor Learner Object Life Cycle	Update Event Context xAPI Messages	Federate Experience Records	Register Content and Activities	CRUD Metadata Values	Provide Enterprise Course Catalog	Return Activity Search	Search Competency	Update/Fetch Career State	CRUD/ Import Job Pool	CRUD/ Import Competency Networks	Calculate Change in Learner Competency	Manage Learner Credentials	Mange Leaner Records	Import Readiness Data	Mange Identity Groups	CRUD/Fetch Users in Enclave	Manage User Personas	Manage user Digital Records	Analytics	Manage dynamic Endpoints	Manage dynamic Resources
Operational Activities	**Learning Event Management**				**Activity and Resource Management**					**Competency Management**								**Identity Management**					**Virtualization Management**	
Conduct Learning Events	X	X	X	O	O	X	O	O	X	X			X	X	X	X		O	X	O	X		X	X
Synchronize Identity Management					X										X	X		X	X	X	X		X	X
Sharing Learning Records																X		X	X	X	X		X	X
Creating Competency Frameworks										X			X	X	X							X	X	X
Manage Job/Duty/Gig Definitions												X	O	O		O						X	X	X
Manage Decision Support Analytics			X	X	X	O	X									X	O	O			X	X	X	X
Maintain Policy Framework																						O	X	X
Curate Experiences		X	X	X	X	X	X	X	X													X	X	X
Maintain Data Federation			X		X	X	X	X				X	X			X	X	O			X		X	X
Register New Activities	X					X	X	X	X				X										X	X
Migrate Legacy Activities	X					X	X	X	X				X										X	X
Maintain Cybersecurity	X				X	X		X			X	X	X	X	X	X	X	X	X		X		X	X
Synchronizing Enterprise Course Catalog						X	X	X	X													X	X	X
Evaluate Competency Frameworks					X		X			X			X	X	X	X	X					X	X	X
Sharing Competency Frameworks							X						X										X	X
Maintain Data Governance			X	X	X	X	X	X			X	X	X	X	X	X		X			X	X	X	X
Create Experiences	X	X		X	X	X	X	X	X													X	X	X
Review Learner Records															X	X		X	X		X	X	X	X
Maintain Device Federations																							X	X
Conduct Audits															X	X	X	X	X		X	X	X	X
Evaluate Experiences					X	X	X	X	X													X	X	X
Evaluate Learners			X	X			X			X	X		X		X	X		X	X	X	X	X	X	X
Register New Activities	O	O				X	X	X	X	X			X										X	X
Manage Credentials			X	X	X					X	X	X	X	X	X			X		X	X	X	X	X

4.5 SvcV-10a Services Business Rules

4.5.1 Minimum (TLA Level 1 & 2) Compliance

- Learning Commands must maintain records in a transactional Learning Record Store (LRS).
- Learning Record Providers (LRP) are edge systems that represent a learning activity which provides the ability for a learner to experience one or more pieces of instructional content
- The instructional content shall be aligned to address or assess an element of an educational or Competency Framework.
- This alignment may be monotonic, hierarchical, or manifold in nature.
- TLA compliant systems shall utilize the xAPI specification for recording learning experiences and paradata about learning experiences.
- LRP Systems may have their own unique xAPI profile and internal architecture.
- LRP systems must register a profile, which may be composed of existing profiles.
- LRP systems are responsible for any branching, sequencing, and micro adaptation within the content.
- LRP systems shall manage their own human performance assessment.
- LRP may archive xAPI statements according to any profile in their own “noisy” LRSs.
- The system owner or controlling agency for each enclave shall be responsible for obtaining the ATO for the enclave.
- The LRP shall be able to normalize human performance data to the states and verbs defined in the TLA MOM profile for LRP that support self-directed, self-determined, or self- regulated learning.

4.5.2 TLA Level 3+ Compliance

- TLA core services shall be able to interface with operational data and human resource system data using an industry standard or open source data or interface specification.
- TLA core data shall be federated using prescribed TLA specifications and standards.
- TLA implementation data topology shall be maintained to optimize retrieval time, security, and data integrity.
- LRPs shall provide boundaries that normalize xAPI messages sent to the Transactional LRS to the TLA MOM verb states.
- The TLA shall include components that satisfy core services, core data and expose required interfaces within a TLA enclave.
- The TLA core services shall include activity management, content and resource management, and competency management.
- The TLA core data shall include the Learner Profile, the Transactional LRS, the Competency Framework, the Experience Index.
- The core services shall allow federation of data between the noisy/transactional/authoritative LRS, Experience Index,” Learner Profile and Competency Framework to external data using the REST API.
- TLA core services shall comply with the TLA MOM profile for data communication between services.
- TLA core services shall manage federation state only through the TLA MOM.
- TLA core services shall manage federation state independent of any edge systems.
- TLA core services shall expose a RESTful API as per the TLA interface specification.
- The Experience Index shall comply with the content and resource metamodel.
- The Competency Framework shall comply with the competency metamodel (IEEE P1484.20.1)
- The Learner Profile shall comply with the learning profile metamodel.
- LRPs are to be edge systems in the TLA topology.

- LRP edge systems shall normalize communication to core services conforming to the TLA MOM IEEE P9274.3.1.
- LRP Systems shall be responsible for their own adjudication of student behavior against the standards defined in the Competency Framework.
- LRP edge systems shall report applicable context values as defined in the Competency Framework.
- TLA core services shall expose interfaces to allow for agility in presentation technology.
- All user interfaces shall be edge systems.
- The core service data shall include severable data structures to support the Transactional LRS. The Learner Profile, the Experience Index, and the Competency Framework shall report all their data to the Transactional LRS.
- The API shall support secure socket layer and encryption.
- The core services should use a publication subscribe messaging topology internally.
- The core services shall use a secure, non repudiable identity hashing system to store user identity in records.
- The core services shall support reconciliation of noncontiguous identity hash systems between federates.
- The core services shall support use of a globally unique and non repudiable identity management system in the overall learning ecosystem.
- The core services shall support server and network virtualization services maintained external to the enclave.
- The core services shall support tagging and encryption of all data in transit for systems that require that level of robustness.
- The core service data shall support the minimum metadata and data labeling requirements for global interoperability.
- The core services may assign locally defined and maintained metadata and data labeling requirements.
- Locally assigned metadata and data labeling standards and enumerations shall be documented in an enclave API, made available as part of the cybersecurity MOA process.
- The enclave API shall comply with the TLA DIV-2 logical data model.
- The core services must not include an individual's PPI when producing their xAPI statements.

4.6 SvcV-10b Services State Transition Diagram

Figures 17, 18, and **19** include diagrams that describe the state of the learner acting within a TLA compliant enclave, as the collection of microservices proposed in the TLA systems concept represent a stateless federation (although the actual components used to create the service may have state and may be different between installations, pending service/agency unique solutions). Essentially this describes the detailed life cycle for the TLA MOM.

4.7 SvcV-10c Services Event Trace Diagram

Figure 20 shows the nested sequence of data filtering and analysis, learning planning, and learning execution control within the five control loops that were described in the report.

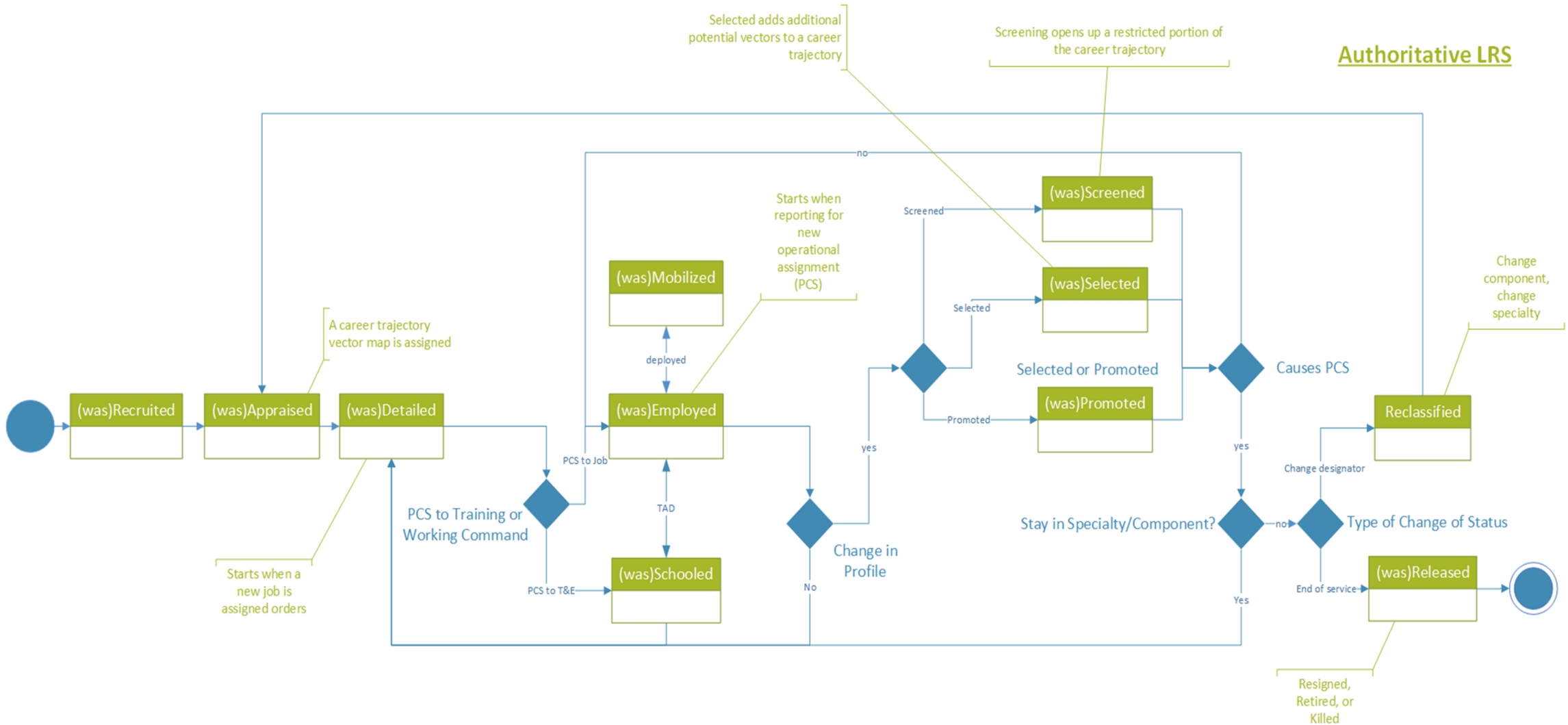

Figure 17. SvcV-10b Services State Transition Diagram (Learner Career States).

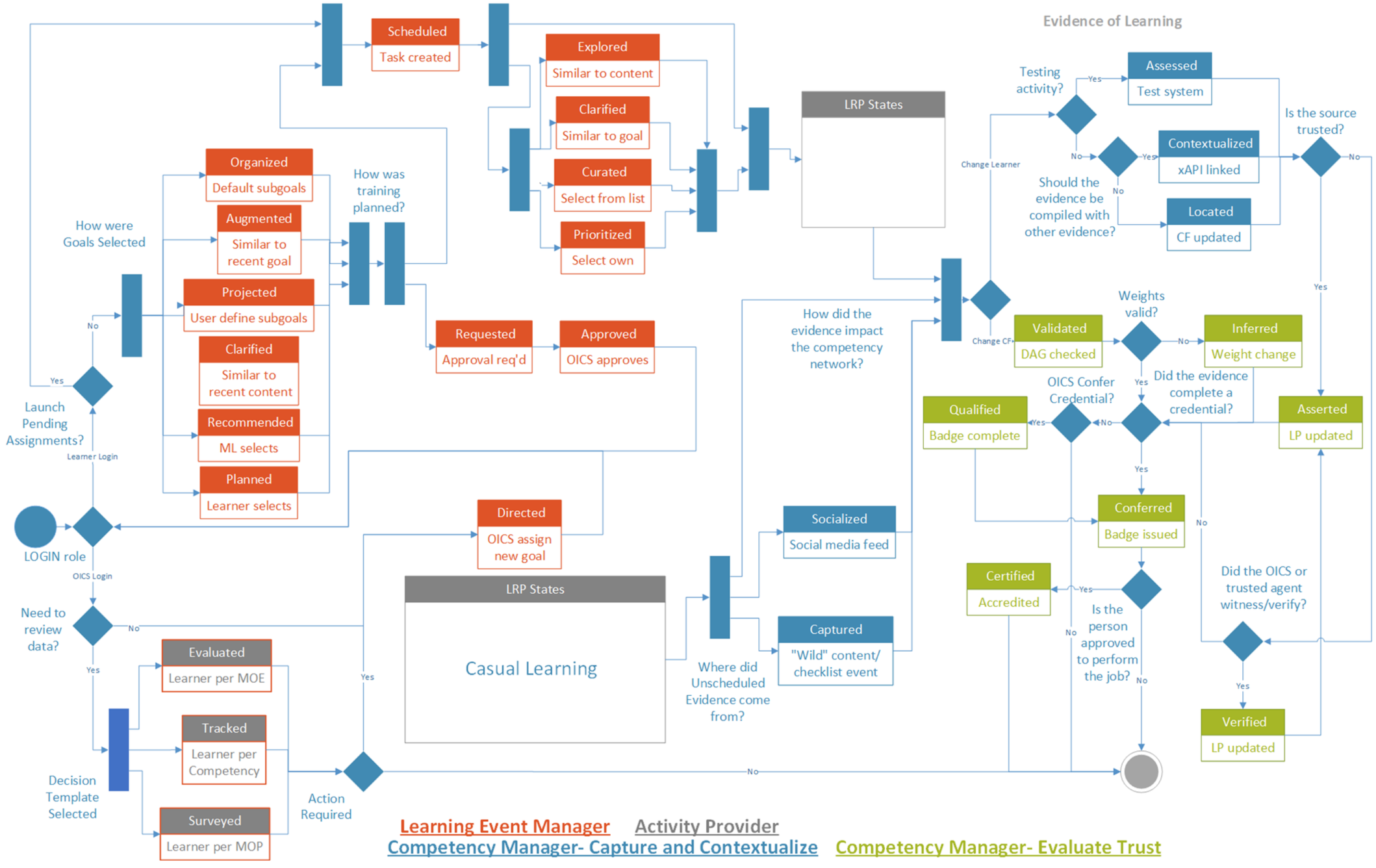

Figure 18. SvcV-10b Services State Transition Diagram (Learning Event States).

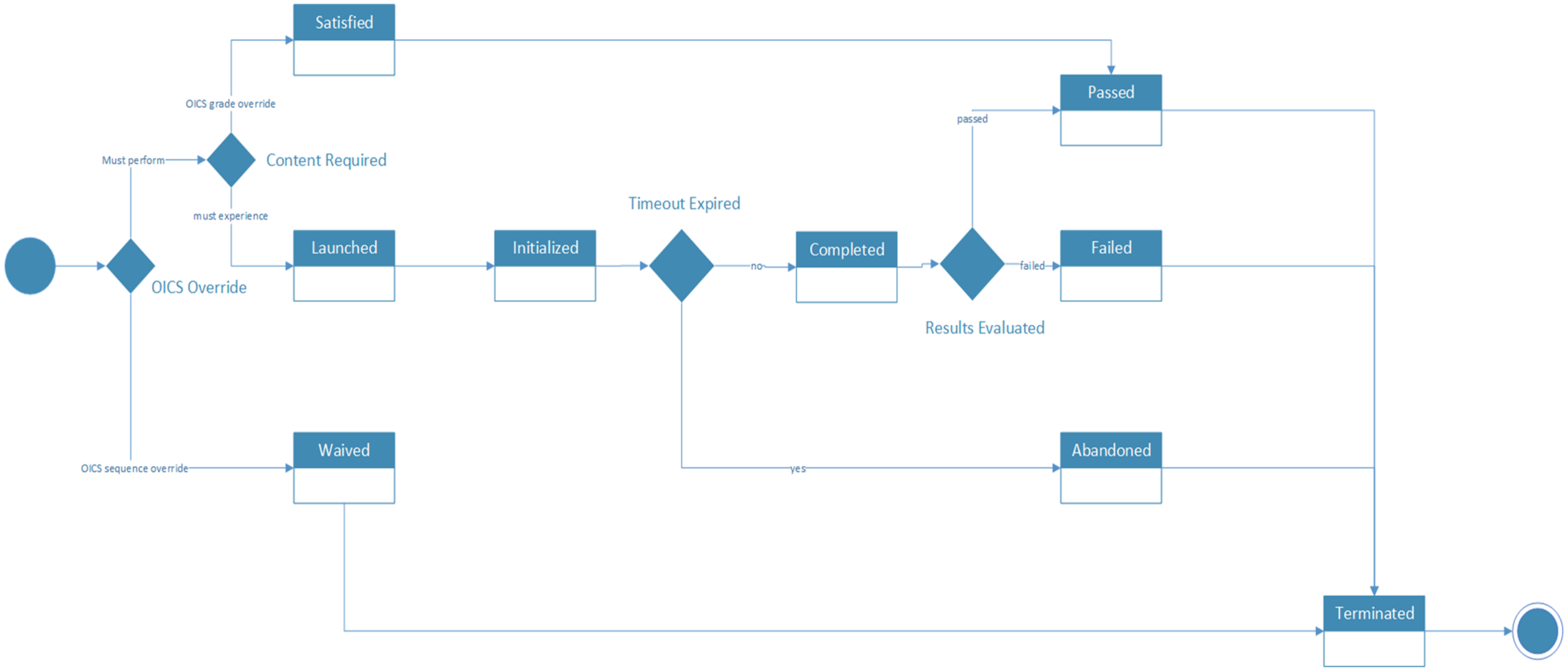

Figure 19. SvcV-10b Services State Transition Diagram (Learning Record Provider States).

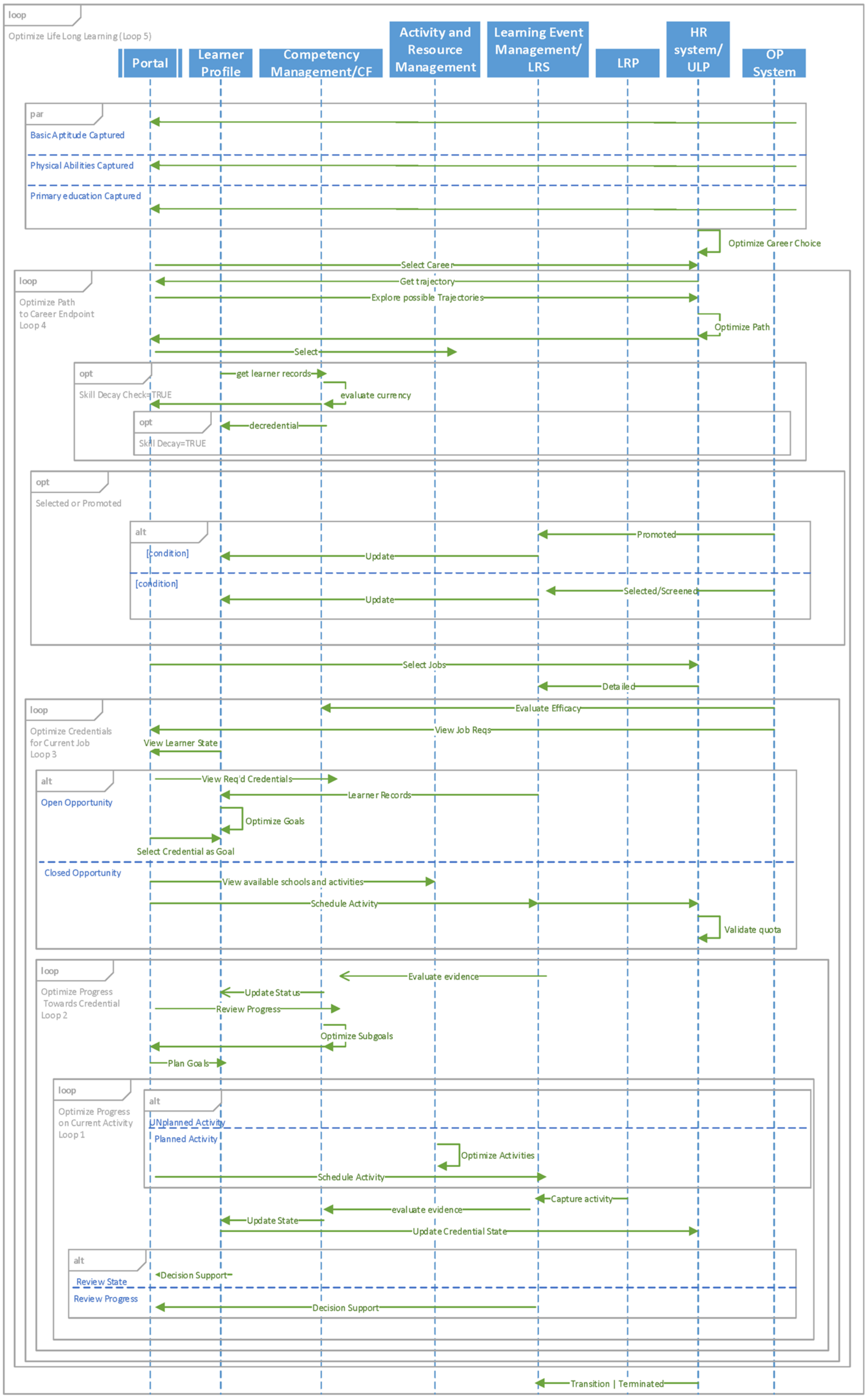

Figure 20. SvcV-10c Services Event Trace Diagram.

5.0 STANDARDS VIEWS (STDV)

5.1 StdV-1 Standards Profile

5.1.1 TLA Specifications and Standards

Research is continually performed to evaluate how standards and specifications might be used across the future learning ecosystem, at various stages of a career trajectory, and across institutional boundaries. **Table 8** provides a mapping of relevant specifications and standards for each TLA component or service. This table summarizes the candidate standards and specifications utilized or investigated in 2018 and 2019. It represents the current state of specifications under evaluation. The StdV-2 view provides an objective end-state of specifications that were down-selected from this list for the 2019 Reference Implementation, as well as the proposed standards that will complete the TLA policy framework.

Table 8. Summary of TLA Specifications. *A breakdown of each candidate specification that was evaluated in 2018 to show how it was used. The specifications are grouped and listed according to the TLA component it is aligned with. There is an expectation that TLA components and their outputs adhere to the referenced specifications. Supporting vocabularies, rules, and software ensure this process.*

TLA Component	Standard/Specification	Transport	Data Store / Registry
Activity Registry	LRMI	JSON	Experience Index
	IEEE 1484.12.1 LOM	XML	Experience Index
	Schema.org Vocabularies		Experience Index
Activity Stream	IEEE xAPI	HTTP / HTTPS with JSON payloads	Learner Record Store
	SISO HPML		Human Performance Data Model
Competency Management	ASN™		CaSS
	CASE ™		CaSS
	O*Net		CaSS
	Medbiquitous		CaSS
	RCD		CaSS
Credentials	CTDL	Credential Authoring Language	Credential Registry
	IMS Global Open Badge		
Data Analytics and Visualization Environment	Multiple	DAVE Algorithms, DAVE Visualizations, Data Cards	Dashboards, TLA Portal
Learner Profile	CaSS Proprietary		
	Enterprise Learner Record	OICD, JSON, OpenBadge2.x	Learner Profile
	Comprehensive Learner Record	Proprietary	Learner Profile
Identify Management / Single Sign On	OpenID Connect (profile of OAuth2.0)	HTTP / HTTPS with JSON payloads	TLA Common Education and Training Portal
Learner Record Provider - eBooks	ePUB 3, xAPI		

The following sections describe the candidate specifications and standards for each TLA component or service, providing an evaluation of capabilities and recommended extensions to support TLA requirements with additional insights on how they complement or compete with other specifications.

