



## The ADL Initiative

# Total Learning Architecture: 2018 Reference Implementation Specifications and Standards

Advanced Distributed Learning (ADL)  
1901 N. Beauregard St., Suite 600  
Alexandria, VA 22311  
May 2019

*This work was supported by the U.S. Advanced Distributed Learning (ADL) Initiative W900KK-17-D-0004. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the ADL Initiative or the U.S. Government. The U.S. Government is authorized to reproduce and distribute reprints for Government purposes.*

DISTRIBUTION STATEMENT A. Approved for public release.

# TABLE OF CONTENTS

1. Introduction.....	1
1.1 Future Learning Ecosystem .....	2
1.2 Specifications and Standards .....	2
1.3 2018 TLA Reference Implementation .....	3
1.4 2018 TLA Test and Demonstration .....	7
1.5 2018 Data Analytics and Visualization .....	8
2. TLA Specifications and Standards.....	9
2.1 Activity Registry.....	10
2.1.1 Learning Resource Metadata Initiative (LRMI) .....	10
2.1.2 IEEE 1484.12.1 Learning Object Model (LOM) .....	11
2.1.3 Dublin Core Metadata Initiative (DCMI) Metadata.....	12
2.1.4 Schema.org Vocabularies .....	12
2.2 Activity Streams .....	13
2.2.1 Experience API (xAPI).....	14
2.2.2 IMS Global Caliper .....	14
2.2.3 W3C Activity Streams 2.0 .....	15
2.2.4 SISO Human Performance Markup Language (HPML).....	15
2.3 Competency Management .....	16
2.3.1 Achievement Standards Network™ (ASNTM) .....	17
2.3.2 Competencies and Academic Standards Exchange™ (CASE™) .....	17
2.3.3 O*Net.....	18
2.3.4 MedBiquitous Competency Framework.....	19
2.3.5 IEEE 1484.20.1 Reusable Competency Definitions (RCD) .....	19
2.4 Credentials .....	19
2.4.1 Credential Transparency Description Language (CTDL).....	21
2.4.2 Credential Registry .....	21
2.4.3 IMS Global Open Badges .....	21
2.4.4. W3C Verifiable Claims .....	21
2.5 Learner Profile .....	21
2.5.1. Comprehensive Learner Record (CLR) .....	22
2.5.2. Learner Information Package (LIP) .....	22
2.5.3. IEEE Public and Private Informaiton for Learners (PAPI Learner) .....	23
2.5.4. Airmen Learning Record (ALR).....	23
2.6 Recommendation Engine.....	24
2.6.1. Fast Learning from Unlabeled Episodes for Next-Generation Tailoring (FLUENT) .....	24
2.6.2. Navigator for Integrated Learning Environments (NILE).....	24
2.6.3. Adaptive Instructional Sciences – IEEE (C/LT/AIS) P2247.1 .....	25
2.7 Launch Service .....	25
2.7.1. xAPI Launch .....	25
2.7.2. cmi5.....	25
2.8 Assessment Service.....	25
2.8.1. cmi5.....	25
2.9 Identity Management .....	26
2.9.1. Privacy and Security for TLA (PS4TLA) .....	28
2.10 Miscellaneous .....	27
2.10.1. Learning Tools Interoperability (LTI) .....	27
2.10.2. Open Pathways .....	27
2.10.3. Sharable Content Object Reference Model (SCORM)) .....	27
2.10.4. IEEE Actionable Data Book (ADB).....	27
2.10.5. ePub .....	28
2.10.6. IEEE P1589 Augmented Reality Learning Experience Models (ARLEM) .....	28