5.1.2 Activity and Resource Registry

The Activity and Resource Registry includes an Experience Index that stores metadata about each TLA learning activity. The approach used in the 2018 Reference Implementation relied heavily on the Learning Resource Metadata Initiative (LRMI) specification. While LRMI shows promise for tagging new content, there are thousands of learning resources tagged using metadata schemas managed under different organizations. Given the current state of technology, the TLA needs to be compatible with many of the more common metadata formats.

All data formats currently being investigated only support human-readable descriptions and don't consider the type of metadata generated by modern machine learning algorithms. These systems generate metadata based on a statistical analysis to describe concepts such as engagement, effectiveness, or any number of other descriptors that would be useful to other TLA components. In the future, an Activity Registry will include data and connected services that discover, catalog, and store information about TLA compatible learning activities. A primary goal of the 2019 research was to understand how the Activity Registry can be used to drive an Enterprise Course Catalog, populated by different education and training organizations. Other 2019 research included the identification of approaches for integrating paradata into the Activity Registry. The following metadata standards are being looked at to describe TLA content.

5.1.3 Learning Resource Metadata Initiative (LRMI)

The LRMI[6] is a common metadata framework developed by Creative Commons and the Association of Educational Publishers (AEP) for describing and tagging of educational resources in web-based instruction and training. The LRMI metadata schema was adopted by Schema.org in April 2013. It allows anyone who publishes or curates educational content to use LRMI markup to provide rich, education-specific metadata about their resources with the confidence that this metadata will be recognized by major search engines.

The LRMI specification is a collection of classes and properties for metadata markup and description of educational resources. The specification provides clear guidance of the terms within and how to use them both in coding and through descriptive language to be followed by those implementing it. The attributes defined by the metadata are clear and the rules surrounding the specification drive interoperability. The LRMI 1.1 specification is stable and has seen significant adoption.

The LRMI specification includes an "AlignmentObject" as part of the specification. This object describes an alignment between a learning resource and a node in an educational framework (e.g., Competency Framework). This feature was used extensively in the 2018 Reference Implementation. The 2018 Alignments included educational audience, educational use, competency object, simple or complex, interactivity level, and others. While limited, these use cases proved the ability of the AlignmentObject to serve its intended purpose. 2019 research has focused on building out a minimum set of metadata requirements that should be implemented for any future learning activities or content.

[6] *http://lrmi.dublincore.org/*

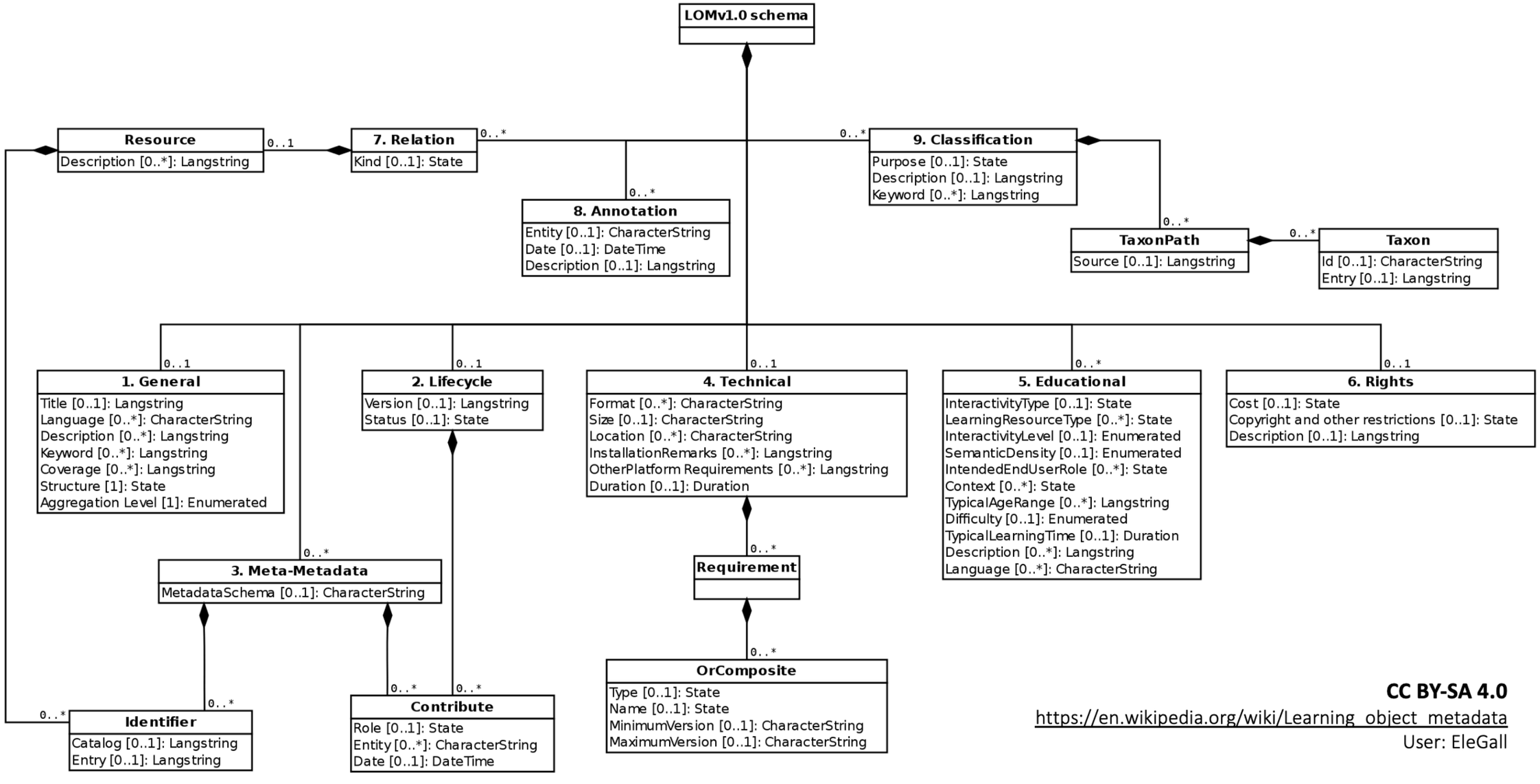

Figure 21. Learning Object Metadata. *LOM comprises a hierarchy of elements that includes nine categories, each of which contains sub-elements. The semantics of an element are determined by its context: they are affected by the parent or container element in the hierarchy and by other elements in the same container.*

5.1.4 IEEE 1484.12.1 Learning Object Model (LOM)

As shown in **Figure 21**, LOM[7] provides a broad framework for describing learning objects to facilitate search, evaluation, acquisition, and use. LOM is used by the SCORM reference model to provide descriptive information about a learning object, including the title, author, description, keywords, educational objective, and other relevant information. The LOM data model specifies which aspects of a learning object should be described and what vocabularies may be used for the descriptions; it also defines how this data model can be amended by additions or constraints. The metadata is hierarchical, with a root and leaf nodes. Alignment can be connected to a discipline, idea, prerequisite, educational objective, accessibility, restrictions, educational level, skill level, security level, or competency.

The purpose of this standard is to allow the creation of LOM instances in XML. This allows for interoperability and the exchange of LOM XML instances between various systems. When implementing the LOM as a data or service provider, it is not necessary to support all the elements in the data model, nor need the LOM data model limit the information which may be provided.

The creation of an "application profile" allows a community of users to specify which elements and vocabularies they will use. Elements from the LOM may be dropped and elements from other metadata schemas may be brought in; likewise, the vocabularies in the LOM may be supplemented with values appropriate to that community. For example, the Healthcare LOM[8], developed by the Medbiquitous consortium extends the LOM standard and provides custom vocabularies for some metadata elements.

The attributes defined by the metadata are clear and the rules surrounding the specification drive interoperability. The LOM specification (1484.12.1-2002) is stable and has seen significant adoption. ADL Initiative stakeholders have thousands of SCORM courses that have been encoded with LOM metadata so any TLA component that relies on metadata needs to be compatible with LOM. As with most metadata formats, consistency of quality metadata is a known issue.

5.1.5 Dublin Core Metadata Initiative (DCMI) Metadata

The Dublin Core Schema[9] is a set of vocabulary terms that describe digital resources and physical ones such as books or CDs, and objects like artworks. The Dublin Core Metadata Element Set is a vocabulary of 15 properties used for resource description. It is part of a larger set of vocabularies and specifications maintained by the DCMI. DCMI metadata may be used for multiple purposes, including simple resource description, combining metadata vocabularies of different metadata standards, providing interoperability for metadata vocabularies in the linked data cloud, and Semantic Web implementations.

The full set of vocabularies also includes sets of resource classes, vocabulary encoding schemes, and syntax encoding schemes. The terms in DCMI vocabularies are intended to be used in combination with terms from other, compatible vocabularies in the context of "*application profiles*" and the DCMI Abstract Model. As part of an extended set of DCMI Metadata Terms, Dublin Core became one of most popular vocabularies for use with the widely used Resource Description Framework (RDF), more recently in the context of the Linked Data movement.

[7] *https://ieeexplore.ieee.org/document/1032843/*

[8] *https://www.medbiq.org/working_groups/learning_objects/HealthcareLOMSpecification.pdf*

[9] *http://www.dublincore.org/specifications/*

The DCMI assumed stewardship of the LRMI specification in 2014. The Dublin Core schema is relevant because it is widely used. While the educational alignment aspects of DCMI are not as robust as LOM or LRMI, the ability to tie into additional vocabularies provides an attractive mechanism to identify and catalog content from different communities of interest, industries, or demographics.

5.1.6 Schema.org Vocabularies

Founded by Google, Microsoft, Yahoo and Yandex, Schema.org vocabularies[10] are developed by an open community with a mission to create, maintain, and promote schemas for structured Internet data. Each schema.org Item Type has its own set of descriptive properties. The broadest Item Type is *"Thing,"* which has four properties (name, description, URL, image). More specific "*Types*" share properties with broader "*Types.*" For example, a *"Place," "Person,"* or "*CreativeWork*" is a more specific type of "*Thing*."

LRMI's adoption into schema.org vocabularies provide many benefits. In theory, nearly any schema.org *"Thing"* could be a learning resource. Therefore, LRMI addresses those metadata properties that distinguish content when it is deliberately used for learning. This was done by adding learning-resource properties to key root types (e.g., CreativeWork). Currently, *CreativeWork* properties include *"Educational Use"* and *"Educational Alignment".* A more specific type of *CreativeWork* includes a "*Course"*[11] which may be offered as distinct instances at which take place at different times or take place at different locations or be offered through different media or modes of study. An educational course is a sequence of one or more educational events and/or other types of *CreativeWork* which aims to build knowledge, competence or ability of learners.

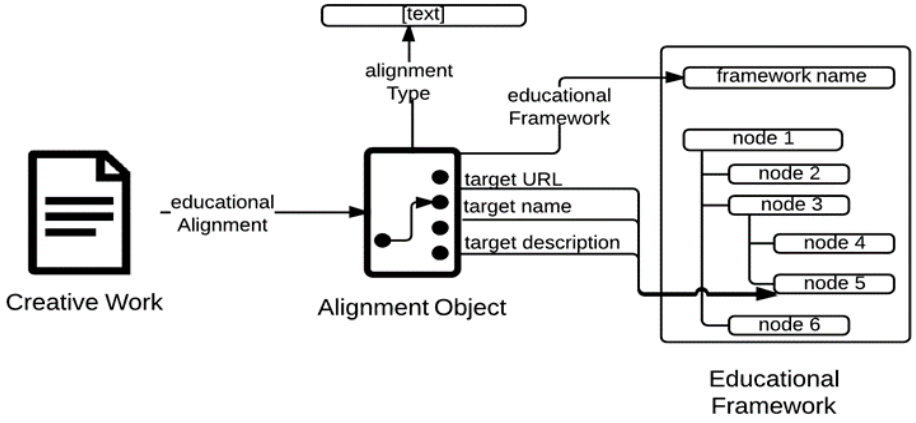

Figure 22. Alignment between a Schema.org Creative Work and a node in an Educational Framework[12]. The 2018 TLA Reference Implementation used LRMI's Alignment Object to reference a Competency Framework that provided a structured description of required knowledge, skills, abilities, and their interrelated relationships.

As shown in **Figure 22**, a learning activity is a schema.org → *CreativeWork* → "Thing" that inherits the properties that every schema.org *Thing* has and can be used to support multiple forms of alignment that are possible between a resource and an educational framework. The AlignmentObject can also be used to distinguish between resources that teach and assess. This presents the ability to collect paradata about how different types of content apply to different instructional domains and enables new insights into which content is more effective.

[10] *https://schema.org/*

[11] *https://schema.org/Course*

[12] *https://blogs.pjjk.net/phil/explaining-the-lrmi-alignment-object/*

5.1.7 Activity Streams

The FLE offers a wide range of learning content across the continuum of learning. An Activity Stream is a list of events generated by individuals, groups, applications, or learning activities that provide details about the ongoing experiences to other TLA components.

The types and variety of activities that are used for learning can often be associated with a specific delivery modality. Instructor-led classroom training will create one set of instructional activities, while serious games and simulations have the potential of generating a completely different set of activities. This has potential to have two similarly named activities with two different contexts for how those activities are being applied and the experiences they encompass. A common vocabulary is necessary to ensure all learning activities accurately describe the experience. By formalizing this vocabulary, a set of attributes and rules about the data is established, such as how they are stored, retrieved, and accessed by other components, systems or activities.

The different activity stream specifications investigated for inclusion in the TLA are similarly structured. Each specification includes serialized data streams that consist of statements about activities. Such statements typically involve a subject (the person doing the activity), a verb (what the person is doing), and a direct object (what the activity is being done to or with).

The subject of an activity is nearly always the learner but could foreseeably be an instructor, cohort, or other. The direct object of an activity is presented differently depending on its context. Verbs must conform to a common vocabulary; otherwise different organizations will use different verbs to describe the same activity or the same verb to describe different activities.

5.1.8 Experience API (xAPI)

The xAPI[13] specification is in the process of becoming a standard through the Institute of Electrical and Electronics Engineers – Learning Technology Standards Committee (IEEE-LTSC)[14]. The xAPI specifies a structure to describe learning experiences and defines how these descriptions can be exchanged electronically. The main components of xAPI are the data structure called Statements and the data storage/retrieval capability called the Learning Record Store (LRS). The xAPI specification has stringent requirements on the structure of this data and the capabilities of the LRS. Statements are data triples that use an Actor, a Verb, and an Object to describe any experience. Each statement also includes timestamps and unique, resolvable identifiers. The transport is HTTP/HTTPS with JSON payloads.

Any enabled device can send xAPI statements including mobile phones, serious games and simulations, CPR dummies, and any number of other learning systems. The xAPI Profile Specification[15] offers a common way to express controlled vocabularies across these different mediums, provides instructions on the formation of xAPI statements, and describes patterns of xAPI usage that provides additional context to a domain, device, or system. The xAPI Profiles Specification also adds tools to support authoring, management, discovery and/or adoption, including additional data elements and properties.

[13] *https://github.com/adlnet/xAPI-Spec*

[14] *https://www.tagxapi.org/*

[15] *https://github.com/adlnet/xapi-profiles*

An LRS is the implementation of the server-side requirements associated with the xAPI specification. It is the application interface for storing, accessing, and often visualizing the data about learning experiences, activities, and performance. The LRS is essentially a Web service that leverages a REST API for the storage and retrieval of xAPI data. A learner's xAPI data and transcripts stored within one LRS can be extracted and sent to other LRSs, enabling learning experiences to follow them from one organization to another.

An LRS could be optionally integrated with any application such as an LMS, Human Resources system, or could serve as centralized data store in an enterprise learning ecosystem. Third party applications which send or retrieve learning activity data will interact with the LRS as the data store for xAPI data. From this perspective, an LRS is also required to validate the format of the statements as many of the requirements in the xAPI specification are targeted toward the LRS component.

5.1.9 Caliper

Developed by the IMS Global Learning Consortium, Caliper is essentially a competitor to xAPI, in that it records learning event data. However, Caliper is more normalized than xAPI and while that typically means a faster or more compact data transmittal and storage format, it represents a more brittle architecture. Caliper was removed from review in 2019.

5.1.10 W3C Activity Streams 2.0

The W3C Activity Streams[16] is an open format specification for activity stream protocols, which is similar in function to the xAPI in the TLA topology. In the 2019 Reference Implementation, "activity streams" are tracked using the MOM profile of xAPI. The implementation of linked data does not use JSON-LD but is more thread-safe than JSON-LD in the open ended FLE.

5.1.11 Human Performance Markup Language (HPML)

Developed by the Simulation Interoperability Standards Organization (SISO), HPML[17] is an XML-Schema-based language intended to support the evaluation of individuals and teams as they perform their job functions. HPML provides schemas for organizing the information relevant to defining performance measurements, including computations, measures, assessments, results, and instances/periods. Specifically, it is an XML based language designed to express performance measurement concepts in a format that is both machine and human readable.

HPML enables the explicit combination and transformation of performance data into performance measurements and assessments. These are decoupled from a specific training system but can be used to specify the data elements to be collected from a system, the calculations to use to process the data, and when to produce performance measurement results. As shown in **Figure 23**, HPML provides a flexible framework for configuring and executing performance measurement and assessment. The schema is separated into six distinct groups that make up the core components of HPML and can be expanded with additional links in the schemas.

[16] *https://www.w3.org/TR/activitystreams-core/#documents*

[17] *https://discussions.sisostds.org/index.htm?A0=SAC-PDG-HPML*

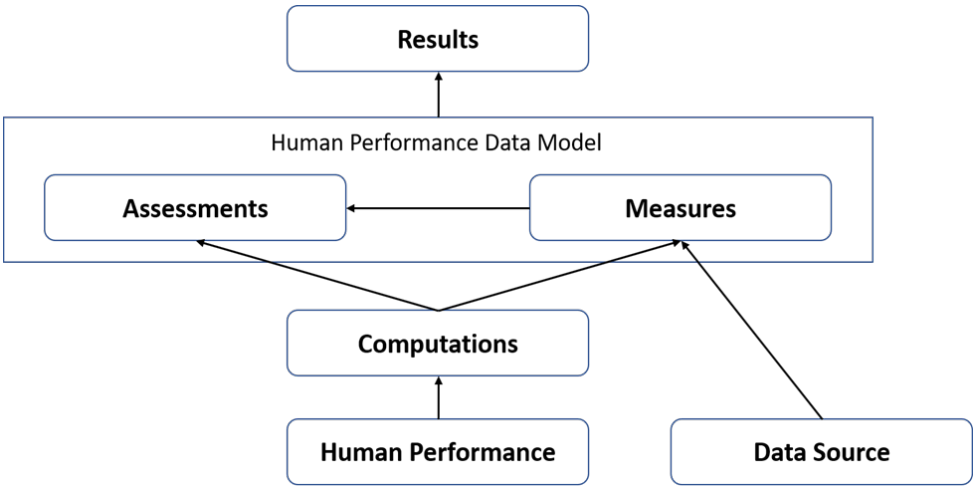

Figure 23. HPML High-Level Conceptual Architecture. *HPML includes a Human Performance Data Model with rules to dictate how performance data are measured, computed, and assessed. It is agnostic on the kinds of data used.*

HPML as a specification includes both the markup language used to author the activity stream and the "Human Performance Data Model" used to measure and assess performance based on the incoming stream of data. In the 2019 Reference Implementation, all adjudication of performance has been moved to edge systems and away from core data. Thus, HPML may still be a part of an edge system solution, but it is not part of the TLA policy framework per se.

5.1.12 Competency Management

Competency management requires the generation of rich and traceable data about learning experiences, how they relate to skill proficiency, and the knowledge, skills, abilities, and behaviors that individuals need to do their job. Competencies describe specifically what people need to do to be effective in their roles, and it clearly establishes how their roles relate to organizational goals and success. Each individual role has its own set of competencies needed to perform the job effectively.

Competency Based Learning represents a transition from curricula focused on abstract knowledge and pursuit of certificates, to curricula built around authoritative performance indicators that guide learning experiences based on challenges in the workplace that unlock human potential. Proficiency is a complex and critical concept that requires relevant, trusted data that can be used as evidence about an individual's mastery against a specific set of competencies. A Competency Framework is a structure for defining the knowledge, skills, abilities, and attitudes (or other characteristics) required to do a job. Competency Frameworks are widely used in business for defining and assessing competencies within organizations in both hard and soft skills that jointly define successful job performance. There are numerous Competency Frameworks available and numerous specifications that drive them.

The 2019 effort focused on determining a meta-metamodel for describing competencies as a series of Directed Acyclic Graphs (DAG) and thus the Reusable Competency Definition (RCD) objects provide a mathematical formalism for describing competencies, rather than a framework of competencies themselves. The subordinate frameworks, ASN, CASE, O*net, MedBiquitous, etc. can be represented within this formalism, as appropriate for the communities of practice they represent.

5.1.13 Achievement Standards Network (ASN)

ASN provides access to machine-readable representations of learning objectives and curriculum standards[18]. It provides an RDF-based framework based on the syntax-independent DCMI abstract model (DCAM). The DCAM is intended to support development of Dublin Core Application Profiles (DCAP) of which the ASN DCAP is an example. The ASN framework is made up of "Standards Documents," which represent the overall Competency Framework; and "Statements," that represent the individual achievements within the overall framework. A set of core properties define the relationships between the two in terms of an "Entity Relationship" model. Structural relationships replicate the relationships between different components of the Standards Document and semantic relationships define the relationships of meaning between statements (e.g., assertion of equivalence).

ASN is designed for interoperability and open access to learning objectives. It has seen wide adoption in the K-12 community. The ASN Description Framework (ASN-DF) also provides the means to create "ASN profiles" through inclusion of additional properties and classes from other namespaces and definition of constraints on data patterns. ASN-DF provides a small vocabulary of classes and properties and a set of mechanisms for tailoring an ASN Profile based on the Dublin Core's conceptualization of application profiles and description set templating as well as refinements to these conceptualizations developed by the U.S. Library of Congress to support Bibilographic Framework (BIBFRAME) profiling.

5.1.14 Competencies and Academic Standards Exchange (CASE)

The IMS Global Learning Consortium created the CASE specification[19] to define how systems exchange and manage information about learning standards and competencies in a consistent and digital way. CASE connects standards and competencies to performance criteria and provides a way to transmit rubrics between various platforms. Within CASE, the underlying structure of both a competency and an academic standard are represented using the same data model. The data model is composed of three core constructs:

- **The root definition document** – the "CFDocument" is the top-level structure that holds the set of statements that define the individual competencies/academic standards.
- **The set of composition statements** – the "CFItem" is the set of statements into which the top-level competency/academic standards have been decomposed.
- **The rubric** – the "CFRubric" defines how mastery of the competency/standard can be achieved. This requires the definition of specific criteria used for each of the scores that can be awarded during an assessment.