3. 2018 TLA Reference Implementation .....	29
3.1 Logical Architecture .....	29
3.2 Physical Architecture .....	30
3.3 System Components .....	33
3.3.1. <i>Activity Registry</i> .....	33
3.3.2. <i>xAPI Activity Streams</i> .....	34
3.3.3. <i>Learner Record Store</i> .....	34
3.3.4. <i>Competency Management System</i> .....	34
3.3.5. <i>Learner Profile</i> .....	35
3.3.6. <i>Recommendation Engine</i> .....	35
3.3.7. <i>Single Sign On</i> .....	36
3.4 Concept of Execution .....	36
3.5 Interface Design .....	38
3.5.1 <i>Interface Identification and Diagrams</i> .....	38
3.5.2 <i>Advanced Message Queuing Protocol (AMQP)</i> .....	38
3.5.3 <i>Representational State Transition (RESTful)</i> .....	38
3.5.4 <i>Experience Application Program Interface (xAPI)</i> .....	38
3.6 Computational Resources .....	40
3.7 Lessons Learned and Future Research .....	41
4. 2018 TLA Test and Demonstration .....	42
4.1 Technical Planning .....	43
4.2 TLA Content Demonstration .....	44
4.2.1 <i>CODIAC Course Description</i> .....	45
4.2.2 <i>CODIAC Competency Framework</i> .....	47
4.2.3 <i>CODIAC Content Discovery and Alignment</i> .....	48
4.2.4 <i>Instrumenting CODIAC Content</i> .....	49
4.2.5 <i>Sequencing and Delivery</i> .....	52
4.3 Technical Integration .....	54
4.4 TLA Test Event at Fort Bragg .....	57
4.4.1 <i>Logistics and Administration</i> .....	58
4.4.2 <i>Hardware and Network Connectivity</i> .....	58
4.4.3 <i>Pre-Tests, Post-Tests, Surveys, and Focus Groups</i> .....	59
4.4.4 <i>Learner Management and User Experience</i> .....	60
4.4.5 <i>Data Collection and Management</i> .....	61
4.4.6 <i>Data Analytics and Visualization</i> .....	62
4.4.7 <i>Lessons Learned</i> .....	66
5. Conclusion and Next Steps .....	69

## LIST OF TABLES

---

Table 1. 2018 TLA Components.....	5
Table 2. 2018 TLA Services.....	6
Table 3. Summary of TLA Specifications.....	9
Table 4. AWS Server Specifications.....	32
Table 5. TLA Reference Implementation Application Layer Protocol Port Usage.....	40
Table 6. Key Planning Events.....	44
Table 7. CODIAC ELOs and TLOs.....	46
Table 8. 2018 TLA Learning Record Providers.....	49
Table 9. Well Structured Tasks.....	52
Table 10. Ill-Defined Tasks.....	53
Table 11. Competency Classifications.....	70

## LIST OF FIGURES

---

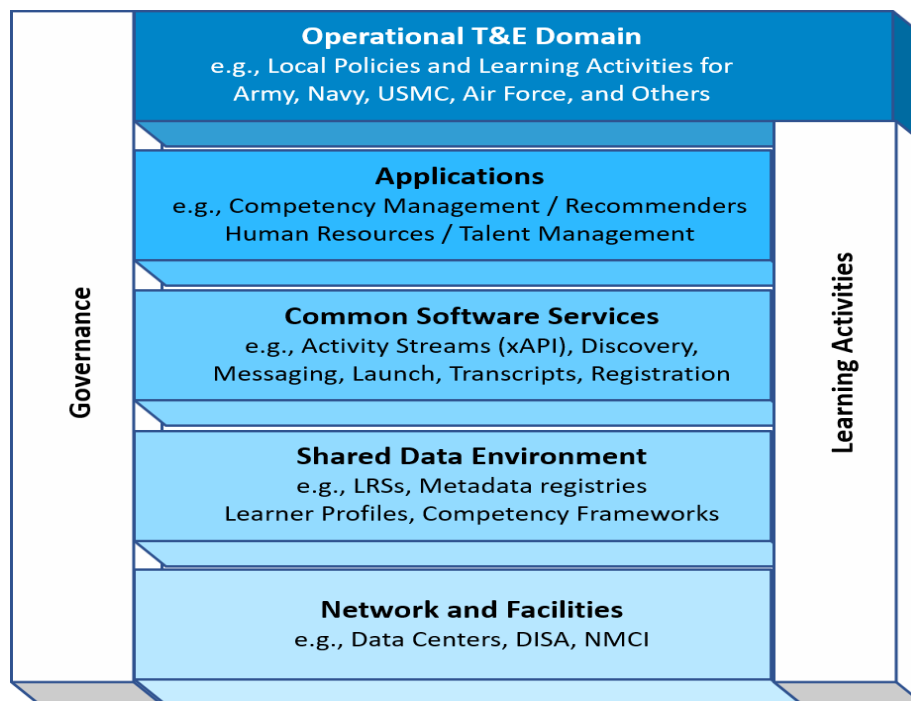
Figure 1. TLA Service Layers.....	1
Figure 2. 2018 TLA Reference Implementation: Logical View.....	4
Figure 3. 2018 TLA Test and Demonstration.....	7
Figure 4. Learning Object Metadata.....	11
Figure 5. Alignment between a Schema.org CreativeWork and a Node in an Educational Framework.....	13
Figure 6. HPML High-Level Conceptual Architecture.....	16
Figure 7. O*NET Content Model.....	18
Figure 8. CDTL Class Structure.....	20
Figure 9. Logical TLA Services Architecture.....	31
Figure 10. 2018 TLA Reference Implementation Physical Architecture.....	33
Figure 11. Competency and Skills System.....	35
Figure 12. TLA 2018 Reference Implementation Concept of Execution (COE).....	37
Figure 13. TLA Reference Implementation Components and Interfaces.....	39
Figure 14. CODIAC.....	45
Figure 15. CODIAC Competency Framework.....	47
Figure 16. Competency Framework.....	48
Figure 17. xAPI Statement Mappings.....	50
Figure 18. TLA Metadata Spreadsheet.....	51
Figure 19. Well Structured Tasks.....	53
Figure 20. Ill-Defined Tasks.....	54
Figure 21. Home Page of 2018 TLA Test and Demonstration FLUENT Interface.....	54
Figure 22. FLUENT Interface Showing the CODIAC Skill Tree Structure and Goal Selection.....	55
Figure 23. SWEG(A) Classroom at Fort Bragg.....	56
Figure 24. Orientation Briefing.....	59
Figure 25. Activity Levels of All Learners.....	62
Figure 26. Statements Generated per Learner.....	63
Figure 27. Statements Generated per Competency.....	63
Figure 28. Statements per Minute.....	64
Figure 29. Empirical Distribution Function.....	65
Figure 30. Competency States and Learner Paths.....	65
Figure 31. 2019 Technical Specifications and Standards.....	69
Figure 32. 2019 Data Streaming Architecture.....	71
Figure 33. 2019 Data Analytics and Visualization Environment.....	73