The CASE specification defines internal relationships between statements like "Parent/Child," "Precedes," "Is Related To," "Exemplar," and "Is Part Of." All Competency Frameworks published in CASE format can be linked together in a network of equivalent or aligned competencies. Having universal identifiers for each competency makes it possible for any tools or applications to share information between systems.

[18] *http://www.achievementstandards.org/*

[19] *http://www.imsglobal.org/activity/case*

5.1.15 O*Net

The Occupational Information Network (O*NET)[20] is sponsored by the U.S. Department of Labor, Employment and Training Administration (USDOL/ETA) to facilitate and maintain a skilled workforce. Central to the project is the O*NET database, which contains hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy. Every occupation requires a different mix of knowledge, skills, and abilities, and is performed using a variety of activities and tasks. As shown in **Figure 24**, the O*NET database identifies, defines, describes, and classifies occupations through Experience Requirements (Training, Licensing), Worker Requirements (Basic and Cross-Functional Skills), Occupation Requirements (Work Activities, Context), Worker Characteristics, Occupation Specific Information, and Occupational Characteristics.

The value of the O*NET Database to the TLA is in leveraging the existing resources these government sponsored activities have already amassed. Their Military Transition search connects occupations in the O*NET database to other classifications systems within the Military. This is accomplished through data from the Military Occupational Classification (MOC) system at the Defense Manpower Data Center (DMDC). This capability is also available via web services. Other resources include "Careers in the Military" and links to Army, Navy, Marine Corps, and Air Force "Credentialing Opportunities On-Line" (COOL) projects.

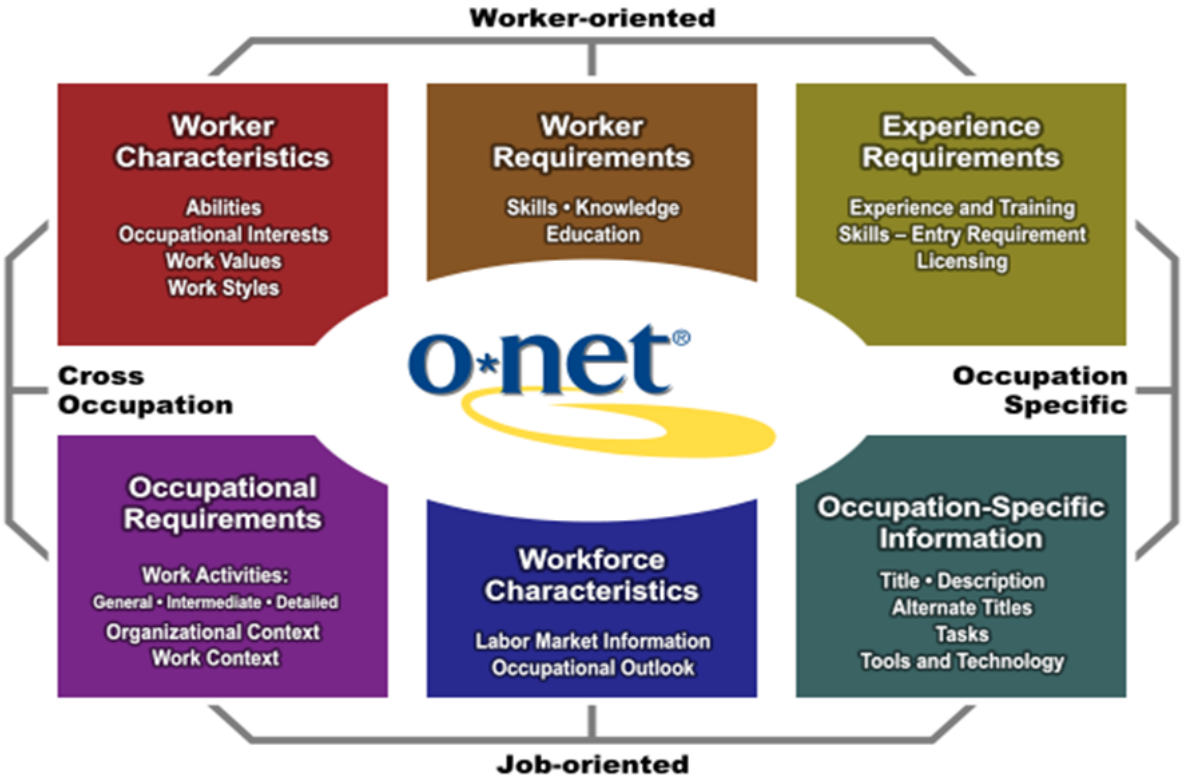

Figure 24. O*NET Content Model*. O*Net provides the framework that identifies and organizes the distinguishing characteristics of an occupation. The model defines an occupation as a standardized, measurable set of variables called "descriptors." This hierarchical model starts with six domains that expand to 277 descriptors.*

[20] *https://www.onetonline.org/*

5.1.16 MedBiquitous Competency Framework

The MedBiquitous Competency Framework[21], ANSI /MEDBIQ CF.10.1-2012, is a technical standard for representing Competency Frameworks in XML, accredited by the American National Standards Institute. Organizations that publish Competency Frameworks can do so in this standard format, making it easier to integrate Competency Frameworks into educational technologies like curriculum management systems. The standard allows medical schools and other health profession schools to connect their curriculum, learning resources, and assessment data back to a common set of competencies, ultimately enabling competency-based views of the curriculum and of learner performance. The data model establishes relationships between *"Competency Objects"* that narrow or broaden the definition of overall competency.

The MedBiquitous Competency Object specification provides a consistent format and data structure for defining a competency object, an abstract statement of learning or performance expectations, and information related to the statement. Statements can be learning outcomes, competencies, learning objectives, professional roles, topics, classifications/collections, etc. The Competency Object may include additional data to expand on or support the statement. This specification is meant to be used with the MedBiquitous Competency Framework specification.

5.1.17 IEEE 1484.20.1 Reusable Competency Definitions (RCD)

The current RCD standard[22] defines a data model for describing, referencing, and sharing competency definitions, primarily in the context of online and distributed learning. The standard provides a way to represent formally the key characteristics of a competency, independently of its use in any specific context. It enables interoperability among learning systems that deal with competency information by providing a means for them to refer to common definitions with common meanings.

This specification enables the storage of a Competency Framework in the form of a Dynamic Acyclic Graph (DAG) where competency objects define the knowledge, skills, conditions, and other factors that role up into an ability to do a job. The edges between each competency object inform the relationship between them and have the potential to identify whether they're dependent, complimentary, conflicting, or other. This provides an extensible mathematical underpinning to a Competency Framework that accommodates the relationships defined in any other foreseeable Competency Framework.

The Data Model for RCD[23] was put together in September 2018 to revise the 2008 standard. The Competencies WG 20 intends to take the Credential Ecosystem Mapping Project's mapping of competencies metadata and update RCD to represent the most common elements that are found in multiple standards addressing competencies and Competency Frameworks. The ADL Initiative is a participant in the LTSC working group and is keenly interested in the newer version of the RCD standard to describe the mathematical formalism of competency data from other sources.

[21] *https://www.medbiq.org/working_groups/competencies/index.html*

[22] *https://ieeexplore.ieee.org/document/4445693*

[23] *http://sites.ieee.org/sagroups-1484-20-1/*

5.1.18 Credentials

A credential is a testament of qualification and competence issued to an individual by an authoritative third party. Examples of credentials include academic diplomas, degrees, certifications, professional licenses, or other proof of occupational qualification. Within the TLA, credentials are an exchange format by a trusted party that formally encapsulate a set of *"Competencies."* By their nature, they are linked to other TLA components such as Competency Frameworks, assessment rubrics, or Talent Management Systems. This requires the establishment of attributes and rules that allow TLA components to process and compare credentials in the same, interoperable way, particularly in Learner Profiles across instantiations of the TLA. This also requires a common way to describe, store, and access credentials in order to make fair comparisons of the achievement that was performed to acquire them.

5.1.18.1 Credential Transparency Description Language (CTDL)

CTDL[24] is a vocabulary comprised of terms that are useful in making assertions about a credential and its relationships to other entities. CTDL is modeled as a directed graph using RDF for describing data on the web. Like an activity stream, the "triple" is the basic grammatical construct in making CTDL assertions about "things" and is comprised of three simple components: a subject, a predicate and an object. This structure allows simple statements to enable a rich description of credential-related resources including credentialing organizations and specific subclasses of credentials such as *Degrees, Certificates,* and *Digital Badges*. The comprehensiveness of this specification makes it ideal for defining TLA credentials.

5.1.18.2 Credential Registry

The Credential Registry[25] is both a repository of credential information and a set of services that make it easier to use that information. The Credential Registry works with CTDL to allow the storage of credentials that have been expressed using that specification. It also registers credentialing organizations that issue these credentials including universities, colleges, schools, professional associations, certification organizations, and more.

Since it is strictly a registry, it only stores the description of a credential in the abstract sense and does not include any personal information or personally obtained credentials. This information will typically be stored in a Learner Profile. As a registry, it does allow users to see what various credentials represent in terms of competencies, transfer value, assessment rigor, third-party approval status and more.

The Credential Engine project's developers are using DCAP to create systems that communicate virtually all aspects of credentials. The Technical Advisory Committee promotes collaboration across different standardization initiatives that are developing data models, vocabularies, and schemas for credentials and Competency Frameworks. The Credential Registry uses technology and CTDL to capture, link, update, and share information about credentials so it can be organized and centralized within the registry, made searchable by customized applications, and linked-to from anywhere on the open Web.

[24] *http://credreg.net/ctdl/handbook*

[25] *https://www.credentialengine.org/credentialregistry*

5.1.18.3 IMS Global Open Badges

Open Badges[26] are visual representations of verifiable achievements earned by recipients. Open Badges is a technical specification and set of associated open source software designed to enable the creation of verifiable credentials across a broad spectrum of learning experiences. The Open Badges standard describes a method for packaging information about accomplishments, embedding it into portable image files as digital badges, and establishing resources for its validation and verification. Open Badges contain metadata about achievements such as who earned a badge, who issued it, and what it means. Open Badges 2.0 expands on this to include versioning, endorsements, and full use of JSON-LD.

Open Badges are expressed as linked data so that badge resources can be connected and reference by other systems. This metadata can also be embedded within the graphic. The Open Badges vocabulary defines several data classes used to express achievements. There are three core data classes (Assertions, Badge Classes, and Profiles) that define mandatory and optional properties as well as the restrictions on the values those properties may take. Each *Badge Object* may have additional properties in the form of an *Open Badges Extension*, a structure that follows a standard format so that other users can understand the information added to badges. Assertions are representations of an awarded badge, used to share information about a badge belonging to one earner.

5.1.18.4 T3 Innovation Network

The T3 Innovation Network was launched in 2018 by the U.S. Chamber of Commerce Foundation and the Lumina Foundation to create a more responsive, dynamic, and equitable talent marketplace through the convergence of Web 3.0 technologies. Ten pilot projects were initiated in 2019 that covered topic areas like open data standards, comprehensive learner and worker records, shared competency infrastructure, and linked data to facilitate the technology infrastructure of the future.

The ADL Initiative 2020 goals align with the T3 Network's goals, specifically with three Pilot Projects: PP1- Data Standards Harmonization; PP3- Learner Record Standards; and PP5- Competency Data Exchange. Outcomes of these efforts include the development of robust learner, worker, and military use-cases. The projects support the mapping and harmonization of standards across the public-private talent marketplace, especially for the implementation and use of a comprehensive learner-worker-military, record. The conclusion of these pilot projects includes a plan for long-term sustainability, and governance/management for continued progress toward a more equitable talent marketplace.

5.1.19 Learner Profile

Learner Profiles exist in many systems and are extremely diversified in nature. It is envisioned that an FLE Learner Profile will house data about people across their entire career. Adult learners are characterized by distinctive personal attributes, knowledge, skills and competencies that they have gained in different contexts through a process of development and growth. A Learner Profile may also include demographic data, student interests, learning preferences, descriptions of preferred learning environments, inter/intra personal skills, existing competencies and those that need to be developed, socio-emotional health, and a myriad of other data. Learner Profiles are dynamic and will change over time. As student interests change and they become competent in new areas, the profile will update to reflect the latest "state" of the learner.

[26] *https://www.imsglobal.org/activity/digital-credentials-and-badges*

The 2019 Learner Profile is based on the attributes defined in the DIV2, but the Enterprise Learner Record (ELR) metamodel will extend to include the management of local and global values. Local values include persistent learner-state messages gathered from the MOM activity stream, local user attributes used for planning of local learning events, and local credential records, including the digitally signed Mom xAPI statements from the "chain of trust" and their association to competency "chains of evidence," as well as the portable digital badge that is exchanged globally. A governance board for evaluation of local attributes to be elevated to global governance is a critical component to future learning ecosystem's ELR/LP federation.

5.1.19.1 Comprehensive Learner Record (CLR)

IMS Global led the development of the CLR[27], formerly known as the Extended Transcript. It was originally designed to support traditional academic programs as well as co-curricular and competency-based education by capturing and communicating a learner's achievements in verifiable, digital form. The CLR contains data about different learning experiences and achievements including course descriptions, syllabi, rubrics, portfolios, performance evaluations, prior learning, internships, and other experiences or assessments.

As a digital transcript, the CLR closely follows the registrar guidance of the American Association of Collegiate Registrars and Admissions Officers (AACRAO) to draw information from an institution's Student Information Systems, LMS, or other internal databases.[28]

The CLR is due to be completed in 2019 but will likely evolve to help foster adoption across higher education institutions. Integration with existing institutional reporting systems and data structures will be critical in enabling this effort to succeed. The ADL Initiative will continue to monitor this effort to measure its applicability to the DoD and other government stakeholders. LIP will be evaluated for incorporation into the larger Enterprise Learner Record metamodel.

5.1.19.2 Learner Information Package (LIP)

The LIP specification[29] provides a standard means for recording information about learners. It will allow information about learners, including their progress to-date and awards received, to be transferred between different software applications. LIP will be evaluated for incorporation into the larger Enterprise Learner Record metamodel. In this specification, Learner Information is separated into 11 main categories, including: Identification, Qualifications/Certifications/Licenses, Accessibility, Activity, Goal, Competency, Interest, Transcript, Affiliation, Security Key, and Relationship. The LIP specification describes the data structures, XML binding, and best practices for formatting, storage, and exchange of learner information.

The specification supports the exchange of learner information among LMSs, Human Resource Systems, Student Information Systems, and other systems used in the learning process. LIP is an older specification and its reliance on XML impacts the access speed for how these systems can load learner information. The *FLE* will require real time learner services that can send and update records on the fly.

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[27] *https://www.imsglobal.org/activity/comprehensive-learner-record*

[28] *https://library.educause.edu/~/media/files/library/2019/1/eli7164.pdf*

[29] *http://www.imsglobal.org/profiles/index.html*

An Accessibility-for-LIP standard[30] is extending the LIP Information Model to better define accessibility preferences for people with disabilities. This work is intended to benefit all learners in situations that require alternative modes of instruction, such as an extremely noisy environment where captions are needed for a video or language barriers.

5.1.19.3 IEEE Public and Private Information for Learners (PAPI Learner)

The PAPI Learner specification[31] is a multi-part standard that specifies the semantics and syntax for storing, retrieving, searching, and exchanging learner information. It defines elements for recording descriptive information about knowledge acquisition, skills, abilities, personal information, learner relationships, preferences, performance, and similar types of information. An important feature of the PAPI Learner standard is the logical division, separate security, and separate administration of several types of learner information.

The PAPI Learner specification partitions learner records into six main information types that support extension:

- **Learner Contact Information** – describes information related to administration.
- **Learner Relations Information** – stores information about the learner's relationships to other users of learning systems, such as teachers and other learners.
- **Learner Security Information** – stores information about the learner's security credentials, e.g. passwords, private keys, public keys, biometrics.
- **Learner Preference Information** – describes preference information intended to improve human computer interactions and the automatic adaptation and personalization of systems to specific needs of the learner.
- **Learner Performance Information** – is about the learner's history, current work, or future objectives. PAPI performance information is primarily created and used by learning technology components to provide improved or optimized learning experiences.
- **Learner Portfolio Information** – is a representative collection of the learner's works or references to them that is intended for presentation and evidencing of his achievements and abilities.

This standard permits different views of the learner information (e.g., learner, teacher, parent, school, employer) and addresses issues of privacy and security. The data models associated with this specification are not sufficiently complete to cover all the learner data that needs to be exchanged between TLA components, particularly those related to pedagogical/andragogical aspects such as defining an "*Educational Pathway."*

5.1.19.4 Airmen Learning Record (ALR)

The vision of the Air Force Learning Services Ecosystem (AFLSE) is to support a continuum of learning that deliberately prepares airmen with the required competencies to meet the challenges of the 21st century. The ALR is a comprehensive record of all learning airmen achieve during their careers, including educational transcripts, training records, performance reports, and ancillary training transcripts.

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[30] *https://www.imsglobal.org/accessibility/acclipv1p0/imsacclip_infov1p0.html*

[31] *http://metadata-standards.org/Document-library/Meeting-reports/SC32WG2/2002-05-Seoul/WG2-SEL-042_SC36N0175_papi_learner_core_features.pdf*

The airman's learning record is a centralized location to record all learning, whether it occurs in a specialized training or education program, on-the-job, or even off-duty. The learning record will enhance the ability to analyze the readiness of the Air Force by capturing an airman's knowledge and skills gained throughout the Continuum of Learning (training, education, and experiences), documenting progress and achievements, and identifying gaps and opportunities for growth tied to mission accomplishment from both an enterprise perspective as well as an individual level.

5.1.19.5 Navigator for Integrated Learning Environments (NILE)

NILE builds upon an existing commercial product that has been historically targeted at the K-12 educational domain. They use a *"Google Maps"* approach to create a *recommended* learning path for learners to take. NILE has a content discovery service that has aggregated millions of educational resources into their platform. Recommended learner pathways change based on performance, instructor input, or student choices.

The ADL Initiative is funding the migration from propriety data structures and interface specifications to a TLA-enabled ecosystem to better evaluate how TLA specifications and standards scale. NILE includes numerous enabling technologies (e.g., content discovery service) that are also appealing to the TLA ecosystem of tools and technologies.

5.1.19.6 Adaptive Instructional Sciences – IEEE (C/LT/AIS) P2247.1

The purpose of the Adaptive Instructional Systems (AIS) Working Group[32] is to investigate the market need for standards across a group of instructional system technologies. The output of the working group will be one or more "Project Authorization Requests" to the IEEE, to develop specifications and standards that improve the interoperability across adaptive tools and technologies.

5.1.19.7 xAPI Launch

The xAPI Launch specification[33] is a method of launching xAPI-enabled content that works with online learning modules, static HTML files, offline content, or immersive games and simulations. It does not require a learner identity, the LRS endpoint, or the *Session* information for how the events should be grouped. Implementation requires a minimal HTTP request and handles the creation and transmittal of xAPI data to the LRS on behalf of the Activity. While this specification is mature, it is not widely adopted.

5.1.19.8 cmi5

cmi5[34] is an xAPI-based specification that replicates many of the features and capabilities associated with SCORM. cmi5 provides definitions of certain xAPI statements, a launch process, a course structure, and runtime communications between an LMS and learning content. cmi5 allows the setup of several "global" variables including actor, xAPI endpoint and security token, and the automated communication of some xAPI statements. The Launch portion of cmi5 allows developers to avoid "hard coding" the LRS information into the LMS. cmi5 could be expanded to support a secure, single sign-on experience by decoupling the data models and behaviors from the implementation details. Implementation details could be defined as part of the cmi5 launch profile which allows it to be used for web and native applications.

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[32] *http://sites.ieee.org/sagroups-2247-1/*

[33] *https://github.com/adlnet/xapi-launch*

[34] *https://github.com/AICC/CMI-5_Spec_Current/blob/quartz/cmi5_spec.md#content_launch*

5.1.20 Assessment Service

The nature of assessment in a competency-based educational program is more focused on the learner's ability to demonstrate their understanding of key concepts by having them apply their learned skills in different contextual situations. The 2018 TLA Reference Implementation used a variety of traditional assessment activities that included multiple choice tests/quizzes, Situational Judgement exercises built in Unity3D, mobile applications and live group activities. Future implementations require a common approach for communicating competency assertions across TLA components and systems.

Competency evidence will be aggregated from multiple communities inside and outside the organization. Performance indicators, organizational metrics, and other systems/databases in use across the enterprise will continually be analyzed and assessed to measure the proficiency of individuals and teams within the organization.

Many of the standards and specifications referenced in this document include rubrics for measuring performance (e.g., HPML, CASE, Open Badges, etc.). Each has its own data structure, evaluation metrics, and format, and each needs to be considered as part of the TLA assessment service. Common vocabularies/taxonomies are also required to ensure the myriad of assessments that might be used in the TLA are all speaking the right language and crediting the right learner with the right competencies.

5.1.20.1 Question & Test Interoperability (QTI)

The QTI specification[35] enables the exchange of item and test content and results data between authoring tools, item banks, test construction tools, learning platforms, assessment delivery systems, and scoring/analytics engines. The data model is described abstractly using UML to facilitate binding to a wide range of data-modeling tools and programming languages.

To support interchange between systems, the data model also supports an XML binding. The IMS QTI specification has been designed to support both interoperability and innovation through the provision of well-defined extension points. These extension points can be used to wrap specialized or proprietary data in ways that allow it to be used with other test items. QTI 2.2 is very stable and has been built on other stable, adopted versions of QTI. QTI 2.2 adoption is strong. TLA Assessment Activities could leverage the data models of QTI to gain interoperability. However, QTI was not used in 2019.

5.1.21 Identity Management

The FLE requires data exchange across different organizational boundaries and inherently different IT enclaves. The 2018 TLA Reference Implementation used Keycloak to manage individual access and permissions to all TLA components and activities. Usernames were anonymized through the creation of a Universal User ID (UUID) that each component used when communicating data about each learner.

Most tools and technologies are focused on protecting Personally Identifiable Information (PII) inside the organizational firewall; however, there are numerous use cases within the TLA where information about a learner needs to be communicated between different organizations.

[35] *https://www.imsglobal.org/question/index.html#version2.2*

This is currently achievable at a minimal level through services like ID.me[36] and Login.gov[37]. Both follow the National Institute of Standards and Technology (NIST) SP 800-63 Digital Identity Guidelines[38].

5.1. 21.1 The OpenIDConnect/OAuth

Open ID Connect (OIDC) is an open source consortium industry standard for recognizing ID through third party verification. It relies on JSON and the use of encrypted identity tokens. It allows for multiple local identities to be reconciled to a master identity. It is part of the OAuth family of standards, OAuth is associated with access to resources, enabled by that verified identity.

5.1.21.2 Privacy and Security for TLA (PS4TLA)

The PS4TLA[39] research seeks to make recommendations for implementing a Privacy-by-Design model where privacy and security strategies are an inherent component of the FLE. Areas of study include user data characteristics, output characteristics, data location and ownership, data sharing, and privacy support mechanisms. This research will result in a requirements specification for tools and technologies that manage a learner's PII and privacy preferences, while also providing individual learners with the knowledge required to enact their own privacy control across TLA activities, systems and services.

5.1.22 Miscellaneous

5.1.22.1 Learning Tools Interoperability (LTI)

The IMS Global Learning Consortium's LTI Specification[40] prescribes a way to connect learning applications and tools with platforms like LMS, portals and learning object repositories, in a secure, standard manner. LTI is comprised of a central core and optional extensions to add optional features and functions. The LTI core establishes a secure connection and confirms the tool's authenticity while the extensions add features like the exchange of assignment and grade data between an assessment tool and LMS gradebook. While LTI is tool-oriented, the underlying data model includes elements about the learner and could lend itself well to a TLA Learner Profile.

5.1.22.2 Sharable Content Object Reference Model (SCORM)

SCORM defines a specific way of constructing learning content so that it can be shared across Learning Management Systems. SCORM is a set of existing standards and specifications that control how content is developed, packaged, described, and delivered across systems. A Sharable Content Object (SCO) is the most granular piece of training in a SCORM world. The Content Aggregation Model (CAM) determines how a piece of content should be delivered in a physical sense.

At the core of SCORM packaging is a file titled the "imsmanifest.xml." This file contains every piece of information required by the LMS to import and launch content without human intervention. The SCORM run-time specifies how the content communicates with the LMS while the content is playing. There are two major components to this communication. First, the content must "find" the LMS. Once found, it can communicate through a series of "get" and "set" calls and an associated vocabulary.

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[36] *https://www.id.me/*

[37] *https://login.gov/*

[38] *https://pages.nist.gov/800-63-3/*

[39] *https://www.youtube.com/watch?v=opmiFzqfwXo*

[40] *https://www.imsglobal.org/activity/learning-tools-interoperability*

SCORM is entrenched in the traditional DL community and is still widely used for managing Online Learning. It provides an important capability for the TLA to deliver online content. The SCORM/xAPI wrapper provides additional capabilities to enable SCORM courses to report to an LRS.

5.1.22.3 IEEE Actionable Data Book (ADB)

ADB is a transformative blend of experiential analytics and rich media, delivered through interactive eBook technology. ADB was created as a reference model based solely on open standards. These include the International Digital Publishing Forum's ePub3 specification, HTML5, Bluetooth, xAPI, and W3C packaging standards for interactive content. It appears work on this specification is no longer ongoing.

5.1.22.4 ePub3

The ePub (or EPUB) specification[41] defines a distribution and interchange format for digital publications. The EPUB format provides a means of representing, packaging and encoding structured and semantically enhanced Web content — including HTML, CSS, SVG and other resources — for distribution in a single-file container. EPUB has been widely adopted as the format for digital books. With new versions, the EPUB format's capabilities can support a wider range of publication requirements, including complex layouts, rich media, interactivity, and global typography features. EPUB is expected to be used for a wide range of content, including books, magazines, and professional and scientific publications.

This specification is relevant to different types of content the TLA can support and was used as part of the Personalized eBook for Learning (PeBL). EPUB in general has seen major adoption, but the adoption of version 3.1 is inconclusive at this time. Rules are specific and will promote interoperability among tools that leverage EPUB 3.1. This specification indirectly competes with the ADB specification. However, ADB was designed with consideration of the EPUB specification.

5.1.22.5 IEEE P1589 Augmented Reality Learning Experience Models (ARLEM)

The purpose of the ARLEM specification[42] is to become an overarching integrated conceptual model that describes interactions between the physical world, the user, and digital information to establish context for Augmented Reality (AR) applications used for learning. It will define the data models, modeling languages and their bindings to chosen representation formats (e.g. XML, JSON). The specification has not yet been released as a version 1.0 specification, so a thorough review has not been possible.

A review of draft documentation found that while ARLEM attempts to formulate a standardized taxonomy around AR, it doesn't provide enough vocabulary to support Virtual Reality (VR) or Mixed Reality (MR) learning environments, and therefore requires extrapolation. As this specification matures, the ADL Initiative will continue to investigate how these learning activities can integrate with the TLA.

5.2 StdV-2 Standards Forecast

5.2.1 Objective TLA Specifications and Standards

The TLA objective system state uses a series of TLA and industry specifications and standards for message transport, component registry and learning data metamodels under the aegis of the TLA policy framework. Identifying, validating, and modifying these specs and standards is a key goal of the ongoing TLA research.

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[41] *https://www.w3.org/Submission/2017/SUBM-epub31-20170125/*

[42] *http://arlem.cct.brookes.ac.uk/*

This Standard View 2 (StdV-2) provides the latest vision of the objective system state policy framework. It will be updated as these specifications are evaluated, matured, and standardized.

5.2.2 Core Data Services

The TLA data strategy includes four major repositories within the data lake. Each repository should follow one of the core metamodels specified in the TLA:

- **Learner Profile** – stores user attributes and results and conforms to the Enterprise Learner Profile metamodel. The ULP metamodel combines portable credentials, universal identity reconciliation and traceability to local data including audits of competency evidence, learner state, and global and local learner attribute data.
- **Experience Index** – stores activities and content that comprise potential learning experiences. It conforms to the LRMI specification as amended for the TLA (LRMI+).
- **Competency Framework** – stores the jobs, credentials, and KSAO behaviors and the relationships between them that define the purpose or educational alignments of learning. It conforms to the IEEE P1484.20.1 Reusable Competency Definition (RCD) object standard.
- **Learner Record Store** – stores the xAPI statements from learning record providers and listening services within the TLA core that define the context under which learning occurred, or *learner state*, according to the TLA Master Object Model (IEEE P9274.3.1). The LRS captures paradata, which along with learning event records and learner state records are in the Javascript Object Notation (JSON) protocol defined for the xAPI (IEEE P9274).

5.2.3 TLA Policy Framework

The ADL Initiative's policy document is the DoDI 1322.26. As the TLA achieves initial operational capability, this document should shift to a DoD Directive (DoDD) that prescribes the "shall use" language for integrating xAPI (IEEE P9274) into distributed learning solutions. As the TLA adoption matures, other types of training such as those under the authority of DoDD 1322.18 (Military Training) , DoDI 1322.27 (Urban Terrain Training), DoDI 1322.24 (Medical Training) , DoDD 5000.59 (Use of Modeling and Simulation for Training) and DoDD 3200.11 (Maintenance of Access to Live Ranges for Training) may shift to align with the data standards of the ADL Initiative.

The TLA policy framework includes subordinate specifications and standards as fungible references to the DoDI 1322.26. The first standard is the xAPI described in the following sections. The second is the TLA umbrella standard defining the "business rules" for adoption, migration, development, fielding and sustainment of learning computational assets and data that comport with the TLA goals and interface specifications to fully support the TLA provided capabilities. Under the TLA standard are the TLA interface specifications and the TLA reference metamodels (see **Table 9**) that comprise the TLA ecology.

The TLA policy framework will include service specific instructions for the adoption of TLA compliant components to build enclaves, the assignment of overall roles and permissions within the ecosystem, and the definition of data model owners to provide the system governance for data metamodel configuration control and sharing of analytics templates and results.

Table 9. Summary of TLA Objective Specifications. *This table shows specifications selected for use in the TLA. The specifications are grouped and listed according to the TLA component it is aligned with. There is an expectation that TLA Components and their outputs adhere to the referenced specifications. Supporting vocabularies, rules, and software ensure this process.*

TLA Component	Standard/Specification	Transport	Data Store / Registry
Activity Registry	LRMI++ ECC Metamodel	JSON	Experience Index
	Schema.org Vocabularies		Experience Index
Activity Stream	xAPI IEEE P9274	HTTP / HTTPS with JSON payloads	Experience Index
	Master Object Model IEEE P9274.3.1	JSON	Transactional LRS
	Cmi5	JSON	Transactional LRS
Competency Management	RCD IEEE P1484.20.1	HTTP / HTTPS with JSON payloads	Competency Framework
	O*Net		
Credentials	CTDL	Credential Authoring Language	Authoritative LRS
	IMS Global Open Badge 3.0	HTTPS	Authoritative LRS
Learner Profile	Enterprise Learner Record Metamodel	HTTPS	Learner Profile
Learner Service	LTI	HTTP	Experience Index
	OpenAPI	HTTP	Experience Index
Identity Management	OpenID Connect (profile of OAuth2.0)	HTTP / HTTPS with JSON payloads	Learner Profile
	PrivacyAPI	TBD	Learner Profile
Learner Record Provider - eBooks	ePUB 3 +	JSON	Transactional LRS
Learner Record Provider - LMS	SCORM	JSON	Transactional LRS
Learner Record Provider – adaptive instruction/ITS	Adaptive Instructional Services P2247.1		Transactional LRS
Learner Record Provider – VR/AR	IEEE P1589 Augmented Reality Learning Experience Models (ARLEM)		Transactional LRS

The following sections evaluate selected standards and recommended extensions to support TLA requirements. Additional insights show how they complement or compete with related specifications.

5.2.4 Experience Index

The Experience Index includes an Activity and Resource[43]Registry and a Content Registry that store metadata about TLA learning activities and the content that can optionally be viewed or experienced within the activity.

[43] *Resources include specific devices, as well as local and non-local (e.g. WWW, "In the wild") data resources used to support learning (e.g. a YouTube video). This registry supports from within the firewall to Zero Trust Network (ZTN) security, integrity and non-repudiation.*

The approach used in the 2018 Reference Implementation relied heavily on the LRMI specification. It also had a single "activity index" which treated every document-context instance as unique. The 2019 Reference Implementation split these into two separate data stores to simplify configuration management and to accommodate for the same content being used in different instructional modalities.

A slightly modified version of LRMI, included as a DIV-3 metamodel in this architecture document, is still the transmittal format for experiences. The modified LRMI includes some new fields and modified datatypes. The enclave specific data structures for experiences includes site specific attributes to be used as part of local device management and adaptation solutions, but the modified LRMI supports transmittal to the Enterprise Course Catalog.

A subset of activities and content within a given installation will be collected into *content sets*, which are ordered hierarchies of activity-content tuples aligned to a Competency Framework, normally referenced to a credential of some type (i.e. a badge awarded for completing a course). The content set data structure supports transition from the legacy course formats (e.g., SCORM's Content Aggregation Model or Learning Object Metamodel) to the TLA specific structures. Content sets which have been made public are visible to the Enterprise Course Catalog service, which includes a single service registry pointing to all active course elements in the various experience indices across the FLE.

5.2.4.1 Learning Resource Metadata Initiative (LRMI) and Extensions

The Learning Resource Metadata Initiative (LRMI)[44] specification is a common metadata framework developed by Creative Commons and the Association of Educational Publishers for describing and tagging educational resources in web-based instruction and training.

The LRMI metadata schema was adopted by Schema.org in April 2013, which allows anyone who publishes or curates educational content to use LRMI to provide rich, education-specific metadata about their resources with the confidence that the metadata will be recognized by major search engines. The LRMI 1.1 specification is stable and has seen widespread adoption—its metadata attributes are clearly defined, and its usage rules drive interoperability.

The ADL Initiative has conducted extensive analyses of the common educational metadata standards in current use. As legacy standards cannot fully accommodate today's broad range of learning experiences, the 2019 TLA Reference Implementation employs an augmented version of LRMI as a transmittal format for exchanging data that federates to the Enterprise Course Catalog. This format includes all of LRMI 1.1 with supplemental data fields to describe learning experiences (content and activities) and content sets.

A key part of LRMI 1.1 is the *AlignmentObject* type. This object, used extensively in 202018, describes an alignment between a learning resource and a node in an educational framework. The 2019 Reference Implementation more explicitly ties these alignments to a Competency Framework metamodel based on the IEEE P1484.20.1 Reusable Competency Definition (RCD) specification, with the *job_duty_gig* and *role_persona* data elements defining a career arc. This allows the *AlignmentObject* to better serve its intended purpose in the context of the TLA.

[44] *http://lrmi.dublincore.org/*

In addition, fields were added to enable more detailed data collection and distribution, support mobile and cloud technologies, and incorporate non-traditional learning methods, including serious games, augmented/virtual reality, LVC (live, virtual, constructive) simulations, and in-person training activities such as classes, seminars, and field exercises. Looking ahead, the ADL Initiative seeks to submit a metadata strategy recommendation to the DoD and the Office of Personnel Management (OPM) for use in their joint DoD Enterprise Course Catalog and Enterprise Learning Record Repository. The ADL Initiative identified four criteria that are critical for future metadata standards:

- **Usability** – The metadata must be searchable and filterable and provide the information necessary for someone not familiar with it to understand its use. Each field must fulfill at least one of those functions.
- **Extensibility** – The standard must be able to incorporate future enhancements.
- Real-time performance – Analytics is a vital component of the future learning ecosystem. The ability to work with data in real time is becoming increasingly important to learners, educators, administrators, and developers.
- **Human and Machine Readability** – The data must simultaneously be suitable for human consumption and scalable for use with advanced machine learning techniques.

The ADL Initiative will continue to solicit feedback and recommendations from its stakeholders and other communities of interest to improve these metadata recommendations and implementation strategies.

Once the guidance is finalized, the DADLAC will consider formalizing these standards in policy—specifically, DoD Instruction 1322.26. That is, the DADLAC is expected to recommend that any new courseware developed across the DoD as well as any major refurbishments to existing courseware adhere to forthcoming content metadata guidelines.

5.2.4.2 Schema.org Vocabularies

Founded by Google, Microsoft, Yahoo and Yandex, Schema.org[45] is developed by an open community with a mission to create, maintain, and promote schemas for structured data on the internet. Each Schema.org item type has its own set of descriptive properties. The broadest item type is *Thing*, which has four properties (name, description, URL, image). More specific types share properties with broader types. For example, a *Place*, *Person*, or *CreativeWork* is a more specific type of *Thing*.

LRMI's adoption into Schema.org vocabularies has many benefits. In theory, nearly any Schema.org *Thing* could be a learning resource. Therefore, LRMI addresses those metadata properties that distinguish content when it is deliberately used for learning. This was done by adding learning resource properties to key root types (e.g., *CreativeWork*), such as *educationalUse* and *educationalAlignment*.

A more specific type of *CreativeWork* is a *Course*.[46] A *Course* is a sequence of one or more educational events and/or other types of *CreativeWork* that aims to build knowledge, competence, or ability of learners. They can be distinct instances that take place at different times or locations or are offered through different media or modes of study.

[45] *https://schema.org/*

[46] *https://schema.org/Course*

As shown in **Figure 24**, a learning activity is a Schema.org → *CreativeWork* → *Thing* that can be used to support multiple forms of alignment between a resource and an educational framework. The *AlignmentObject* type can also be used to distinguish between resources that teach and those that assess. This presents the ability to collect a substantial corpus of paradata about how different kinds of content apply to different instructional domains and enable new insights on which are more effective.

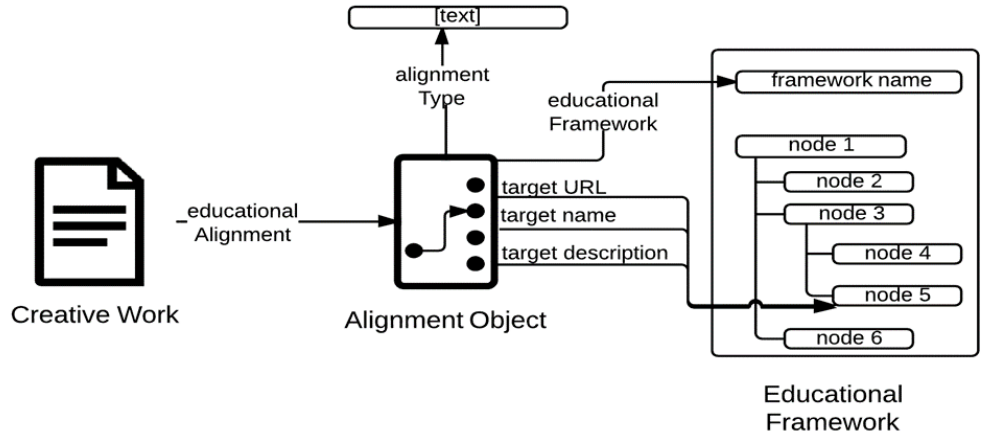

Figure 24. Alignment Between a Schema.org Creative Work and a Node in an Educational Framework[47]. *The 2018 TLA Reference Implementation used LRMI's Alignment Object to reference a Competency Framework that provided a structured description of required knowledge, skills, abilities, and their interrelated relationships.*

While Schema.org is visible to the AWS sandbox area, it is not generally accessible to protected Global Information Grid systems, particularly at higher levels of classification. The TLA enterprise will have to maintain a clone of Schema services, through an integrated DoD Schema Server.

5.2.5 Activity Streams

One learner may spend time reading technical articles or writing a blog post while another interacts with video content and interactive exercises. An Activity Stream is a list of events generated by individuals, groups, applications, or learning activities that provide details about the ongoing experiences to other TLA components.

The types and variety of activities that are used for learning can often be associated with a specific delivery modality. Instructor-led classroom training will create one set of instructional activities, while serious games and simulations have the potential of generating a completely different set of activities. This has potential to have two similarly named activities with two different contexts for how those activities are being applied and the experiences they encompass. A common vocabulary is necessary to ensure all learning activities across different communities accurately describe the experience. By formalizing this vocabulary, a set of attributes and rules about the data is established such as how they are stored, retrieved and accessed by other components, systems or activities.

The different activity stream specifications investigated for inclusion in the TLA are similarly structured. Each specification includes serialized data streams that consist of statements about activities. Such statements typically involve a subject (the person doing the activity), a verb (what the person is doing), and a direct object (what the activity is being done to or with). The subject of an activity is nearly always the learner but could foreseeably be an instructor, cohort, or other.

[47] *https://blogs.pjjk.net/phil/explaining-the-lrmi-alignment-object/*

The direct object of an activity is presented differently depending on its context. Verbs need to conform to a common vocabulary. Otherwise different organizations will use different verbs to describe the same activity or the same verb to describe different activities.

5.2.5.1 Experience API (xAPI) IEEE P9274

The xAPI[48] specification is in the process of becoming a standard through the Institute of Electrical and Electronics Engineers – Learning Technology Standards Committee (IEEE-LTSC)[49]. The xAPI specifies a structure to describe learning experiences and defines how these descriptions can be exchanged electronically. The main components of xAPI are the data structure called Statements and the data storage/retrieval capability, or LRS. The xAPI specification has stringent requirements on the structure of these data and the capabilities of the LRS. The transport is HTTP/HTTPS with JSON payloads.

Statements are data triples that use an Actor, a Verb, and an Object to describe any experience. This core syntax can be augmented with extensions, defined in the xAPI profile. Each statement also includes timestamps. Actors and Objects use locally unique, resolvable identifiers. The xAPI Profile Specification[50] IEEE P9274.2.1 offers a common way to express controlled vocabularies across these different mediums, provides instructions on the formation of xAPI statements, and describes patterns of xAPI usage that provides additional context to a domain, device, or system. The xAPI Profile Specification also adds tools to support authoring, management, discovery and/or adoption, including additional data elements and properties.

An LRS is the implementation of the server-side requirements associated with the xAPI specification. The LRS is a key component of the xAPI architecture. It is the application interface for storing, accessing, and often visualizing the data about learning experiences, activities, and performance. The LRS is essentially a Web-service that leverages a REST API for the storage and retrieval of xAPI data.

A learner's xAPI data and transcripts stored within one LRS can be extracted and sent to other LRSs, enabling learning experiences to follow them from one organization to another. An LRS could be optionally integrated with any application such as an LMS, Human Resources system, or it could serve as centralized data store in an enterprise learning ecosystem. Third party applications which send or retrieve learning activity data will interact with the LRS as the data store for xAPI data. From this perspective, an LRS is also required to validate the format of the statements as many of the requirements in the xAPI specification are targeted toward the LRS component.

5.2.5.2 Master Object Model (MOM) IEEE P9274.3.1

The TLA MOM is an xAPI profile that defines an object life cycle for the learner. This approach facilitates better composability for TLA compliant enclaves and federations, because there is no technical "state manager" required, rather services respond to messages, irrespective of source, that correspond to a learning life cycle that encompasses both deliberate (scheduled) and informal (ad hoc) learning.

[48] *https://github.com/adlnet/xAPI-Spec*

[49] *https://www.tagxapi.org/*

[50] *https://github.com/adlnet/xapi-profiles*

The MOM also helps to contextualize the conditions under which the learning events occurred, the degree of trust in the evidence generated, and the context along the learning continuum from pedagogy to self-regulated learning in which the learning event occurred. These help in customizing the learning environment to the learner and allow for “edge systems” in the form of advanced learning devices (e.g. intelligent tutors or adaptive/self-regulated learning devices) to advance the federation learner state in the same way as a self-reporting event.

5.2.5.3 cmi5

The cmi5[51] is an xAPI-based specification that replicates many of the features and capabilities associated with SCORM. cmi5 provides definitions of certain xAPI statements, a launch process, a course structure, and runtime communications between an LMS and learning content. cmi5 allows the setup of several “global” variables including Actor, xAPI Endpoint and Security Token, and the automated communication of some xAPI statements. The Launch portion of cmi5 allows developers to avoid “hard coding” the LRS information into the LMS. cmi5 could be expanded to support a secure, single sign-on experience by decoupling the data models and behaviors from the implementation details. Implementation details could be defined as part of the cmi5 launch profile which allows it to be used for web and native applications. There are known security concerns over the JavaScript credentials and the code is not portable without modification.

To facilitate reuse and migration of legacy SCORM content, cmi5 defines a packaging method and a communication protocol consistent with xAPI. The Course Structure File within cmi5 is an XML file that contains each of the launchable Assignable Units (AU). Together, these replicate the features of SCORM’s CAM. SCORM requires all-inclusive and self-contained content and references, but in contrast, cmi5 allows the Course Structure File to reference external content.

The cmi5 object life cycle approximates the SCORM Run Time Environment (RTE - the SCORM implementation of IEEE 1484.11) by specifying verbs within the cmi5 profile. The cmi5 course structure format extends the SCORM life cycle by allowing "MoveOn" criteria to be met, which can effectively "waive" certain AUs such that the LMS would skip over them in delivery to the learner. Objectives can also be tagged to any AU or Blocks. The cmi5 xAPI Profile is stable and expects to fold into the xAPI standardization efforts of the IEEE as is.

5.2.6 Competency Management

Competency management requires the generation of rich and traceable data about learning experiences, how they relate to skill proficiency, and the knowledge, skills, abilities, and behaviors that individuals need to do their job. Competencies describe specifically what people need to do to be effective in their roles, and it clearly establishes how their roles relate to organizational goals and success. Each individual role has its own set of competencies needed to perform the job effectively.

Competency Based Learning represents a transition from curricula focused on abstract knowledge and pursuit of certificates to curricula built around authoritative performance indicators that guide learning experiences based on challenges in the workplace that unlock human potential. Proficiency is a complex and critical concept that requires relevant, trusted data that can be used as evidence about an individual’s mastery against a specific set of competencies.

[51] *https://github.com/AICC/CMI-5_Spec_Current/blob/quartz/cmi5_spec.md#content_launch*

A Competency Framework is a structure for defining the knowledge, skills, abilities and attitudes (or other characteristics) required to do a job. Competency Frameworks are widely used in business for defining and assessing competencies in both hard and soft skills that jointly define successful job performance. There are numerous Competency Frameworks available and numerous specifications that drive them.