# 1. INTRODUCTION

The Total Learning Architecture (TLA) program sponsored by the ADL Initiative seeks to develop a set of policy and standards defining the process for developing a *learning ecology*, where multiple services and learning opportunities (of various modalities and points of delivery) can be managed in an integrated environment. The TLA serves to:

- 1) shift from a course-centric focus to a learner-centric focus, where competence is managed more efficiently (for savings in cost and schedule) and effectively for the learner's professional development path;
- 2) provide the opportunities for data interoperability between implementations to aid in enterprise-wide decision support analysis and in reuse of competency and content between agencies, and;
- 3) capture all experiences, including on-the-job training (OJT), use of performance support and job aids, simulation, distributed learning, and traditional classroom learning to provide a more rounded portrait of personnel capability and aptitude to aid in the team building and detailing process.

The TLA employs a Service Oriented Architecture (SOA) approach to developing a flexible, modular system to optimize the time, cost, and effectiveness of learning delivery and analysis. It is composed of interchangeable software services and databases integrated to create an efficient learning environment for the user. The layered architecture of the TLA results in a separation of concerns amongst the different TLA components. **Figure 1** shows the different layers within the TLA. These applications utilize common services and shared data to deliver instructional activities and provide overall management of the experience. TLA services are built around a set of defined set of specifications.



**Figure 1. TLA Service Layers** – The TLA's service layers centralize external access to data and functions, hides the complexity of implementation across physical components, and allows for versioning of the services across the TLA ecosystem. This enables a suite of learning applications to use common services and shared data to glean insights about learners, content, context, and competencies within the 2018 TLA Test and Demonstration.

## 1.1 FUTURE LEARNING ECOSYSTEM

Ecology is the branch of biology which studies the dynamic interactions between plants, animals, and micro-organisms and their environment, working together as a functional unit. Ecologies are living systems containing a diversity of factors that interact with each other and are self-organizing, adaptive, and fragile.

The term ecology has been applied to the concept of learning as a metaphor for the many different tools, technologies, systems, and processes that interact with each other to promote knowledge. The term ecosystem is often used to describe all sources of learning that are available to employees within their organization; however, each organization has its own processes, contexts, relationships, and interactions that provides opportunities and resources for learning, development, and achievement. Further, the current landscape of institutional learning technologies consists of multiple data stovepipes even within the same organization. Training and education systems do not share information well with human resourcing and personnel systems; nor do they share data with operational systems that are the true indicators of organizational performance.

The *future learning ecosystem* is defined by personalized and competency-based learning environments that promote interoperability and accessibility of learning resources across organizational boundaries and throughout an individual's life. Today we understand that learning takes place both inside and outside the classroom. We live and work within a digital web of learning resources and learning experiences; each resource connects to others and feeds an overall structure in which learning takes place. At the heart of this ecosystem is the learner and the associated policies and processes used to track their learning experiences across the continuum of learning.