*5.2.6.1 O*Net*

The Occupational Information Network (O*NET)[52] is sponsored by the U.S. Department of Labor, Employment and Training Administration (USDOL/ETA) to facilitate and maintain a skilled workforce. Central to the project is the O*NET database, which contains hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy. Every occupation requires a different mix of knowledge, skills, and abilities, and is performed using a variety of activities and tasks. As shown in **Figure 24,** the O*NET database identifies, defines, describes, and classifies occupations through Experience Requirements (Training, Licensing), Worker Requirements (Basic and Cross-Functional Skills), Occupation Requirements (Work Activities, Context), Worker Characteristics, Occupation Specific Information, and Occupational Characteristics.

The value of the O*NET database to the TLA is in leveraging the existing resources these government sponsored activities have already amassed. Their Military Transition search connects occupations in the O*NET database to other classifications systems within the military[53]. This is accomplished through data from the Military Occupational Classification (MOC) system at the Defense Manpower Data Center (DMDC). This capability is also available via web services. Other resources include *"Careers in the Military"* and links to Army, Navy, Marine Corps, and Air Force COOL projects.

5.2.6.2 IEEE P1484.20.1 Reusable Competency Definitions (RCD) Working Group (WG) 20

The current RCD standard[54] defines a data model for describing, referencing, and sharing competency definitions. The standard provides a way to formally represent key characteristics of a competency, independent of its use in any specific context. It enables interoperability among learning systems dealing with competency information by allowing them to refer to common definitions with common meanings.

This specification enables the storage of a Competency Framework in the form of a Directed Acyclic Graph (DAG) where competency objects define the knowledge, skills, conditions and other factors that role up into an ability to do a job. The edges between each competency object inform the relationship between them and have the potential to identify whether they're dependent, complimentary, conflicting, or other. This provides an extensible mathematical underpinning that accommodates the relationships defined in any other foreseeable Competency Framework.

The Data Model for RCD WG 20[55] was put together in 2018 to revise the 2008 standard. The WG 20 will take the Credential Ecosystem Mapping Project's mapping of competencies metadata and update RCDs to represent the most common elements that are found in multiple standards addressing competencies and Competency Frameworks. The ADL Initiative will monitor this working group's progress.

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[52] *https://www.onetonline.org/*

[53] *https://www.onetcenter.org/crosswalks.html*

[54] *https://ieeexplore.ieee.org/document/4445693*

[55] *http://sites.ieee.org/sagroups-1484-20-1/*

5.2.7 Credentials

A credential is a testament of qualification and competence issued to an individual by an authoritative third party. Examples of credentials include academic diplomas, degrees, certifications, professional licenses, or other proof of occupational qualification. Within the TLA, credentials are an exchange format by a trusted party that formally encapsulate a set of Competencies. By their nature, they are linked to other TLA components such as Competency Frameworks, assessment rubrics, or Talent Management Systems. This requires the establishment of attributes and rules that allow TLA Components to process and compare credentials in the same, interoperable way, particularly in Learner Profiles across instantiations of the TLA. This also requires a common way to describe, store, and access credentials in order to make fair comparisons of the achievement that was performed to acquire them.

5.2.7.1 Credential Transparency Description Language (CTDL)

CTDL[56] is a vocabulary comprised of terms that are useful in making assertions about a Credential and its relationships to other entities. CTDL is modeled as a directed graph using RDF for describing data on the web. Like an activity stream, the "triple" is the basic grammatical construct in making CTDL assertions about "things" and is comprised of three simple components: a subject, a predicate and an object. This structure allows us to make simple statements that enable a rich description of credential-related resources including credentialing organizations and specific subclasses of credentials such as Degrees, Certificates, and Digital Badges. Two super classes called Agent and Credential define families or sets of subclasses used throughout the CTDL. The primary classes also include the Condition Profile used to define sets of constraints on the credential described by an Assessment Profile, Learning Opportunity Profile, or Competency Framework. These are used to express learning goals and outcomes.

5.2.7.2 Credential Registry

The Credential Registry[57] is both a repository of information regarding credentials and a set of services that make it easier to use that information. The Credential Registry works with CTDL to allow the storage of credentials that have been expressed using that specification.

It also registers credentialing organizations that issue these credentials including universities, colleges, schools, professional associations, certification organizations, and more. Since it is only a registry, it only stores the description of a credential in the abstract sense and does not include any personal information or personally obtained credentials. This information will typically be stored in a Learner Profile. As a registry, it does allow users to see what various credentials represent in terms of competencies, transfer value, assessment rigor, 3rd party approval status and more.

The Credential Engine project's developers are using DCAP process to create systems that communicate all virtually all aspects of credentials. The Technical Advisory Committee promotes collaboration across different standardization initiatives that are developing data models, vocabularies, and schemas for credentials and Competency Frameworks. The Credential Registry uses technology and CTDL to capture, link, update, and share information about credentials so it can be organized and centralized in the Registry, made searchable by customized applications and linked-to from anywhere on the open Web.

[56] *http://credreg.net/ctdl/handbook*

[57] *https://www.credentialengine.org/credentialregistry*

5.2.7.3 Open Badges

Open Badges[58] are visual representations of verifiable achievements earned by recipients. Open Badges is a technical specification and set of associated open source software designed to enable the creation of verifiable credentials across a broad spectrum of learning experiences. The Open Badges standard describes a method for packaging information about accomplishments, embedding it into portable image files as digital badges, and establishing resources for its validation and verification. Open Badges contain detailed metadata about achievements such as who earned a badge, who issued it, and what it means. The Open Badges 2.0 specification expands on this capability to include versioning, endorsements, and full use of JSON-LD.

Open Badges are expressed as linked data so that badge resources can be connected and reference by other systems. This metadata can also be embedded within the graphic. The Open Badges vocabulary defines several data classes used to express achievements. There are three core data classes (Assertions, Badge Classes, and Profiles) that define mandatory and optional properties as well as the restrictions on the values those properties may take. Each Badge Object may have additional properties in the form of an Open Badges Extension, a structure that follows a standard format so users can understand the information added to badges. Assertions are representations of an awarded badge, used to share information about a badge belonging to an earner.

5.2.8 Learner Profile

There are challenges in creating a lifelong learning profile. What elements of the Learner Profile should the learner be in control of? How does learner information pass from one organization to another? What Authoritative Systems have permissions to write to the learner's profile? How do we represent learner context? Within the context of the future learning ecosystem, it is envisioned that a Learner Profile will house data about people across their entire career. Adult learners have distinctive personal attributes, knowledge, skills, and competencies gained in different contexts through a process of development and growth. A Learner Profile may also include demographic data, student interests, learning preferences, descriptions of preferred learning environments, personal skills, existing competencies and those that need to be developed, socio-emotional health, and myriad other data. As student interests change and they become competent in new areas, the profile will update to reflect the latest "state" of the learner.

5.2.8.1 Enterprise Learner Record Repository (ELRR)

The ELRR is a topic of interest across industry, academia, and military domains. The T3 Innovation Network is working closely with standards organizations to complete a standard mapping within a comprehensive learner, worker, military record (LWMR). Specific standards initiatives that they are working with include: CEDS, Credential Engine (CTDL/ASN), HR Open Standards, IMS Global (OpenBadge3.0/CASE), PESC, and IEEE. Their current efforts have produced four use-cases that cover: 1) Signal, Search and Discover; 2) Apply, Screen and Verify, 3) Manage Participation, Completion and Transition, and 4) Conduct Performance Analytics. ELRR efforts are also supported by the IEEE Integrated Learner Record (ILR) standard initiative. Short-term goals include developing ELRR-centered use cases and conducting a requirements analysis to determine necessary ELRR components.

[58] *https://www.imsglobal.org/activity/digital-credentials-and-badges*

5.2.9 Launch Service

The ability to "launch" learning resources across devices, platforms, operating systems, and browsers is a fundamental requirement of the future learning ecosystem. A TLA Launch service will ultimately be designed as a plugin-based protocol that can launch activities according to different launch standards that are applicable to different systems, platforms, or learning modalities.

5.2.9.1 Learning Tools Interoperability (LTI)

The IMS Global Learning Consortium's LTI specification[59] prescribes a way to connect learning applications and tools with platforms like LMSs, portals and learning object repositories, in a secure and standard manner. LTI is comprised of a central core and optional extensions to add optional features and functions.

The LTI core establishes a secure connection and confirms the tool's authenticity while the extensions add features like the exchange of assignment and grade data between an assessment tool and LMS gradebook. While LTI is tool-oriented, the underlying data model includes elements about the learner and could lend itself well to a TLA Learner Profile.

The xAPI launch specification[60] is a method of launching xAPI-enabled content that works with online learning modules, static HTML files, offline content, or immersive serious games and simulations. It does not require the identity of the learner, the LRS endpoint, or the *"Session"* information for how the events should be grouped. These are coordinated during the device and activity registration process. Implementation requires a minimal HTTP request and handles the creation and transmittal of xAPI data to the LRS on behalf of the activity. While this specification is mature, it has not yet been widely adopted.

5.2.9.2 OpenAPI and REST

The TLA standard specifies the use of OpenAPI and REST for service-to-service communications. Database operations using SQL, ODBC and similar connection protocols should be implemented within the corresponding core service. The TLA specifies a REST interface for all data insert and request operations, through these standardized services. Using REST allows the programs to communicate with human readable formatted text using only HTTP requests. Hypertext is the standard way to communicate over the world wide web. The OpenAPI project is an industry consortium that proposed a simplified, common way to describe the structure and endpoint specifications of APIs.

For scalability, TLA recommends use of a publish/subscribe (pub/sub) messaging service. Common pub/sub services today include the use of streaming services like Kafka or Azure. Specification of a given service provider is not part of the TLA framework. The use of a streaming service for the TLA requires a listener to sit on the LRS that receives the given HTTP requests and forward the statements to the LRS instead of making a direct connection. This prevents having to develop polling messaging services, as the TLA specifies the use of stateless services to allow a fully composable ecosystem to evolve.

[59] *https://www.imsglobal.org/activity/learning-tools-interoperability*

[60] *https://github.com/adlnet/xapi-launch*

5.2.10 Identity Management

The future learning ecosystem requires data exchange across different organizational boundaries and different IT enclaves. The 2018 Reference Implementation used Keycloak to manage individual access and permissions for all TLA components. Usernames were anonymized through the creation of a UUID that each component used when communicating data about each learner. Most tools and technologies are focused on protecting PII inside the organizational firewall; however, there are numerous use cases within the TLA where information about a learner's needs to be communicated between organizations.

This is currently achievable at a minimal level through services like ID.me[61] and Login.gov[62]. ID.me provides identify management, authentication and group affiliation verification for numerous government and business customers. Login.gov allows users to log into multiple government agencies with a single user account. The approaches used to manage these capabilities could be relevant to the TLA. Both platforms follow the NIST SP 800-63 Digital Identity Guidelines[63].

5.2.10.1 Privacy and Security for TLA (PS4TLA)

The PS4TLA[64] research seeks to make recommendations for implementing a *Privacy by Design* model where privacy and security strategies are an inherent component of future learning. Areas of study include user data characteristics, output characteristics, data location and ownership, data sharing, and privacy support mechanisms. This research will result in a requirements specification for tools and technologies that manage a learner's PII and privacy preferences, while also providing individual learners with the knowledge required to enact their own privacy control across TLA activities, systems and services.

6.0 PROJECT VIEWS (PV)

6.1 PV-1 Project Portfolio Relationships

The PV-1, as depicted in **Figure 25**, shows the various research portfolio items in the TLA effort and the stakeholders/end users they support.

6.2 PV-2 Project to Capability Relationships

The PV-3 shows the overall TLA lines of effort. As shown in **Figure 26**, the projects in the PV-1 contribute to these lines (each of which is tied to an element of the TLA policy framework) as defining specification requirements, reducing uncertainty for project requirements, or transitioning to a program-of-record that can provide the capability.

[61] *https://www.id.me/*

[62] *https://login.gov/*

[63] *https://pages.nist.gov/800-63-3/*

[64] *https://www.youtube.com/watch?v=opmiFzqfwXo*

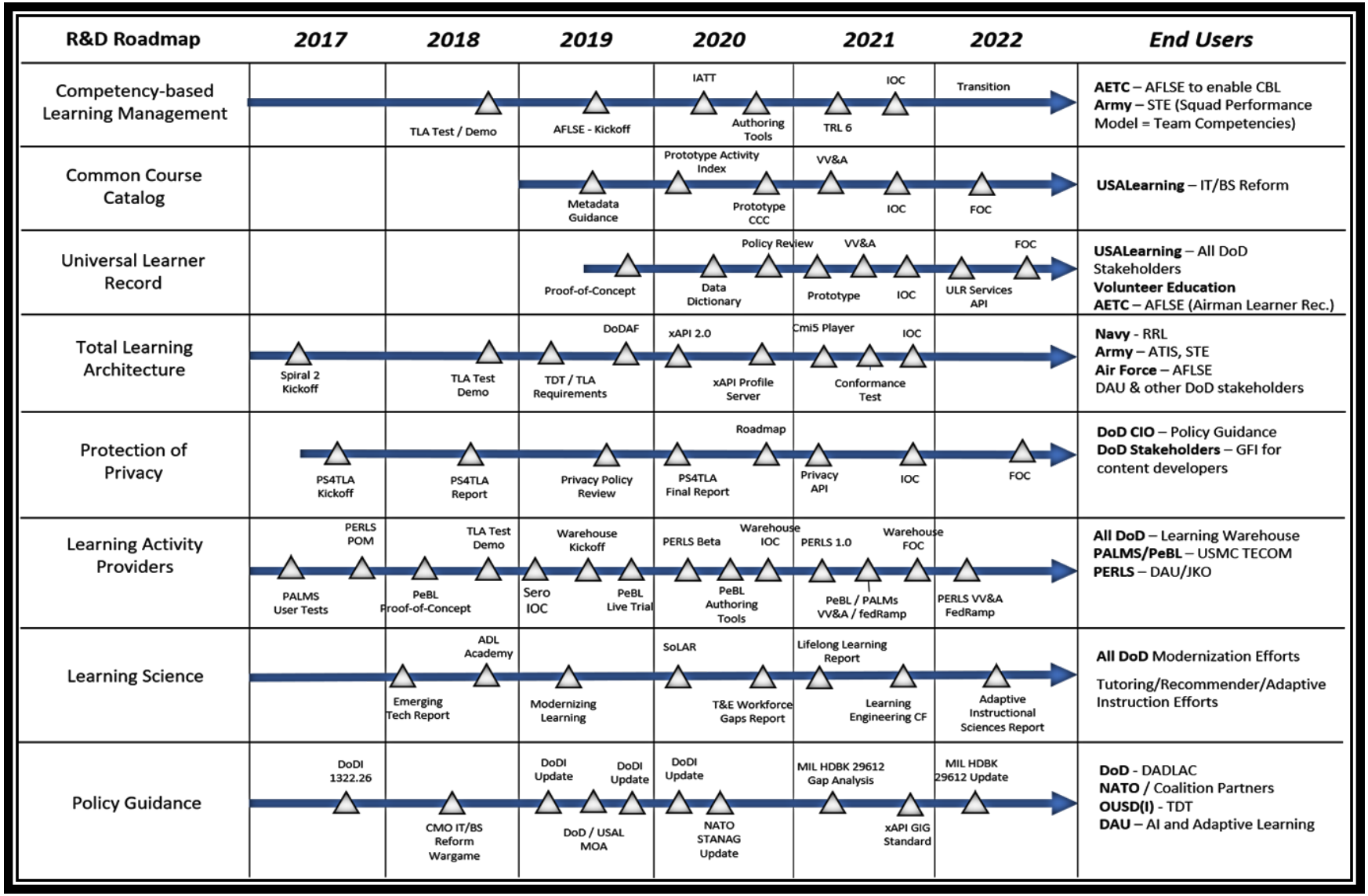

Figure 25. PV-1 Project Portfolio Relationships.

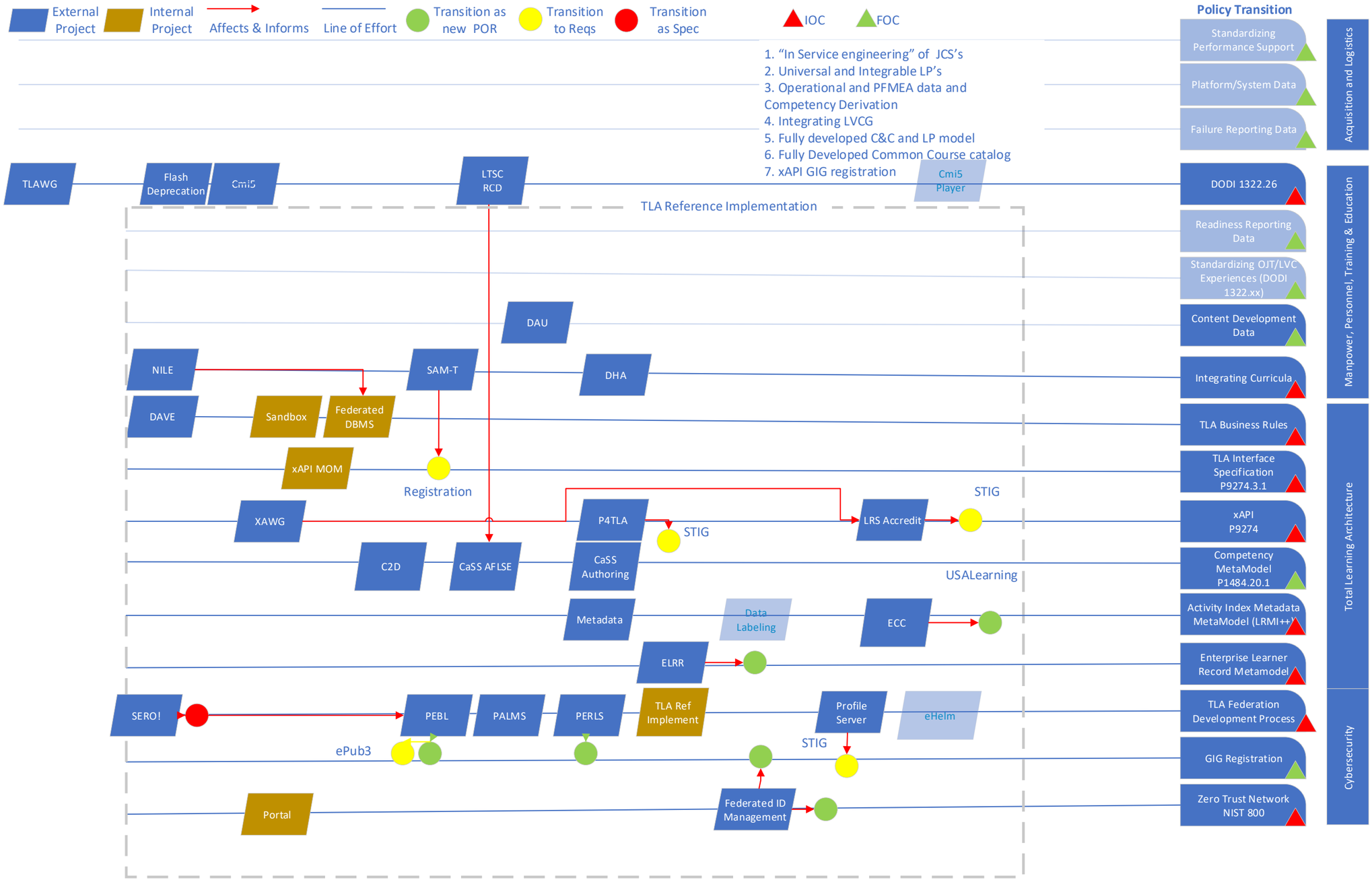

Figure 26. PV-3 Project to Capability.

TOTAL LEARNING ARCHITECTURE

2019 Report - Appendix D - TLA Systems and Subsystems Design Document

Prepared by
The ADL Initiative

Table of Contents

1.0 2019 TLA Reference Implementation

This document describes the logical, physical, and operational implementation of the 2019 Total Learning Architecture (TLA) demonstration. It introduces the interface definitions that form the core of the objective TLA policy framework upon which future implementations will be built, as well as full descriptions of the commercial items used for the current TLA Reference Implementation.

The 2018 Reference Implementation used point-to-point communication links for data sharing. A goal for 2019 was to replace the point-to-point with a scalable publish/subscribe (Pub/Sub) messaging service based on Apache Kafka. Beyond the migration to a Kafka-based data streaming architecture, the 2019 Reference Implementation work developed the software necessary to test, monitor, and evaluate critical TLA services, data formats and standards, with an eye toward performance at-scale in a heterogenous environment (i.e. the ”future learning ecosystem”).

The computational hosting environment is provided by USALearning enabling a 24/7 continuous environment for validating TLA concepts in operationally relevant environments. While the 2019 work was conducted on the development cluster, the Reference Implementation configuration-management pipeline supports a three tiered deployment strategy with a development cluster, a test and evaluation cluster, and a production cluster to ensure software is efficiently tested before migrating to the live TLA Reference Implementation.

This appendix includes the major sections of a system/subsystem design description (SSDD) – Data Item Description DI-IPSC-81431. It is tailored to provide the additional guidance required to reconstitute the Reference Implementation given access to a GitHub repository of component containers.

1.1 Logical Architecture

Figure 1 is adapted from the Common Education Data Standards (CEDS)[1] data model for understanding the relationship between learning data and the processes used to create or manipulate those data. This model recognizes that each act of learning places a *learner*, in an organizational *context*, exposed to a learning *resource*. The intersection of all three represents a learning event.

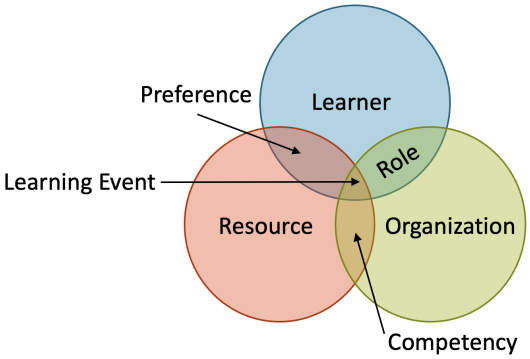

Figure 1. The Learning Event. *The Learning Event is the intersection of Learner, Organization, and Learning Resources.*

The basic processes of student registration, student tracking, content presentation, performance tracking, etc. currently provided by a Learning Management System (LMS) must be present in any learning environment. But the idea of an LMS as a *specific product* creates a vendor lock for all functions within that product, or suite of products, often developed by the same vendor. It also limits the workflow options to those supported by the LMS User Experience, which is derived from the “factory model” of learning and the “Shannon/Weaver model” of learning transfer inherent in traditional models of content delivery.

[1] *https://ceds.ed.gov/Default.aspx*

The value of the TLA is facilitated by decoupling LMS functions from different learning activities, and the ability to segregate the management of student and instructor experiences within learning environments from the actual act of providing learning.

The factory model of learning starts with an isotropic curriculum and pushes as many students through as possible. The Shannon/Weaver model of communication theory posits a transmitter (teacher) and a passive receiver (student) of a message (instruction) using assessments to verify receipt. The TLA concept of operations (CONOPS) replaces the "factory model" with a learner-centric integrated supply chain model. From the domain of integrated business to business (B2B) enterprise resource management systems, the TLA now adopts a core/edge paradigm. The edge systems are the devices used to provide learning, which may include traditional LMS, as well as handheld devices, intelligent tutors, electronic publications, simulators, and any other evolving learning technologies.

The core systems include the data and services required to conduct ledgering of the data types that pertain to planning and controlling individual learning events. These events represent the intersection of learners, resources, and organizations. Core services manage the learner bookkeeping functions, while back-end core services manage the virtual network bookkeeping functions necessary to operate in a distributed, cloud-based environment. Ancillary functions, like an access portal, data visualization tools, adaptive algorithms, and any attached learning device, are edge systems that communicate to core. Within the 2019 Implementation, learning *content* – and the *activities* that host it – are considered edge systems.

The key enabling technology of this CONOPS is the Experience Application Program Interface (xAPI). The use of xAPI decouples learning content delivery from the planning and tracking mechanisms. The xAPI specification uses a client-server paradigm of Learning Record Providers (LRP) that generate xAPI statements and Learning Record Consumers (LRC) that use them. Learning Activities are always acting as Learning Record Providers.

Static content viewers, a version of Moodle using the USALearning xAPI adapter, eventually PeRLS[2], and various other learning activities generate xAPI statements capturing learning events. The xAPI statements are normalized to "actionable information" that propagates through the core services to provide evidence of learner competence and are eventually archived to the Learning Record Store (LRS).

The Learning Activities conform to the TLA data contracts (specifically xAPI and the TLA Master Object Model (MOM), used to normalize data) within the learning ecosystem by acting as boundaries between the learner and the core services. The composable arrangement of web-based services, data, and devices operating with strongly typed data contracts provides these planning and tracking functions.

The term "data contract" comes from "Service Oriented Architecture" (SOA) software development and represents the requirements of digital (application, session, and transport layer) and semantic (presentation layer) interoperability between components, deployed as a "contract" for exchange. In the 2019 architecture, core service components can be both LRP and LRC, which has some interesting impacts on the TLA messaging architecture, explored further in the TLA report. This notional configuration of xAPI flow is shown in **Figure 2**.

[2] *https://adlnet.gov/projects/perls/*

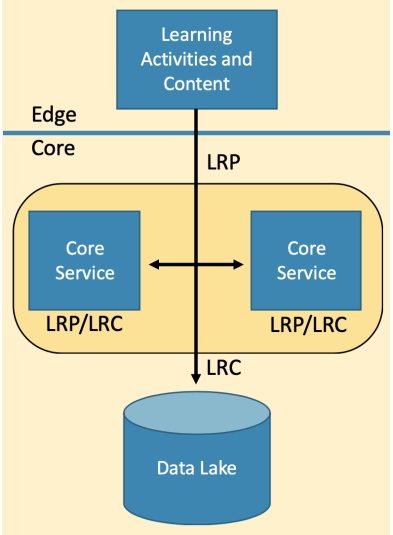

Figure 2. Notional Arrangement of Learning Record Providers and Consumers in the TLA.

The 2019 architecture uses a distributed Pub/Sub type messaging topology that can similarly scale to many concurrent users. The specific Pub/Sub technology chosen was Apache Kafka, although there are similar commercial capabilities available and the TLA policy framework is independent of any specific platform. This change allowed the test and evaluation of "learning at scale," a key objective for 2019. It also facilitated the removal of the singleton state manager of the 2018 Reference Implementation, another key objective for 2019. Many of the primary components used to support the 2018 Reference Implementation were refactored in favor of event-based microservices, with the events representing potential learner states (i.e., the TLA MOM, described later in section 1.5.3.3).

Since multiple learners can access the system simultaneously, and may be at different states, the entire enclave can manage as many "learner threads" as the individual microservices can handle collectively, rather than the number of threads a single-state manager can handle individually.

The performance of these microservices can be extended horizontally by cloning the processes on multiple server instances using cloud-based technology like Hadoop and dynamic load balancing. This was a lesson learned from our work with the *Navigator for Integrated Learning Experience* (NILE) platform, described later in this report.

In summary, the 2019 TLA Logical Architecture reduces complexity by decoupling the features required of any "learning system" into separate core services, core data, back-end services, and edge systems. This architectural paradigm provides several benefits:

- Removes vendor lock for the various components of the overall solution;
- Supports significant horizontal scalability of services;
- Preserves a non-repudiable audit trail of performance evidence in context, while maintaining performance at scale, by careful federation of data and services;
- Allows for a variety of learning modalities beyond web-based e-learning, including mobile devices, intelligent tutors, simulators, operational systems, and legacy LMS solutions;
- Is resilient to future changes in the types of learning technology and the data and metadata required to support that technology and its educational alignment, by careful partitioning of learning data into areas of concern: and
- Accommodates newer models and theories of learning beyond the factory model for how learners and mentors arrange and adapt their own learning environments.

The core service features are separated into service groups associated with the data structures they support. The four data structures in the data lake represent aspects of the learner and their possible learning paths. They are informed by the TLA data strategy outlined in the 2019 TLA report. Moreover, they represent the DoD operationalization of the elements on the CEDS model in **Figure 1**: the characteristics and accomplishments of the learner (Learner Profile), the organization and its defined required competencies (Competency Framework), the instructional and assessment candidate learning *experiences* as resources composed of *activities*, *content,* and their intersection with *competency* (Experience Index) , and the artifacts recording the conduct of learning events (Learning Record Store).

The 2019 refactoring of the TLA Reference Implementation resulted in the microservice based architecture shown in **Figure 3**. The services layer acts as the bridge between learning devices, other TLA components, and shared data stores. Each service exposes the stored data to an application so that information can be transformed into other meaningful data used by other Reference Implementation components. Each service group includes control logic and user interfaces for a set of functions. The data contracts between data and service layers are shown based on the nature of the data exchanged. The behavior and functionality of each service is defined and aligned with TLA business functions. Input-output data flows are identified and aligned with the required TLA data stores. Data models and protocols are defined around candidate TLA standards and specifications. The Service Layer includes:

- Core Services
  - *Competency Management* – tracks overall competency state for selected goals and makes assertions based on evidence provided via xAPI. An instance of the Competency and Skills System (CaSS)[3] hosted the competency framework definitions for the 2019 implementation.
  - *Learning Event Management* – replaced the recommender system used as part of the 2018 Reference Implementation. The 2019 Implementation plans, schedules, tracks, and relays learner experience data through an internally developed set of independent microservices, and tracks learner state through the MOM instead of controlling the implementation state.
  - *Activity Registry and Resource Management* – manages learning experience registration. In the 2019 Reference Implementation, this is managed by an *activity and resource registry* service which manages the Experience Indices, containing metadata for all content in the 2019 content database.
- Back-end Services
  - *Network Resource Management* – discovers TLA services and verifies that a learning resource is available. For the 2019 Reference Implementation, the system handled endpoint assignments through repository-wide environment definitions, Docker[4], and a globally known registry service that allowed services to both retrieve locations of services and register their own endpoints.
  - *Identity Management* – handles protection of PII, login credentials, and identification. In the 2019 Reference Implementation this was done primarily by Keycloak[5], an open-source identity and access management solution. The 2019 Implementation also includes two ID-related additional services: an xAPI adapter to relay session events, and an authorization endpoint for the prototype TLA alias resolution system.
- Edge Systems
  - *Portal* – displays basic data and provides a redirect service for the otherwise protected-access user interfaces native to each of the services listed above.
  - *Decision Management* – is based on the Data Analytics and Visualization Environment (DAVE) project currently being developed under the ADL Initiative.
  - *Learning Devices* – are any activities and content that provide learning opportunities and generate xAPI statements. For 2019 this includes the Moodle LMS, the Personal eBooks for Learning (PEBL), the Pervasive Learning System (PERLS), and the NILE project.

[3] *https://cassproject.org/*

[4] *https://www.docker.com/resources/what-container*

[5] *https://www.keycloak.org/index.html*

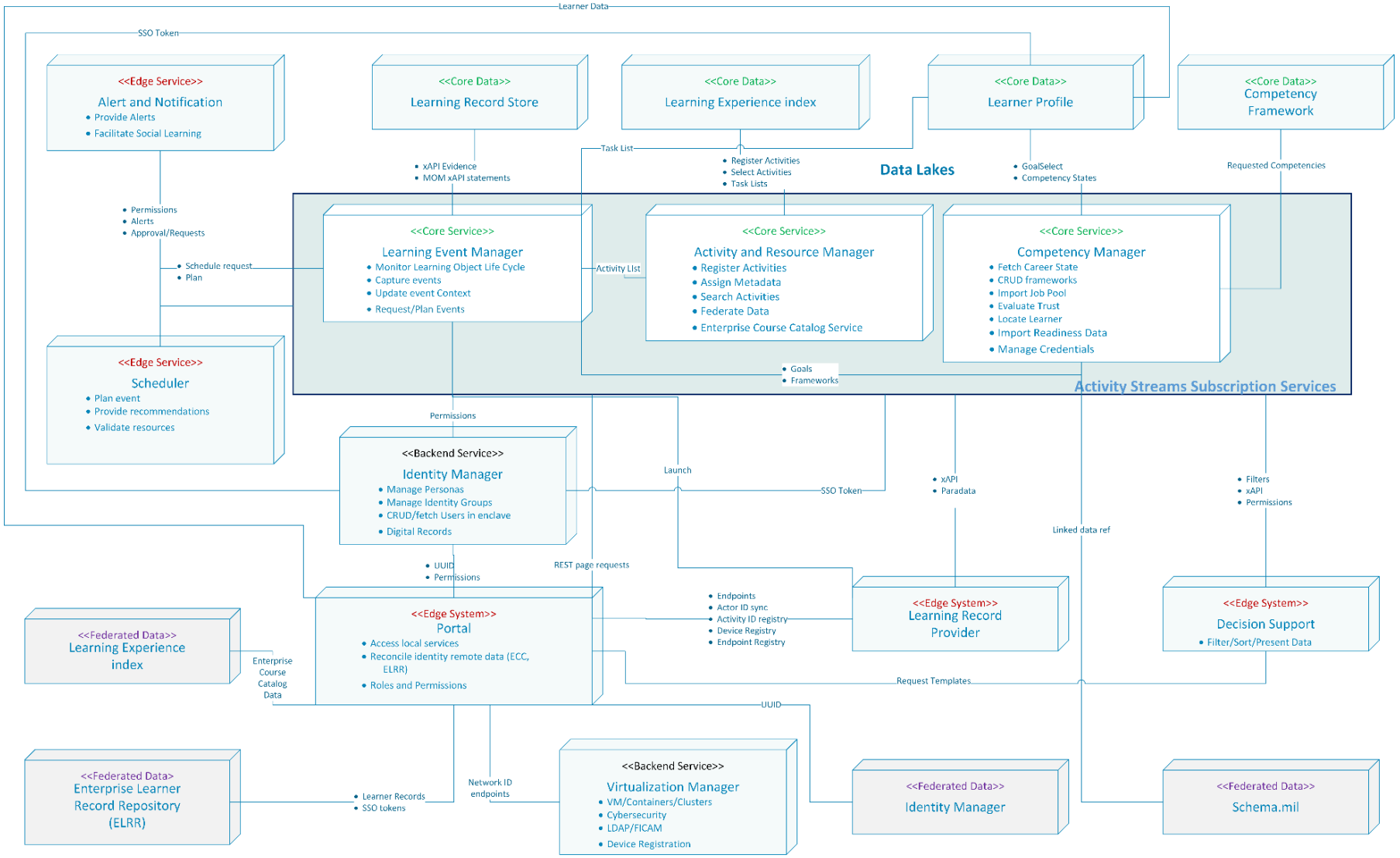

Figure 3. Logical TLA Services Architecture. *The TLA defines an architectural pattern of multiple services, microservices, and interfaces. Different TLA-compliant instances, such as the ADL Initiative's Reference Implementation, may have arrangements of components that don't exactly match their logical counterparts, depending on the vendors chosen. Communication and coordination between services is vital for a successful realization of the architecture but is not defined or constrained as part of the TLA policy framework.*

1.2 Hardware Architecture

The 2019 TLA Reference Implementation uses eight virtual machines, listed in **Table 1**, hosted on Amazon Web Services (AWS). AWS provides the back-end platform hosting, virtualization, and Domain Name Service (DNS) resolution functions. Each machine was procured under contract to USALearning and maintained by the ADL Initiative. The server instances communicate between themselves using either HTTP/S over TCP/IP or by producing and consuming messages to the centralized Kafka cluster, internally to the AWS campus. External clients accessing the portal, the hosted content, or the service redirects may be located outside the AWS campus and connect via REST. The application ports and protocols used to access each service are listed in **Table 2.**

Table 1. TLA Reference Implementation Server Provisions. *Computing and storage presets for each machine used during the 2019 Implementation.*

2019 TLA Sandbox					
Primary Component	**EC2 Type**	**Operating System**	**Volumes**	**Volume Type**	**Storage**
CaSS	T3.XLARGE	UBUNTU 18.04	1	SSD (gp2)	20 GB
MOODLE	T3.XLARGE	UBUNTU 16.04	1	SSD (gp2)	8 GB
MOODLE DB	DB.M4.XLARGE	UBUNTU 16.04	1	SSD (gp2)	250 GB
CONTENT	T3.MEDIUM	UBUNTU 16.04	1	SSD (gp2)	50 GB
LRS	T3.XLARGE	UBUNTU 16.04	1	SSD (gp2)	50 GB
AUTH	T3.LARGE	UBUNTU 16.04	1	SSD (gp2)	8 GB
KAFKA	M4.LARGE	UBUNTU 16.04	1	SSD (gp2)	50 GB
ACTIVITY REGISTRY	T2.MEDIUM	UBUNTU 16.04	1	SSD (gp2)	100 GB

Table 2. Service, Container, and Port Details. *Service, port usage, and container layouts of each machine.*

Auth Server	**https://tla-dev-auth.usalearning.net**				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
Keycloak	Keycloak	8080	proxied	auth	Learning Experience Index core service and UI
Postgres	Postgres	5432			Keycloak's database
Service Registry	Service Registry	8085	proxied	registry	Allows admin and self-registration of service endpoints
Nginx	Nginx	80/443	80/443		Reverse proxy handling ports / SSL
Certbot	Certbot				SSL certificate management and automation

Content Server	**https://tla-dev-content.usalearning.net**				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
NodeJS Static Server	Video Player	3000	proxied	video	Simple xAPI-enabled video player
NodeJS Static Server	PDF Viewer	3000	proxied	pdf	Simple xAPI-enabled PDF viewer
Apache Static	Apache	80	proxied	content	Serves larger static content files
PALMs	PALMs	80	proxied	palms	ADL's PALMs service
MySQL	MySQL	3306			MySQL DB for PALMs
PALMs xAPI	PALMs xAPI				DB Monitor sending xAPI about PALMs
Nginx	Nginx	80/443	80/443		Reverse proxy handling ports / SSL
Certbot	Certbot				SSL certificate management and automation

LRS Server	https://tla-dev-lrs.usalearning.net				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
ADL LRS	ADL LRS	8000	proxied	root	Service running the vanilla ADL LRS w/ Django
Postgres	Postgres	5432			LRS's database
Rabbit MQ	Rabbit MQ	5671			Messaging system used by ADL LRS for activities
Kafka Proxy 1	Kafka Proxy	8085	proxied		Intercepts xAPI statements, writes them to Kafka topic
Kafka Proxy 2	Kafka Proxy	8085	proxied		"
Kafka Proxy 3	Kafka Proxy	8085	proxied		"
Nginx	Nginx	80/443	80/443		Diverts xAPI traffic to proxies, all else to LRS directly
Certbot	Certbot				SSL certificate management and automation

Moodle Server	https://tla-dev-Moodle.usalearning.net				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
	Moodle		proxied	root	Moodle instance running through Apache
	Nginx	80/443	80/443		Reverse proxy handling ports / SSL
Note: The Moodle instance uses an AWS RDS instance of Postgres which has been excluded from this table.					

Kafka Server	https://tla-dev-kafka.usalearning.net				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
Kafka Broker 1	Kafka	19092	19092		Single Kafka broker instance
Kafka Broker 2	Kafka	29092	29092		"
Kafka Broker 3	Kafka	39092	39092		"
Zookeeper 1	Zookeeper	12181			Single Zookeeper instance
Zookeeper 2	Zookeeper	22181			"
Zookeeper 3	Zookeeper	32181			"
Kafka Monitor	Kafka Monitor	3000 (HTTP)	proxied		Exposes a protected WebSocket to monitor Kafka topics from a web browser or mobile device
		8000 (WS)	8000 (WS)	monitor	
Learning Event Manager	Learning Event Manager	3000	proxied	root	Responsible for monitoring xAPI traffic via Kafka and sending collateral statements based on what it observes
Nginx	Nginx	80/443	80/443		Reverse proxy handling ports / SSL
Certbot	Certbot				SSL certificate management and automation

Metadata Server	https://tla-dev-acts.usalearning.net				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
Experience Index	Experience Index	3000	proxied	experience	Experience index mapping activities to competencies
Activity Index	Activity Index	8080	proxied	activities	Activity Index mapping content to venues / devices
Activity Registry	Activity Registry	3000	proxied	registry	Web UI and general handler for the activity registration
Postgres	Postgres	5432			Learning Experience Index's database
Nginx	Nginx	80/443	80/443		Reverse proxy handling ports / SSL
Certbot	Certbot				SSL certificate management and automation

CaSS Server	https://tla-dev-cass.usalearning.net				
Container	**Service**	**Container Port**	**Public Port**	**Public Path**	**Description**
CASS	CaSS			root	Instance of CaSS
CASS	Apache2				Hosts CASS on port 80
CASS	Tomcat				Hosts the CASS SkyRepo Database
CASS	SkyRepo	80			CASS's Database
Learner Profile	Learner Profile	3000		me	Stateful representation of a learner's competencies
Nginx	Nginx	80/443	80/443		Reverse proxy handling ports / SSL
Certbot	Certbot				SSL certificate management and automation

The 2019 Reference Implementation is installed in an AWS virtual private cloud hosted via contract to USALearning. It includes eight virtual machines, which are hosted according to the dynamic load balancing that is provided as part of amazon web services Virtual Private Cloud (VPC). AWS provides the back-end platform hosting, virtualization, and Domain Name Service (DNS) resolution functions. External clients accessing the portal, the hosted content, or the service redirects may be located outside the AWS campus. The software components detailed in section 1.3 are installed on servers as shown in **Figure 4.**

Learning Activities in 2019 include the USALearning modified version of Moodle and the NILE platform. NILE is an open source commercial product developed by Gooru, a Google backed effort dedicated to providing alternatives for K-12 training at low cost. The NILE provides an additional learning activity from the TLA perspective, as well as a federated LRS. Additionally, as the PeRLS and other learning device servers become available, they will provide more connected LRPs. The Generalized Intelligent Framework for Tutoring (GIFT) is an intelligent tutoring component that will act as the LRP/activity for upcoming work with the Simulation and Training Technology Center (STTC) using the Squad Advanced Marksmanship Trainer (SAM-T). The ADL Initiative is also working with the Defense Acquisition University to instrument one of their Faculty Professional Development Courses (FPD420) with xAPI, which may be connected to the TLA Reference Implementation in 2020.

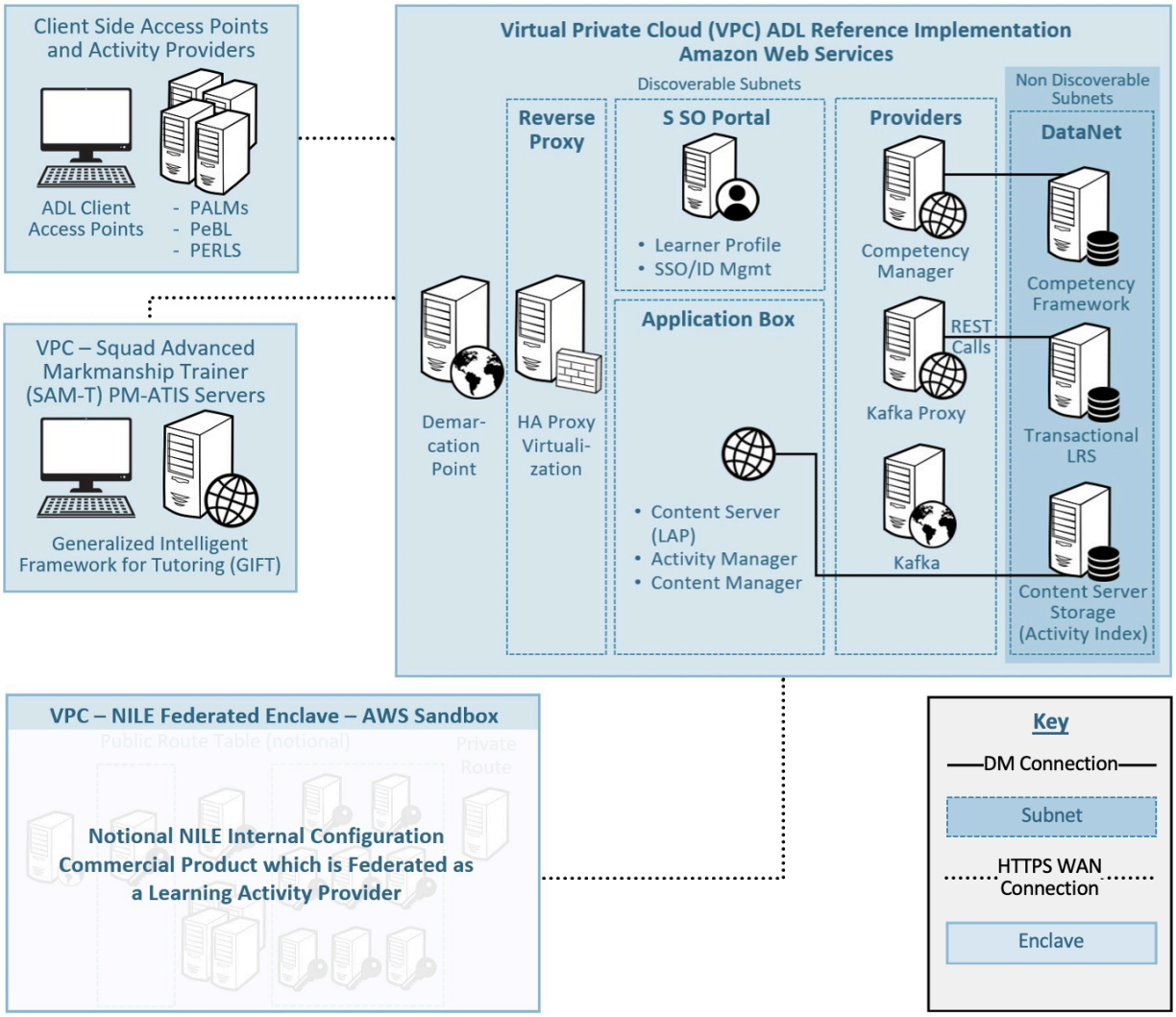

Figure 4. TLA Physical Architecture. *This figure outlines the high-level arrangement and flow of information between the 2019 Reference Implementation Servers. See Table 2 for server names.*

1.3 Software Architecture

This section describes the major components and high-level responsibilities for each TLA software component, as shown in **Figure 5**. The TLA Reference Implementation is structured in a way that allows the test and evaluation of individual components and capabilities. In practice, many of these components will be integrated into a larger system. For example, the learner profile in **Figure 5** pulls data from both the competency management system and the authoritative LRS to test different metamodels, controlled vocabularies, and architectural constraints. Different DoD components already have learner profiles planned or implemented as part of their ongoing modernization strategies. The Army Training Information System (ATIS) instantiates a learner profile to track individual and units as part of the Army Training Management Capability. Likewise, the Air Education and Training Command (AETC) is implanting their version of a learner profile within the Airmen Learner Record program which is part of the Air Force Learning Services Ecosystem (AFLSE).