The key to managing this *lifelong learning* data is the interoperability afforded through the technical standards, specifications, and practices that comprise the TLA research portfolio. These underpin the wide range of learning resources an individual will encounter and enable a federated data strategy that facilitates the sharing of this information with other systems within an organization and even across institutional boundaries. Conceptual interoperability also includes shared vocabularies, system architectures, frameworks, and reference models that help producers and consumers communicate effectively. The TLA research portfolio is grounded in a chain of research that helps the DoD optimize training and education resources, communicate information and knowledge anywhere and anytime, manage an overall data strategy, and enable greater flexibility for how and when learning should occur. This document is divided into the major sections outlined below.

## 1.2 SPECIFICATIONS AND STANDARDS

*The future learning ecosystem powered by the TLA includes an interconnected, evolving community of learners, tools, systems, activities, and content that must all operate together. Making this shift requires the adoption of common technical standards across institutions, systems, and instructional content.*

Technical specifications and standards allow different learning resources to communicate with each other using a mutually agreeable common language. These standards form the fundamental building blocks for life-long learning by establishing consistent protocols that can be universally understood and adopted by any component within the future learning ecosystem to enable data exchange about learners, activities, and experiences. Beyond the interoperability standards required for integrating tools, learning experiences (activities and content), and a myriad of different data types, TLA research is also looking at shared vocabularies, linked data strategies, performance thresholds and an overall data strategy that ties them all together.

The 2018 TLA research investigated relevant standards, specifications, and policies that relate to metadata strategies, competency representation, activity tracking, Learner Profiles, and numerous communications protocols, and interface specifications. A specification/standard provides definitions, rules, roles, and responsibilities for data components within it. In many cases, a standard or specification will also define how and where data is stored or registered. Numerous specifications and standards were reviewed to investigate how they would influence the interoperable nature of the TLA. Candidate specifications were then implemented and tested within the 2018 TLA Reference Implementation.

Within the TLA Reference Implementation, candidate standards and specifications are analyzed to determine whether the spec/standard is partially or entirely appropriate. If changes are required to extend the spec/standard, this work is documented to inform future standards/specification development bodies. It is important to note that the TLA is looking at specifications and standards used across other industrial sectors (e.g., finance, healthcare, manufacturing), across different communities (e.g., K-12 Education, colleges and universities, corporate learning) and for different purposes (e.g., machine to machine communication, evaluation/assessment). The 2018 research portfolio includes specifications and standards that relate to the following:

- **Interoperability standards:** Characteristic definitions of a TLA component, activity providers, and services including performance thresholds, interface specifications, data models/schemas, etc.
- **Classification standards:** Systematic groupings of data, components, systems, or services based on different characteristics or properties.
- **Standards for testing and evaluation:** Characteristics and minimum thresholds measurements for security testing, regression testing, conformance testing, etc.
- **Standards for compliance and certification:** Description of the functions and relationships between administration, curation, quality assurance, lifecycle maintenance, and governance of future learning ecosystem components, systems, and activities/content.