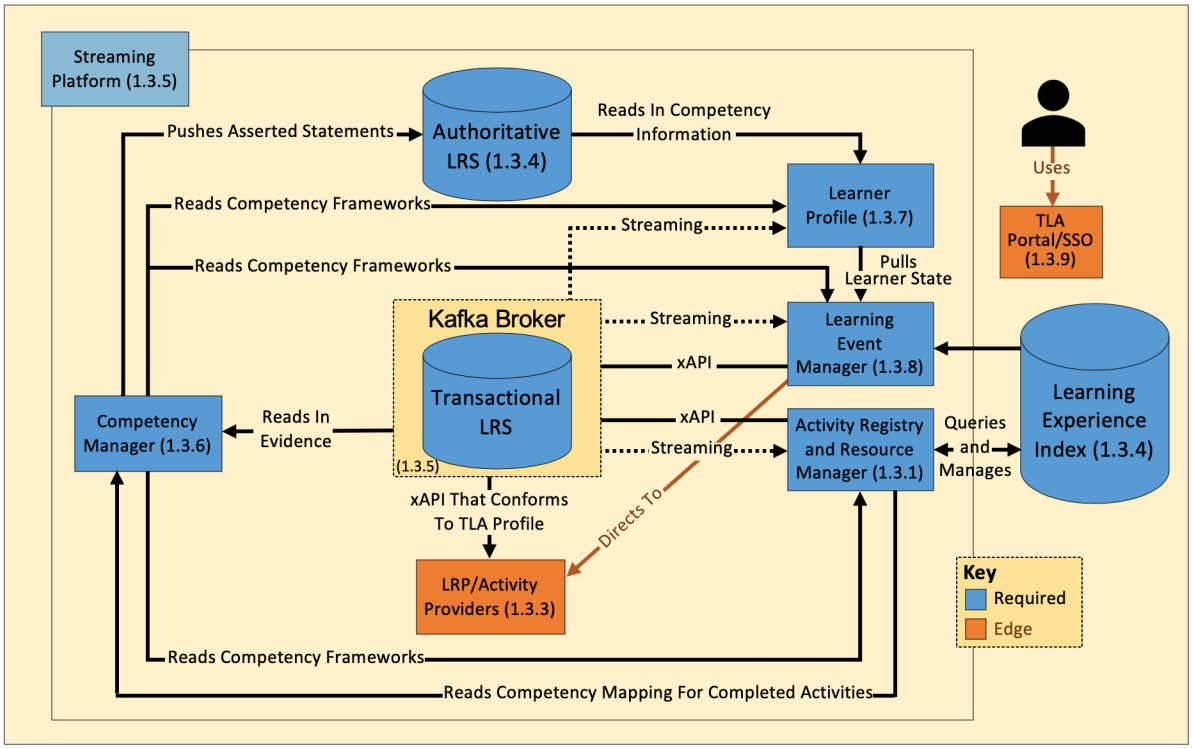

Figure 5. TLA Component Architecture. *Each software "component" refers to a high-level service group that typically consist of several smaller services, each "microservice" performing a specialized job for that component.*

1.3.1 Activity and Resource Registry Manager

An Activity and Resource Registry Manager is the service group associated with capturing, connecting, and sharing data about learning resources available to an organization. Key features include the ability to generate and manage metadata, taxonomies and ontologies, the alignment of content with competencies, paradata, semantic search services, and machine-actionable metadata. In the 2019 Reference Implementation, the Activity and Resource Registry also catalogs information, usage, assertions, and analytical data from a single, sharable metadata repository called the Experience Index. This growing collection of data about potential learning resources can be consumed by any TLA component. The registry service buffers communication with an enclave's Learning Experience Index (or Indices). The microservices within the 2019 Activity and Resource Manager include:

- Create, Read, Update and Delete (CRUD) service for Experience Index
- CRUD Graphical User Interface (GUI)
- Federation Resource Directory
- Federation Data compiler

1.3.2 Experience Index

The metadata attributes in the Experience Index augment the Learning Resource Metadata Initiative (LRMI) specification and makes specific use of the extension for educational alignments. Beyond the general metadata content like publisher, name, and location, the team implemented a limited set of differentiators for 2019.

The Experience Index houses the metadata that describes content resources, instructional activities, and competency objects (describing educational alignment) that can ultimately link to lessons, courses, and

credentials. The Activity and Resource Registry Manager provides a web service to filter and load the subordinate lists to semi-automate the creation of these links. The device registry feature for activities was greatly simplified for 2019, as a user configurable list (rather than hard coded links as in 2018), but this requires further elaboration in 2020 to be user friendly and cybersecurity compliant.

1.3.3 Activity Providers

Activity providers are the edge system LRP that represent the boundary between learning technology and the TLA core services. Activity providers include LMS servers, simulation hosts, device managers, or direct connect devices that host the content, in the form of files, e-publications, scenarios, etc. Together, the content and activity form an "experience" which preserves the intent of the learning and context under which it occurs. Each LRP is uniquely situated to produce learning records that connect a user to learning experiences within an activity. The LRP is responsible for the formatting and population of a learning record that meets xAPI requirements and conforms to the TLA MOM. These learning records can then be transmitted to the LRS, shown previously in **Figure 3**.

1.3.4 Learner Record Store(s)

xAPI-enabled learning activities generate statements, or records of learning that include a basic triple structure consisting of actor, verb, and object. Services transmit these statements over HTTP or HTTPS, typically to a central LRS. An LRS serves as a repository for learning records collected from connected systems where learning activities are conducted. Initially, the 2019 TLA Reference Implementation used a containerized[6] version of the ADL Initiative's open source LRS. In late 2019, a more scalable commercial solution was configured and implemented. Its main function is to store and retrieve the data that are generated from xAPI statements such that all other TLA components may access those data without being dependent on direct communication with each other.

The federated LRS approach separates between noisy LRS (included as edge systems or part of learning activities), Transactional LRS, and Authoritative LRS. The Transactional LRS stores all the local state messages from the various components generating TLA MOM messages, along with raw evidence and baseline assertions. The Authoritative LRS maintains digitally signed verifications of completed qualifications, conferred credentials and certifications to perform jobs. In the 2019 Reference Implementation they are two logical areas of the same physical LRS.

1.3.5 Streaming Platform

During development of the 2018 Reference Implementation, the engineering teams began noticing performance and logical issues resulting from services needing to poll an LRS for recent statements. Specifically, minor differences in clock-time between servers caused some services to miss statements when using a time-gated strategy for polling the LRS. The 2018 solution was to implement an Advanced Message Queuing Protocol (AMQP) solution called RabbitMQ[7] as a message broker and to configure the LRS to forward its new statements to that broker.

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[6] Containerization is the process of deploying a service using one or more containers. Containers are standalone packages of software that contain all necessary dependencies for that software to execute.

[7] https://www.rabbitmq.com/

With this in place, services interested in new xAPI statements could receive them in real-time without worrying about timekeeping deltas or polling performance, but the system itself was a reactionary afterthought and not incorporated into the data pipeline from the start.

For the 2019 Reference Implementation, Kafka facilitates the real-time flow of xAPI traffic between LRPs, the LRS, and Learning Record Consumers (LRC). Kafka is a horizontally scalable message brokering system based on the producer-consumer model, with LRPs as the producers and LRCs as the consumers. By incorporating Kafka into the 2019 Implementation, all systems and services could be developed and integrated with the expectation of time-stamp correct xAPI traffic as a guarantee.

Another notable challenge was the xAPI specification's lack of a mechanism to forward new statements directly to interested parties. As a result, the only guaranteed method for extracting xAPI statements from an LRS is to request them using filters. The result in 2018 was a choice between losing traceability of the human actor that ultimately initiated a chain of events, or a significant reduction in performance. In the 2018 data set, both cases were found upon analysis.

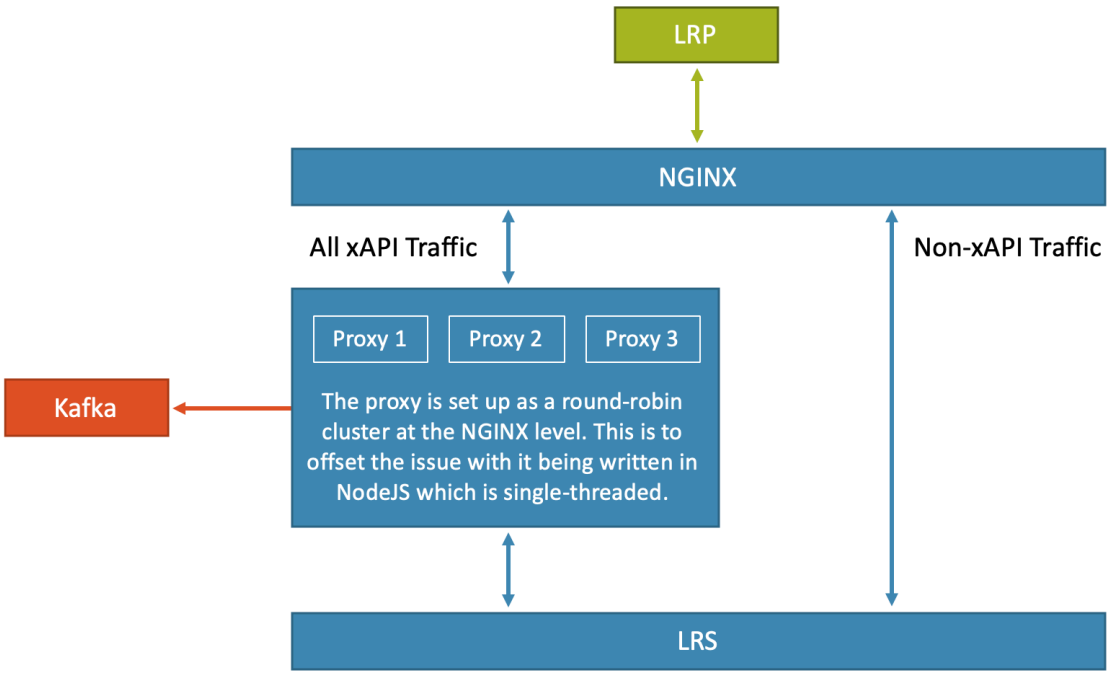

Figure 6. Apache Kafka Proxy Arrangement. *This design enables a "parallel bus" of xAPI statements as described in the TLA main report.*

The communication arrangement is shown in **Figure 6**. To publish the LRS xAPI traffic to the Kafka cluster in real time, xAPI traffic passes through a Kafka-integrated proxy, which monitors both the original request and the LRS's response. Because the xAPI specification guarantees that the statement's MOM-relevant properties are immutable, and because the LRS response contains the assigned Universal Unique Identifiers (UUID) for each accepted statement, the proxy constructs a MOM-equivalent version of that statement without further LRS interaction. All accepted statements can then be transmitted in real-time to the Kafka cluster and subsequently to any component within the TLA network subscribing to xAPI traffic. The proxies are physically installed on the same virtual machine as the LRS.

1.3.6 Competency Management System

A Competency Management System manages evidence of an individual's knowledge, skills, abilities, attributes, experiences, personality traits, and motivators to predict their value toward effective performance. Competencies might include technical skills, business skills, leadership skills, people skills, ethics, professionalism, or any number of topics related to a job. Within the TLA context, the Activity Stream(s) stored in the LRS provide the evidence upon which competency assertions are made. The CaSS platform was used to manage this evidence and infer competency against a competency framework. For the 2019 Reference Implementation, CaSS served as a centralized set of competency frameworks. These were mapped to content descriptors to form the activity metadata. CaSS maintains the competency framework as part of the main application. In the future, the competency framework(s) will be a separate component. The list of Microservices associated with CaSS are:

- CaSS main
- Assertion Helper
- Framework Helper

1.3.7 Learner Profile

In the 2019 Reference Implementation, the learner profile is a standalone data service responsible for preserving learning records about each user in the enclave and updating that learner's perceived state. The learner profile stores three main types of data:

- *Persistent Learner State Data* – A listener in the Learning Event Manager generates the goal/task/event relationship for each learner as a function of captured xAPI statements conforming to the TLA MOM. This state data must be persistent (stays after browser session terminated) but is erased as each task/event is satisfied (based on listening for matching "capture" or "launched" xAPI statements).
- *Local and Global Learner Attribute Data* – This is minimal for 2019. It stores any characteristics of the learner copied from the Enterprise Learning Record Repository (ELRR- a 2020 effort) or entered locally for local level assets (such as recommenders).
- *Local Copy of Discoverable Digital Badges* – These trace back to the digitally signed conferral and assertion statements in the Authoritative LRS and use Linked Data to establish the forensically discoverable chain of evidence for learner competency.

1.3.8 Learning Event Manager (LEM)

Tracking the lifecycle of a given experience observed in the Activity Stream – most notably the attribution of activity in an xAPI statement to an actor's persistent learner profile – falls under the jurisdiction of an LEM. This component consumes xAPI statements from the Kafka stream and relays that information to the learner profile and updates any relevant paradata if the statement referred to a known activity. The microservices associated with the learning event manager are:

- Goal Setting: store goal / competency targets for learners
- Task Scheduling: store scheduled activities for learners
- Decision Support: store pending requests / status of those requests
- xAPI Sorting: recognize authoritative xAPI and relay to the authoritative LRS
- Catalog Listener / Proxy: interface for the known experience index(s) to relay MOM-relevant xAPI

1.3.9 Portal/ Single Sign-On (SSO)

SSO is a property of the TLA's access control of multiple related, yet independent, software systems. Users log in with a single ID and password to gain access to all TLA connected systems. While not a formal component of the TLA, it is expected that TLA components will need a centralized auth[8] system to operate within the stakeholder environment. Keycloak was used for this purpose and has been integrated to protect PII and to provide information security for learners, content, and organizations. This capability has been integrated to protect Personally Identifiable Information (PII) and to provide Operational Security for learners, content, and organizations.

The SSO capability is integrated with the access portal, and the permissions are relayed to all components, preventing the user from having to log in several times. Logically, SSO is part of the back-end services (Identity Management), and the portal is an edge system, but they are a single installation in the Reference Implementation.

1.4 Concept of Execution

For 2019, the workflow for users interfacing with the TLA include a maintenance mode and a learning mode. The Maintenance Mode is purely for privileged users (i.e., maintainers) modifying the underlying data structures of competency, experiences and learner data. The Learning Mode is for either learners or mentors (Observer/Instructor/Controller/Supervisor or OICS) interfacing with the core assets to deliberately plan and schedule future learning or interaction with an instrumented device to conduct learning. The context under which this interaction occurs supplies insight into the way the learner or mentor is configuring their learning environment. Potential contexts are captured in the object life cycle of the TLA MOM. This life cycle is based on use cases developed from modern learning theories as described in Walcutt & Schatz (2019), Modernizing Learning: Building a Future Ecosystem[9].

1.4.1 Maintenance Mode

In Maintenance Mode, administrators can access the Activity and Resource Registry. This enables an OICS to update competencies, experiences, activities, and content available to learners, as well as schedule activities, review curriculum requests, and assign goals. From a component perspective, each component responsible for registering and serving metadata in the 2019 TLA Reference Implementation reacts to and uses administrator-level credentials from the SSO system and grants special maintenance features to those users. For 2019, this mode handled the entry of metadata descriptors for content and activities – a control loop labeled Record Management in the service diagram shown on **Figure 7**.

1.4.2 Learning Mode

Figures 8, 9, and **10** show the basic flow for the Learning Mode, which is largely unchanged from the learner's perspective in 2018, albeit with more robust alternate path handling. Learners access a common portal, review content relevant to their goals, and receive updated content following the system's experience processing. This mode consists of three primary use cases, each included with a corresponding service diagram: goal selection, task selection, and task execution.

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[8] *The term "auth" is shorthand for authentication, authorization, or both. Keycloak is used for both, with access tokens granted by OIDC's authentication layer which then authorize the user's current browser session for access to Keycloak-protected resources and endpoints.*

[9] *https://bookstore.gpo.gov/products/modernizing-learning-building-future-learning-ecosystem*

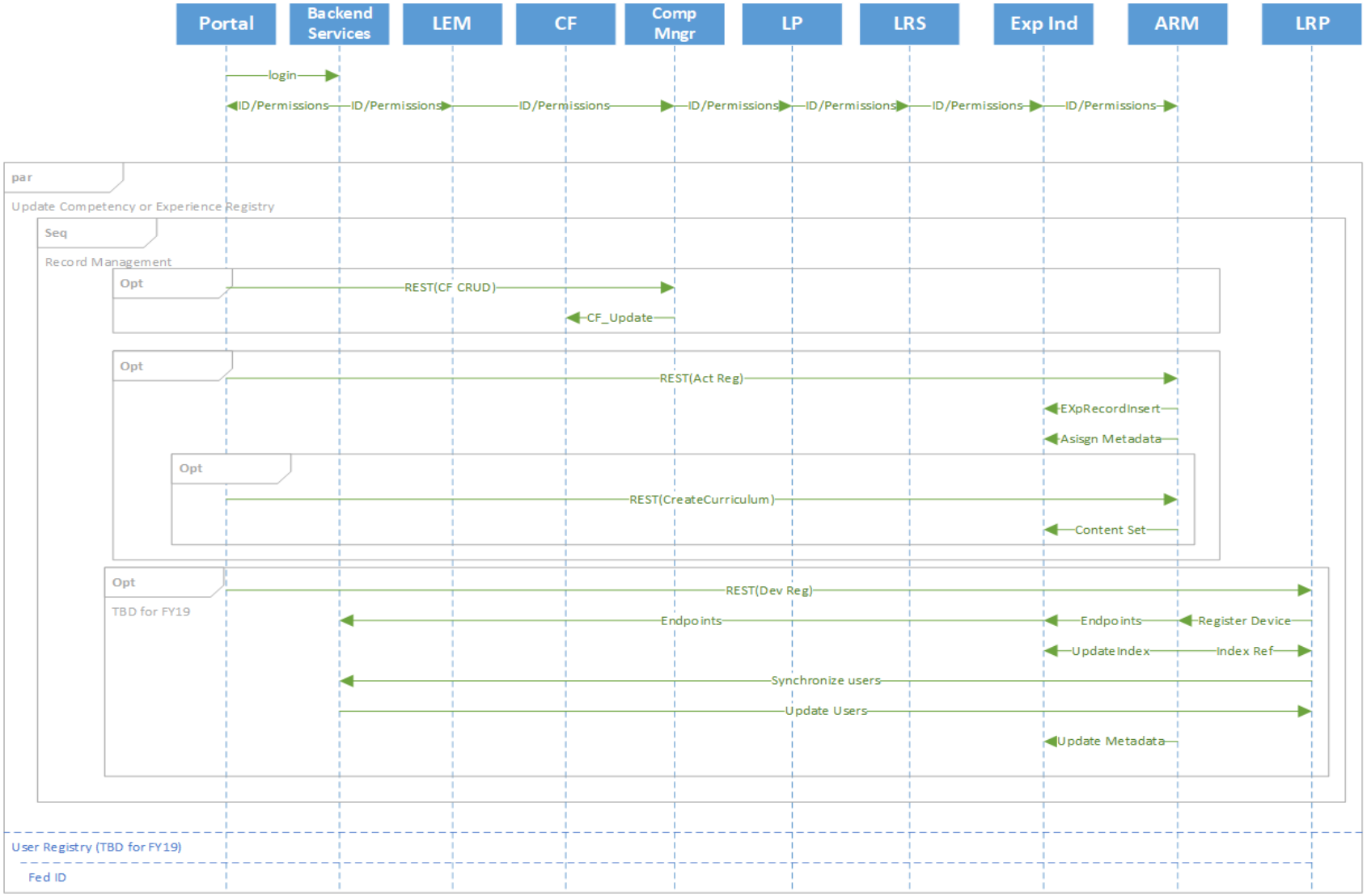

Figure 7. Maintenance Mode. *As this mode deals primarily with the registration of metadata and competencies, the information flows all begin with the login and portal interactions before moving to either the competency manager or activity registry. The last subroutine deals with the notion of Device Registry, a system workflow not built out for the 2019 Reference Implementation but possible using the same components.*

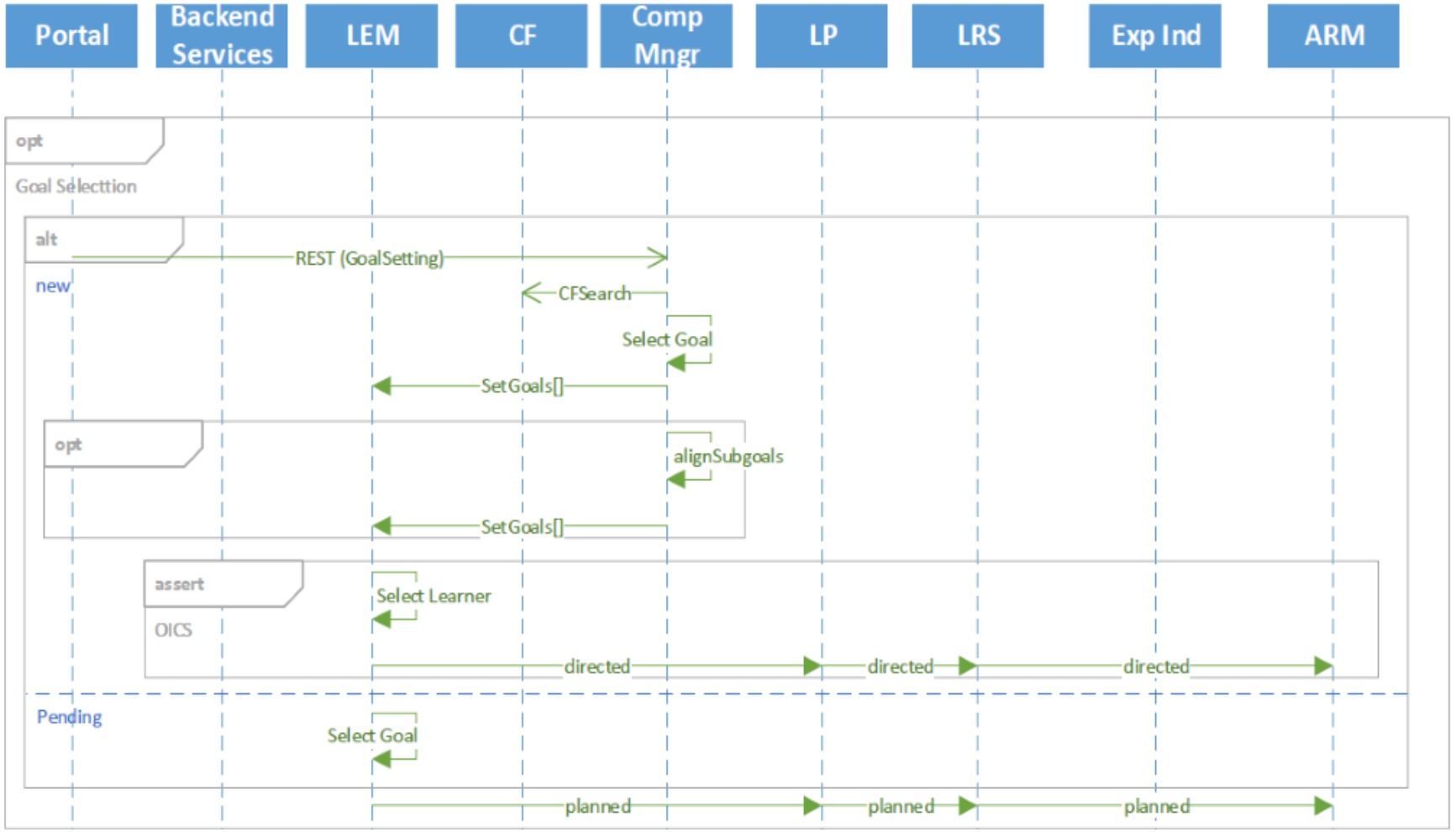

Figure 8. TLA Learner Planning. *The first use case for Learning Mode describes the configuration of a learner's goals within the system. Through the portal, learners can view possible goals known to the competency management component and set those goals for themselves. These goal-setting actions then send messages to the LEM which are communicated to the learner's profile for compilation. Each inner loop typically concludes with information relayed to the LEM, which then feeds both the learner profile, LRS, and the activity registry components. Goals themselves are either self-assigned or can be assigned by someone operating in Maintenance Mode. Aside from the learner organizing their own goals, an OICS may also assign goals to learners manually through the LEM's administrator controls. These actions trigger similar messages regarding the learner and are then carried across the system, with all goal-setting actions prompting a planned statement to the LRS.*