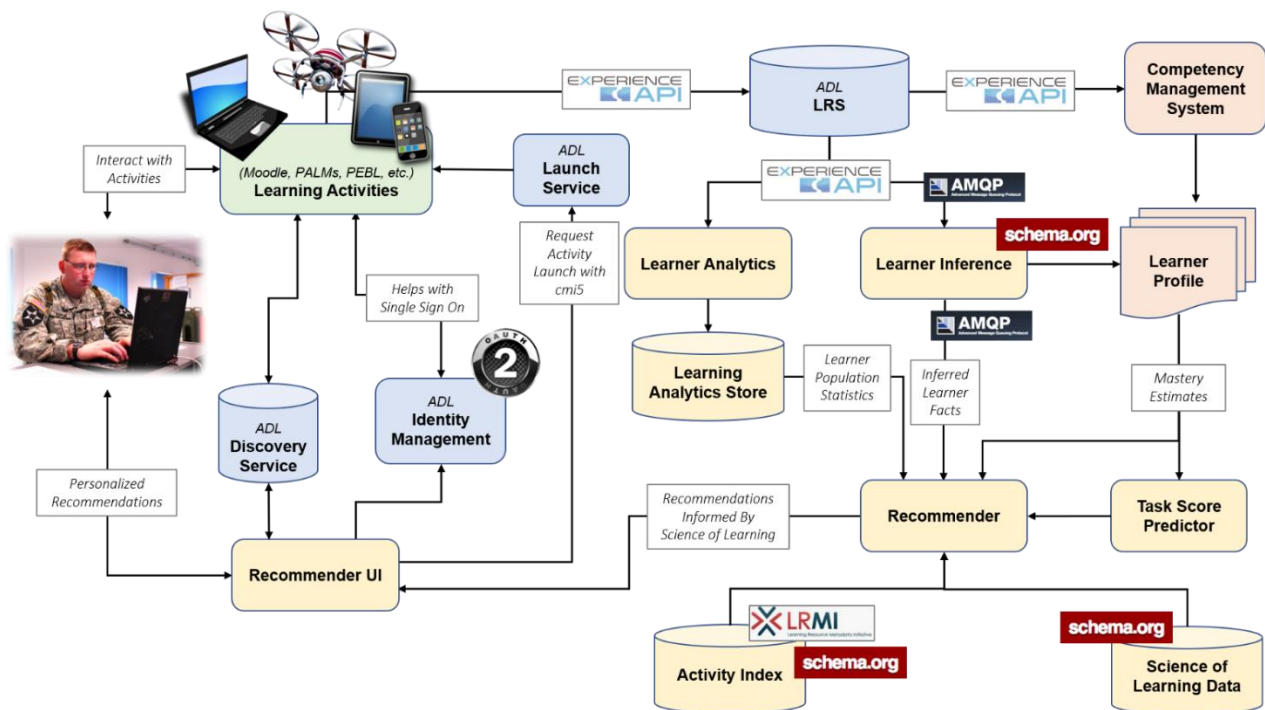
With an ever-increasing amount of options, the task of selecting an approved standard or specification can be difficult. Each has their own advantages and drawbacks, and many have overlapping uses. The future growth of personalization services, data analytics, and integration with other business systems presents numerous challenges in achieving true interoperability between all the disparate data sources required for learning across an enterprise. The ADL Initiative will continue to evaluate different specifications and standards to determine how suitable they are for different aspects of the TLA. Section 2 of this document will describe technical standards and specifications evaluated for use in the 2018 TLA Reference Implementation.

### 1.3 2018 TLA REFERENCE IMPLEMENTATION

The goal of the 2018 TLA Reference Implementation is to evaluate candidate standards and specifications for potential inclusion within the TLA. In creating the 2018 TLA Reference Implementation, the ADL Initiative started with a foundational understanding of existing Information Technology (IT) components commonly utilized in Distributed Learning (DL) today. The reference implementation builds upon these components and in some instances, utilizes the same specifications and standards used by these components. While these existing specifications and standards are considered a starting point for the development of the TLA, the ADL Initiative is investigating additional specifications and standards to determine their applicability and suitability for the future learning ecosystem.

The 2018 TLA Reference Implementation maintained a few high-level considerations and design constraints. First, it was to be developed without proprietary data rights. The commercial products used within the system are open source. All vendor product communication was performed using industry standards. The system and user-action logs were maintained using the experience API. Systems communicated using a RESTful implementation. The system was deployed using Amazon Web Services (AWS) on virtualized server hardware, with purchased Platform and Backend as a Service (PaaS/BaaS).

**Figure 2** shows the major components of the TLA architecture as they were implemented in support of a TLA Test and Demonstration exercise at Fort Bragg in August 2018. This diagram establishes the context for how specifications and standards are currently being applied. The TLA components used in this implementation include a range of Technology Readiness Levels (TRLs) that impact the requirements and even the availability of relevant standards or specifications for certain components of the architecture. A primary goal of the TLA is to support plug and play interoperability of connected components, systems, content, and data. Each implementation of the TLA will utilize any variation of components that are required to meet the goals and objectives for that instance. Approved TLA components and associated specifications/standards will change over time as systems, capabilities, tools, and technologies continue to evolve.



**Figure 2. 2018 TLA Reference Implementation: Logical View** – Activity providers (green) are instrumented with xAPI statements that are streamed to a Learner Record Store (LRS). The ADL Initiative services (blue) include the LRS, Authentication, Identity Management, TLA component discovery, and launch services. A competency management system (orange) collects xAPI assertions from a variety of assessments activities. These assertions are transformed into estimated levels of competency for each learner in the system. A Recommendation Engine (yellow) uses competency information and Learner Profiles to estimate mastery. The Learning Analytics Store collects information about all users in the System. Learner Inference information is also collected about each individual learner in the system. This information is used to augment a Collaborative Filtering algorithm with Content-based filtering that matches content to user characteristics. Learner Inference data was also written back to the Learner Profile that houses competency information. The recommender uses both algorithms to statistically rank each recommendation that was presented to the learner. **For the 2018 Reference Implementation, the Learner Profile and the Activity Index were integrated into other TLA components. However, these will be separate components in future implementations.**



Section 3 provides a detailed description of the specific components and architecture used in the 2018 TLA Reference Implementation. The data that flows between the different learning activities and the core TLA systems and components are areas where specifications and standards were applied in 2018. TLA components can generate terabytes of data in a typical course. Shared services between different components exchange data using a common communication protocol. These protocols are built using commonly available standards or specifications across separate web services. This allows the TLA to stay independent of vendors, products, or technologies and maintains focus on the interoperability between learning systems.