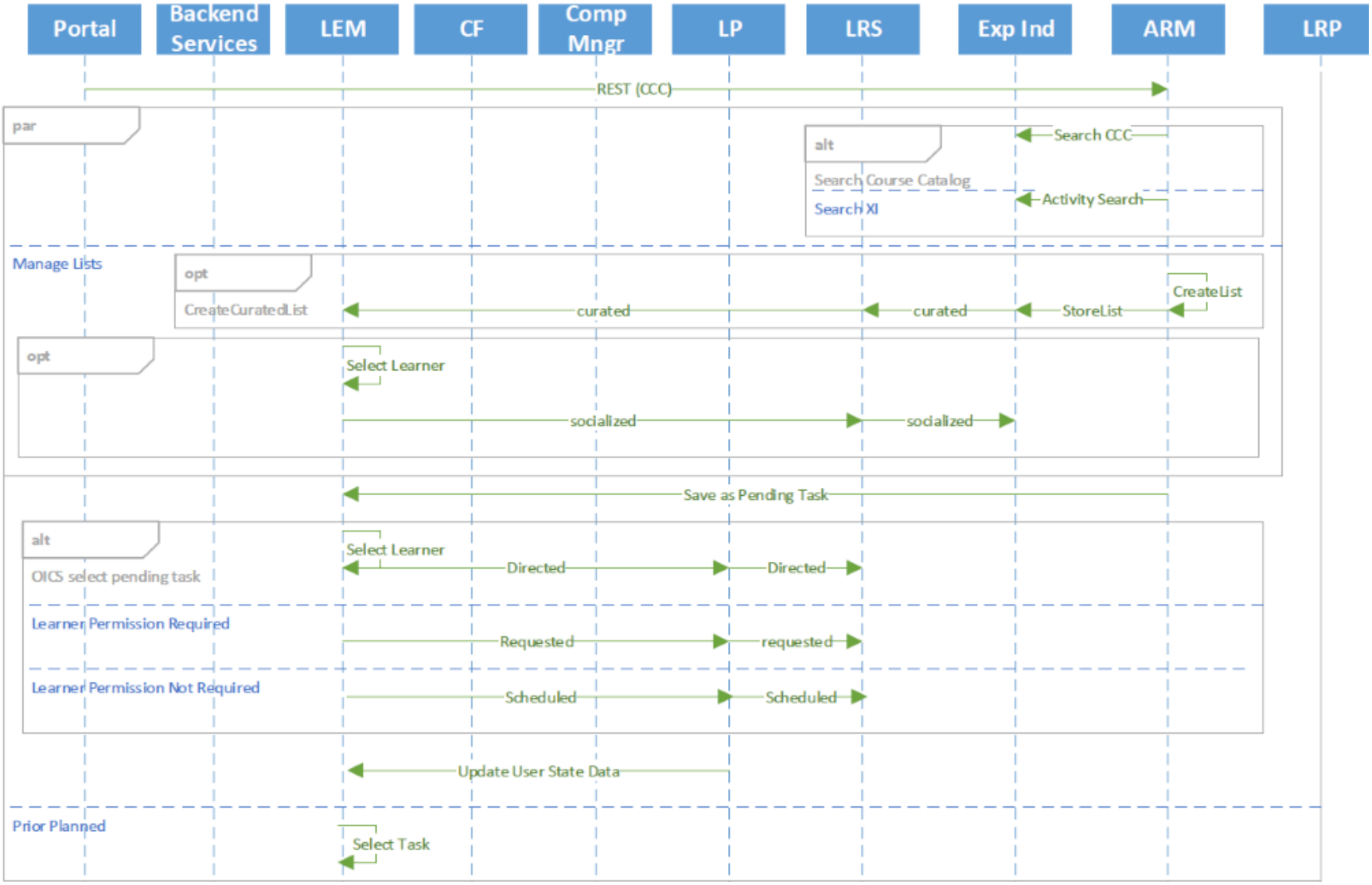

Figure 9. Learner Task Selection. *This phase governs curation and assignment of experiences to a user. Learner task assignments are derived from curated content. The incorporation of the LEM enables the system to propose relevant tasks to a learner's pre-selected goals. The workflow uses the LEM and its Kafka incorporation for real-time updates. For learners, this process functions like a recommendation system, with goal-relevant competency associations being considered during the curation step.*

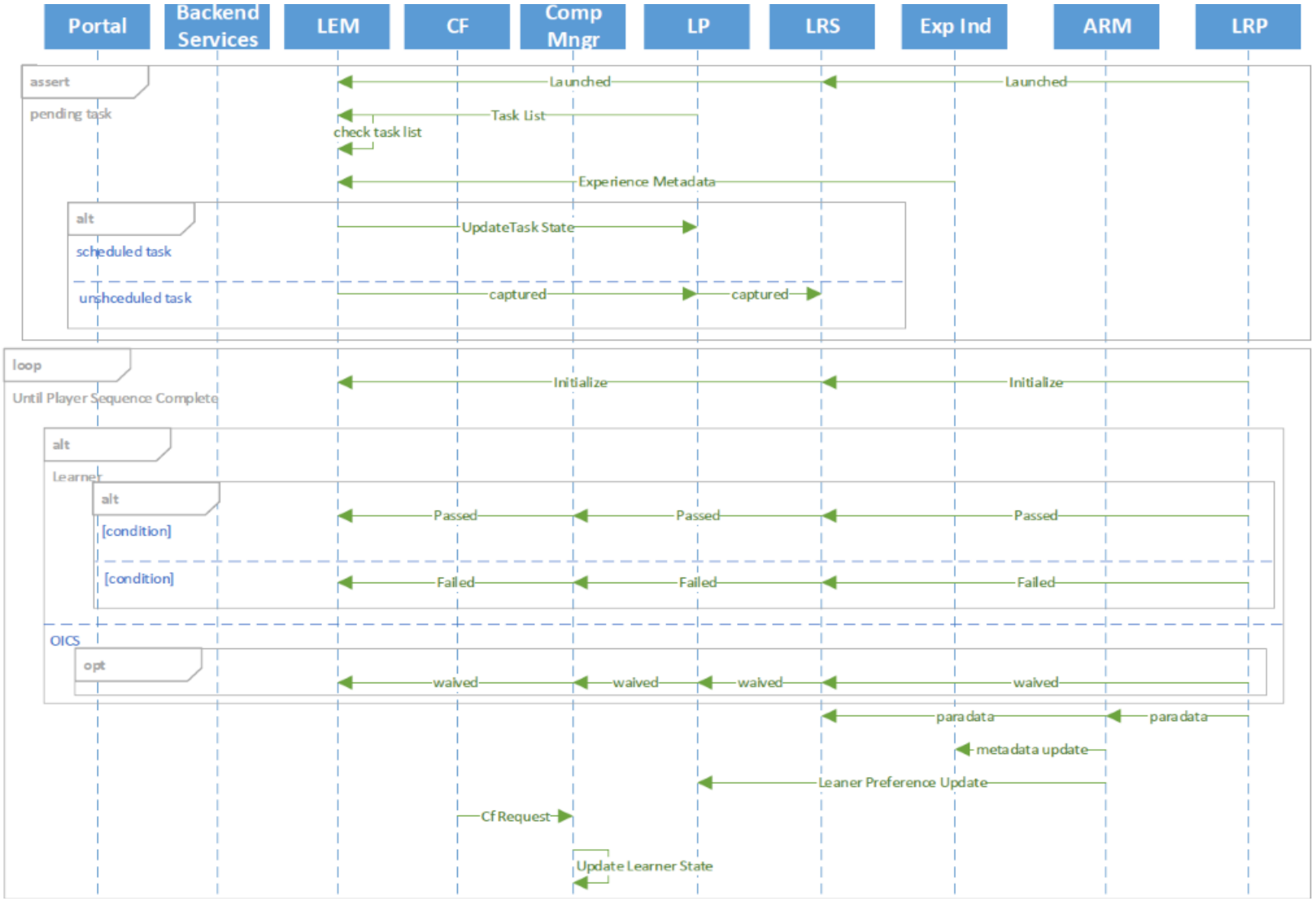

Figure 10. TLA Learner Task Execution. *This stage handles the launching and overall activity lifecycle once a learner engages with a selected experience and its associated LRPs and work through the corresponding activity. This tracking typically occurs at the LEM component, but the learner profile maintains a user's state and must interpret messages from the LEM to make those state adjustments. It also standardizes the flow of execution as activity streams using TLA MOM messages, instead of the ad hoc communication used in 2018.*

As xAPI statements flow through the LRS, the LEM attributes those actions to the user's learner profile and determines whether these statements satisfy a pending task or requirement requested of the user. This task subroutine continues until completion, with the LEM then sending its own xAPI data to close the loop. Once an activity is complete, LRP usage data populates paradata for the corresponding activities, and the activity registry updates both metadata usage and the learner's activity preferences. Finally, the competency management system receives the most recent evidence and updates all related learner state properties.

1.5 Interface Design

The TLA is comprised of a collection of open specifications that define the specific message structures supported by the application programming interfaces used to expose TLA data, services, and systems. The 2019 Reference Implementation interfaces represent the operationalization of service contracts defined in the logical architecture.

1.5.1 Interface Identification and Diagrams

Communications between 2019 Implementation components involved either HTTPS, WebSocket, or Kafka streams. Given the popularity and general simplicity of RESTful APIs (see section 1.5.3 below) in modern web services, HTTPS continues to facilitate most traffic within the 2019 Implementation with two exceptions: notification of new xAPI statements, and learner profile updates. The primary protocol and datatypes are shown in **Table 3** below, with fields listed as JavaScript Object Notation (JSON) being small datatypes that do not belong to an established specification.

Table 3. TLA Reference Implementation Protocol and Interface Matrix. *Primary protocol and interface usage for each component within the 2019 Implementation. For instance, the LRS serves xAPI through its Kafka proxy to three services and receives xAPI through HTTPS from five.*

Serves	Receives										
	XI	AI	AR	LP	IdM	CF	CM	LRS	LEM	Portal	LA
Experience (XI)			JSON						JSON		
Activity Index (AI)			LRMI								
Activity Registry (AR)		LRMI			OIDC			xAPI		LRMI	
Learner Profile (LP)									JSON	JSON	
Identity Manager (IdM)			OIDC	OIDC						OIDC	OIDC
Competency Framework (CF)	CASS			CASS			CASS				
Competency Manager (CM)				xAPI				xAPI			
Transactional LRS (LRS)				xAPI			xAPI		xAPI		
Learning Event Manager (LEM)								xAPI			
Portal					OIDC			xAPI			
Learning Activities (LA)								xAPI			
		Key:	REST	Kafka							

1.5.2 Apache Kafka Interface

Apache Kafka uses a binary protocol over a transmission control protocol connection and defines all APIs as request-response message pairs. Clients initiate socket connections with the Kafka cluster, writing sequences of request messages and reading back the corresponding responses.

1.5.3 Representational State Transition (REST)

REST is an architectural paradigm that defines a set of constraints to be used for creating web services. These constraints maintain data and control logic on the edges of communication and use a series of HTTPS-based requests to a Universal Resource Locator (URL) or specified address for a network resource.

1.5.3.1 Experience Application Program Interface

The xAPI is a specification currently going through a formal standards development process. The main components of xAPI are the data structures called Statements and the data storage/retrieval capability called the LRS. The xAPI specification has stringent requirements on the structure of data and the LRS capabilities. Statements are data triples that use actor, verb, and object to describe any experience. Each statement also includes timestamps and unique, resolvable identifiers. The transport is HTTP/HTTPS with JSON payloads.

1.5.3.2 WebSocket

The WebSocket protocol is a simplified protocol for sending and receiving messages over the Internet, abstracting the complexity of TCP handshakes. Rather than polling for updates through HTTP requests, WebSocket enables real-time communication between clients and servers with nearly universal compatibility. All major browsers support this protocol.

1.5.3.3 Master Object Model IEEE P9274.3.1

The TLA Master Object Model (MOM) is an xAPI profile used to define the internal state of TLA core systems. It normalizes reporting of learning environment configuration state, learning event state, and learner career state so that all attached learning devices report them in the same way. There is no overall state controller for the enclave of CORE components. However, the MOM specifies a potential sequence of events that trigger each microservice to conduct their data processes. The collective state space of the MOM implements a learner "Object Life Cycle" that corresponds to multiple use cases of learning. This is explained in detail in the TLA report.

1.6 Computational Resources

Part of the systems development plan for the 2019 Reference Implementation was to benchmark computational performance. The test appliance included AWS console applications for measuring processor loading and memory allocation. Computational testing for 2019 focused on the LRS configuration's tolerance of burst traffic and an analysis of alternatives on technical approaches for the upcoming Enterprise Course Catalog and the Enterprise Learner Record Repository projects planned in 2020 (in collaboration with USALearning and the Office of the DoD's Chief Management Officer.)

The initial LRS deployment used the ADL Initiative LRS. The Learning Locker LRS used in 2018 had some peculiarities that complicated its integration. Early tests for cybersecurity compliance showed Learning Locker had significantly more Category 1 findings than the ADL Initiative LRS. Since cyber lockdowns are a principal bottleneck in search performance, the ADL Initiative LRS was determined to be more representative of the two. A third LRS from a Data Analytic tools vendor was not available at the beginning of the integration period, although this LRS was available and integrated later.

TOTAL LEARNING ARCHITECTURE

2019 Report - Appendix E - Acronym Table

Prepared by
The ADL Initiative

Acronym	Definition
AACRAO	American Association of Collegiate Registrars and Admissions Officers
ADB	Actionable Data Book
ADD	Architectural Description Document
ADL	Advanced Distributed Learning
AEM	Adobe Experience Manager
AEP	Association of Educational Publishers
AETC	Air Education and Training Command
AFLSE	Air Force Learning Services Ecosystem
AFSC	Air Force Specialty Code
AICC	Aviation Industry Computer-based Training Committee
ALIAS	Advancing Learning Interoperability Across Systems
ALR	Airmen Learning Record
AMQP	Advanced Message Queuing Protocol
ANSI	American National Standards Institute
API	Application Program Interface
AR	Augmented Reality
ARCIC	Army Capability Integration Center
ARLEM	Augmented Reality Learning Experience Model
ASN	Achievement Standards Network
ASN-DF	ASN Description Framework
ATC	Authority To Connect
ATD	Association of Talent Development
AU	Assignable Unit
AV	All View
A/V	Audio Visual
AWPAB	American Workforce Policy Advisory Board
AWS	Amazon Web Server
B2B	Business to Business
BIBFRAME	Bibliographic Framework
CAC	Common Access Card
CAM	Content Aggregation Model
CANTRAC	Catalog of Naval Training Courses
CASE	Competencies and Academic Standards Exchange
CaSS	Competency and Skills System
CBL	Competency Based Learning
CCC	Common Course Catalog (now Enterprise Course Catalog)
CD	Compact Disk
CDS	Cross Domain Solution
CDSE	Center for Defense Security Education
CEDS	Common Education Data Standards
CJSE	Combined Joint Staff Exercise
CLR	Comprehensive Learner Record
CM4LTS	Conceptual Model for Learning Technology Standards
CMI	Computer Managed Instruction
cmi5	Computer Managed Instruction #5
CMM	Capability Maturity Model
CODIAC	Combat Observation and Decision-Making in Irregular and Ambiguous Conflicts
COI	Course Of Instruction
CONOPS	Concept of Operations

Acronym	Definition
COOL	Credentialing Opportunities On-Line
CORS	Cross Origin Resource Sharing
CRUD	Create, Read, Update, Delete
CSS	Cascading Style Sheet
CTDL	Credential Transparency Description Language
CV	Capability View
CV	Curriculum Vitae
DACUM	Developing A Curriculum
DADLAC	Defense ADL Advisory Committee
DAG	Directed Acyclic Graph
DAU	Defense Acquisition University
DAVE	Data Analytics and Visualization Environment
DCAM	DCMI Abstract Model
DCMI	Dublin Core Metadata Initiative
DEERS	Defense Enrollment Eligibility Reporting System
DFAS	Defense Finance and Accounting Services
DHA	Defense Health Agency
DISA	Defense Information Security Administration
DIV	Data and Information View
DMDC	Defense Manpower Data Center
DNS	Domain Name Service
DoD	Department of Defense
DoDD	DoD Directive
DoDAF	DoD Architectural Framework
DoDI	DoD Instruction
DSM	Design Structure Matrix
ECC	Enterprise Course Catalog
EDIPI	Electronic Data Interchange Personal Identifier
ELR	Enterprise Learner Record
ELRR	Enterprise Learner Record Repository
FE&T	Force Education and Training
FICAM	Federated Identity, Credential, and Access Management
FIM	Federated Identity Management
FLE	Future Learning Ecosystem
FLUENT	Fast Learning from Unlabeled Episodes for Next-Generation Tailoring
FOC	Final Operational Capability
FRD	Functional Requirements Document
GB	Gigabyte
GIFT	Generalized Intelligent Framework for Tutoring
GIG	Global Information Grid
GUI	Graphical User Interface
HPML	Human Performance Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
I/ITSEC	Interservice/Industry Training, Simulation and Education Conference
IAM	Identity and Access Management
IATC	Interim Authority To Connect
IATT	Interim Authority To Test
IAVM	Information Assurance Vulnerability Memorandum

Acronym	Definition
ID	Identification
IDA	Institute for Defense Analysis
IEEE	Institute of Electrical and Electronics Engineers
IEEE-SA	IEEE Standards Association
iFEST	Innovation, Instruction, Implementation Federal E-learning Science and Technology
ILR	Integrated Learner Record / Interoperable Learner Record
IMI	Interactive Multimedia Instructional
IOC	Initial Operational Capability
IRI	Internationalized Resource Identifiers
ISD	Instructional Systems Development (or Design)
IT	Information Technology
JCIDS	Joint Capability Integration and Development System
JDTA	Job, Duty, Task Analysis
JITT	Just-In-Time Teaching
JSON	JavaScript Object Notation
KSA	Knowledge, Skills and Abilities
KSAO	Knowledge, Skills, Abilities, and Other capabilities
LEM	Learning Event Manager
LIP	Learner Information Package
LMS	Learning Management System
LOM	Learning Object Model
LRC	Learning Record Consumer
LRMI	Learning Resource Metadata Initiative
LRP	Learner Record Provider
LRS	Learning Record Store
LTI	Learning Tools Interoperability
LTSC	Learning Technology Standards Committee
LVCG	Live, Virtual, Constructive Game
LWMCLR	Learner, Worker, Military Comprehensive Learner Record
M&P	Manpower and Personnel
MBSE	Model Based Systems Engineering
MOC	Military Occupational Classification
MOE	Measure of Effectiveness
MOM	Master Object Model
MOP	Measure of Performance
MOS	Military Occupational Specialty
MPTE	Manpower, Personnel, Training, and Education
MR	Mixed Reality
MSEL	Master Scenario Events List
NASAP	National Association of Student Affairs Professionals
NASPA	National Association of Student Personnel Administrators
NATO	North Atlantic Treaty Organization
NCAW	National Council for the American Worker
NDS	Normalized Data Schema
NEC	Navy Enlisted Classification
NILE	Navigator for Interoperable Learning Experiences
NTSA	National Training and Simulation Association
O*NET	Occupational Information Network
OCSTD	Occupational Classification Standard

Acronym	Definition
ODBC	Open Database Connectivity
OIDC	Open ID Connect
OICS	Observer, Instructor, Controller/ Supervisor
OJT	On the Job Training
OPA	Office of Personnel Analysis
OPM	Office of Personnel Management
OSD	Office of the Secretary of Defense
OUSD(I)	Office of the Undersecretary of Defense for Intelligence
OUSD(P&R)	Undersecretary of Defense for Personnel and Readiness
OV	Operational View
P4STLA	Privacy and Security for TLA
PaaS	Platform as a Service
PAR	Project Authorization Requests
PAPI Learner	Public and Private Information for Learners
PeBL	Personalized eBook for Learning
PEO	Program Executive Office
PERLS	PERvasive Learning System
PESC	Postsecondary Educational Standards Council
PI	Principal Investigator
PII	Personally Identifiable Information
PMO	Program Management Office
POI	Program Of Instruction
POR	Program Of Record
PP	Pilot Project
PPI	Protected Personal Information
Pub/Sub	Publish / Subscribe
PV	Project View
QCL	Qualifications/Certifications/Licenses
QoS	Quality of Service
QTI	Question and Test Interoperability
QRC	Quick Response Code
R&D	Research and Development
RCD	Reusable Competency Definition
RDF	Resource Description Framework
REST	Representational State Transfer
RRL	Ready Relevant Learning
RTS	Runtime Service
SAMR	Substitution/Augmentation/Modification/Redefinition
SAMT	Squad Advanced Marksmanship Trainer
SCO	Sharable Content Object
SCORM	Sharable Content Object Reference Model
SISO	Simulation Interoperability Standards Organization
SOA	Service Oriented Architecture
SOLAR	Science Of Learning And Readiness
SQL	Structured Query Language
SSD	Solid State Drive
SSDD	System/Subsystem Design Description
SSO	Single Sign-On
StdV	Standard View

Acronym	Definition
STE	Synthetic Training Environment
STIG	Security Technical Implementation Guide
STTC	Simulation and Training Technology Center
SvcV	Services View
SYSML	System Modeling Language
TADLP	The Army Distributed Learning Program
TDT	Talent Development Toolkit
TLA	Total Learning Architecture
TLO	Terminal Learning Objective
TRADOC	U.S. Army Training and Doctrine Command
TRL	Technology Readiness Level
ULR	Universal Learner Record (now Enterprise Learner Record)
UML	Unified Modeling Language
URL	Universal Resource Locator
USDOL	U.S. Department of Labor
UUID	Universal Unique Identifier
VPC	Virtual Private Cloud
VR	Virtual Reality
WAN	Wide Area Network
WAWF	Wide Area Work Flow
WG	Working Group
xAPI	Experience Application Program Interface
XML	Extensible Markup Language
ZTN	Zero Trust Networks