A current snapshot of TLA components and services are shown in **Table 1** and **Table 2**. Entries within these tables reflect current capabilities but will change as the TLA evolves. When instantiated in the 2018 TLA Reference Implementation, some TLA components were aggregated with other TLA components to create efficiencies or to facilitate the exploration of candidate specifications between components. Specifically, the *Activity Index* was instantiated as part of the recommendation engine and the *TLA Learner Profile* was instantiated as part of the Competency Management System. However, both components will be decoupled from those systems and will be set up separately in future TLA iterations.

**Table 1. 2018 TLA Components** – *The future learning ecosystem, powered by the TLA, contains several learning systems that must share data and work together to initiate, tailor, and track different learning experiences. This table lists major TLA components used in the 2018 TLA Reference Implementation.*

TLA Component	Short Description	Related Standards
<b>Activity Index / Activity Registry</b>	The Activity Index/Activity Registry manages the relationship between activities, competencies, enabling and terminal learning objectives, and other relevant information about each activity. It also contains access information and permission to allow access to activities. For 2018, the Activity Index was part of the FLUENT architecture and in the future instantiations will be set up as a separate TLA component.	LRMI, Dublin Core Metadata, LOM
<b>Activity Streams</b>	These streams are time-stamped data about learner experiences tracked across learning activities and throughout the TLA. The Experience API (xAPI), version 1.0.3, is used to track performance inside TLA Learning Activities.	xAPI, Caliper, HPML
<b>Competency Framework</b>	The framework is a model that broadly describes performance excellence within the TLA. Each framework includes numerous competency objects that may be applied to multiple occupational roles.	ASN™, CASE™, O*Net, Medbiquitous
<b>Competency Management System</b>	Competency Management System, CaSS, provides a common language/framework to describe competencies, formalizes the mechanism for collecting evidence of attainment, and manages the lifecycle of learning.	RCD
<b>Credential Management System</b>	Credentials are learning artifacts gained through an organization based on merit. CaSS is the backend to Credential Engine. For the 2018 implementation, CaSS was used for both competencies and credentials.	CDTL, Open Badges 2.0, Verifiable Claims
<b>Data Dashboards, Data Analytics, and Visualizations</b>	These components process data to provide insight and reports. Currently connected to LRS functionality. In future implementations, they will pull data from different systems to mashup different data for different users.	xAPI, TBD
<b>Learner Profile</b>	Learner Profiles store learner data about competencies, achievements, context, and other learner characteristics that may influence different TLA components. For 2018, the Learner Profile was part of the CaSS system. In future instantiations, the Learner Profile will be set up as a separate TLA component.	AIS, CLR

TLA Component	Short Description	Related Standards
<b>Learner Record Provider (LRP)</b>	TLA learning activities include videos, PDF documents, SCORM courses, serious gaming applications, e-books, mobile learning content, concept maps, and multiple different types of assessments.	xAPI
<b>Learner Record Store (LRS)</b>	An LRS, Learning Locker, stores xAPI statements across a wide variety of learning activities, experiences, devices, and platforms.	xAPI, Caliper, HPML
<b>Learning Management System (LMS)</b>	An LMS delivers and manages instructional content, and typically handles student registration, online course administration, and tracking, and assessment of student work.	SCORM
<b>Recommendation Engine</b>	FLUENT – Utilizes data from the LRS, Learner Profile, Activity Registry, and metadata attached to learning content to adaptively sequence the delivery of different learning activities to each individual.	AIS (Too early to evaluate)
<b>Single Sign-On</b>	For the purpose of the 2018 TLA Reference Implementation, the ADL Initiative staff utilized Keycloak™ for identity and access management. This capability allows a user to log-in once and have access to multiple applications within the TLA ecosystem. This was also instrumental in establishing universal unique identifiers for each learner to protect each learner's true identity.	OIDC, OAuth 2.0, SAML 2.0

**Table 2. 2018 TLA Services** – This table lists the underlying services used to enable communications between the different TLA components to communicate with each other.

TLA Services	Short Description	Related Standards / Technologies
<b>Assessment</b>	Within the 2018 TLA Reference Implementation, CaSS utilized a component called an Evidence Mapper. This collected assessment evidence and other data used to infer competency for a specific skill.	QTI, AICC, SCORM, IEEE 1484.11, xAPI
<b>Authorization</b>	Authorization is the access granted by an authority to specific activities/components	Keycloak™, CAC, web3, OAuth 2.0
<b>Authentication</b>	Authentication is the means by which identity is validated with the purpose of access	Keycloak™, CAC, web3, OIDC
<b>Content Discovery</b>	This has not currently been implemented within the 2018 TLA Reference Implementation. But it is being considered for future iterations. This service will be closely tied to metadata generation.	OAI/PMH, SKOS
<b>Identity Management</b>	Identity management is a coordination of services and protocols for preserving and representing a learner's uniqueness across the system.	Keycloak™, CAC, web3, OIDC, UUID
<b>Launch</b>	Launch refers to being responsible for delivery and session management of a resource.	Cmi5, WebSockets
<b>Messaging</b>	Within the 2018 TLA Reference Implementation, numerous messaging services were implemented to push data from one component to another.	http/s, Websockets, AMQP
<b>Metadata generation</b>	This capability was manually created for all content used in the 2018 TLA Reference Implementation. Research into automation tools, techniques, and technologies is expected to inform future iterations.	Schema.org Vocabularies, LRMI, OASIS CMIS, LOM, Dublin Core Metadata
<b>Notifications</b>	Notifications is not currently implemented within the 2018 TLA Reference Implementation but being considered for future iterations.	W3C Push Notifications API, WhatWG Notifications API
<b>Search</b>	Search is not currently implemented within the 2018 TLA Reference Implementation but being considered for future iterations.	SPARQL, PLQL, ElasticSearch
<b>TLA Service Registry, aka Discovery</b>	For 2018, this service exposed a RESTful API for either manual or dynamic IP address registration for all major components and services.	XRDS, REST, WS-Discovery, RAMLET

## 1.4 2018 TLA TEST AND DEMONSTRATION

The TLA Test and Demonstration was held in August of 2018 to assess the 2018 TLA Reference Implementation. The 2018 TLA Reference Implementation was developed by a cross-organizational team to evaluate the various software services, technical components, and learning activities, all of which exchanged data using a candidate set of technical standards and specifications. The 2018 TLA Test and Demonstration provided hands-on experience with the 2018 TLA Reference Implementation by students, instructors and administrators. Additional data was collected as content was tailored and instrumented to work within the reference implementation.

A primary goal of this study was to better understand what the impediments to full adoption and/or diffusion of the TLA might be with the current design. Another goal was to assess the practical functionality of the system and the viability of the candidate specifications used in the 2018 TLA Reference Implementation. Numerous communications protocols, interface specifications, and data models (schemas) are required to facilitate the systems to systems interoperability required by the TLA. Many of these candidate specifications required modifications or custom extensions to meet the requirements for delivering the myriad of different learning activities. The 2018 TLA Test and Demonstration included traditional e-learning content, a browser-based concept-map assessment application, an e-book, micro-learning activities, a computer-based serious game, and physical (non-digital) instructor-led learning activities.



**Figure 3. 2018 TLA Test and Demonstration** - The TLA was tested in collaboration with the John F. Kennedy Special Warfare Center and School (JFKSWCS), Fort Bragg, NC.

The 2018 TLA Test and Demonstration showed adaptation across these different learning activities, but within the context of a single course. Future implementations of the TLA will provide the ability to adapt across learning trajectories, careers, and experiences. The 2018 TLA Test and Demonstration used learning content related to an existing course entitled Combat Observation and Decision-Making in Irregular and Ambiguous Conflicts (CODIAC). As shown in **Figure 3**, it was tested by approximately 60 participants from the Army Special Warfare Education Group (Airborne) (SWEG(A)) at the John F. Kennedy Special Warfare Center and School (JFKSWCS). Testing consisted of users interacting with the CODIAC content for 14 hours over five days, with data collected before, during, and after.

Automated data collection efforts at the event produced a significant quantity of data. The system collected over 450,000 xAPI statements during the 4-day event, which were later anonymized and distributed for use in a TLA hack-a-thon held at the 2018 iFest. Other than xAPI statements, the system captured each learner's final competency profile, their activity history, and statistically significant pre-test and post-test differentials. Additionally, the surveys and focus groups collected learner opinions about usability, relevance, and other impressions from various users of the reference implementation. Section 4 of this document provides an overview of the 2018 TLA Test and Demonstration.

## 1.5 2018 DATA ANALYTICS AND VISUALIZATION

The goal of the hack-a-thon was to present opportunities for a broad community of experts to explore the TLA in depth and discuss new or alternative methods to combine and process learning data to empower analytics. The hack-a-thon investigated the potential of learning analytics, identified new ways to visualize collected data, and exposed gaps in the practical use of the Experience API (xAPI) across different types of media. The ADL Initiative provided a large set of TLA data from the 2018 TLA Test and Demonstration for participants to aggregate, analyze, and visualize. High-level goals presented at the beginning of the hack-a-thon included the following:

- Make multi-activity time-series data accessible to a non-data scientist.
- Correlate activities and outcomes for issuing awards, badges, and credentials (micro-credentials).
- Create visualizations from the existing data set based on content, anomaly detection, or other options.
- Identify publicly available data and third-party APIs that can be instrumented with xAPI to drive analytics.

Hack-a-thon attendees came from a variety of organizations spanning industry, academia, and government. Most participants identified as software developers or data scientists and experience levels were mixed. Participants were organized into groups based on level of experience and focus area. Participants had the opportunity to network with experienced developers, educators, and data scientists to learn best practices for implementing, structuring, storing, and processing xAPI data and other data generated by TLA components at scale. Section 5 of this document presents and discusses these results.

## 2. TLA SPECIFICATIONS AND STANDARDS

Research is continually performed to evaluate how standards and specifications might be utilized across the *future learning ecosystem*, at various stages of a career trajectory, and across institutional boundaries. **Table 3** below 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 for 2018. The following sections provide an in-depth synopsis of how each specification or standard was investigated, utilized, and/or modified to support the 2018 TLA Reference Implementation.

**Table 3. Summary of TLA Specifications** – This table breaks down each specification to show how and where 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
<b>Activity Registry</b>	LRMI	Json	Activity Index
	IEEE 1484.12.1 LOM	XML	Activity Index
	Dublin Core Metadata	XML, RDF	Activity Index
	Schema.org Vocabularies		Activity Index
<b>Activity Stream</b>	IEEE xAPI	http/https with json payloads	Learner Record Store
	IMS Global Caliper	http/https with json-LD payloads	Learner Record Store
	W3C Activity Streams 2.0	Json, json-LD	Needs Research
	SISO HPML		Human Performance Data Model
<b>Competency Management</b>	ASN™		CaSS
	CASE™		CaSS
	O*Net		CaSS
	Medbiquitous		CaSS
	RCD / RCDEO		CaSS
	Others		CaSS
<b>Credentials</b>	CTDL	Credential Authoring Language	Credential Registry
	IMS Global Open Badge		
	W3C Verifiable Claims		
<b>Data Analytics and Visualization Environment</b>	Multiple	DAVE Algorithms, DAVE Visualizations, Data Cards	Dashboards, TLA Portal
<b>Learner Profile</b>	CaSS Proprietary		
	Airmen Learner Record		
	TBD Research		
<b>Learner Service</b>	TBD Research		
<b>Recommender</b>	AIS	Needs Research	N/A
<b>Identify Management / Single Sign On</b>	Keycloak™	OpenID Connect (profile of OAuth2.0)	TLA Common Training and Education Portal
<b>Learner Record Provider - eBooks</b>	ePUB 3 (formerly IEEE ADB), xAPI		

The following sections describe the candidate specifications and standards used for each TLA component or service, providing a thorough evaluation of capabilities and recommended extensions to support TLA requirements with additional insights describing how they complement or compete with other related specifications.

## 2.1 ACTIVITY REGISTRY

The Activity Registry includes an Activity 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 is to understand how the Activity Registry drives a *Common Course Catalog*, populated by different stakeholders. Other research slated for 2019 includes the identification of approaches for integrating paradata into the Activity Registry. The following metadata standards are being looked at to describe TLA content.

### 2.1.1 Learning Resource Metadata Initiative (LRMI)

The LRMI<sup>1</sup> is a common metadata framework developed by Creative Commons (CC) 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](http://Schema.org) in April 2013. This 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. LRMI 1.1 specification is very stable and has seen significant adoption. Within the context of the 2018 TLA Reference Implementation, LRMI was selected because it provided the most contextually relevant data fields to empower the FLUENT recommender.

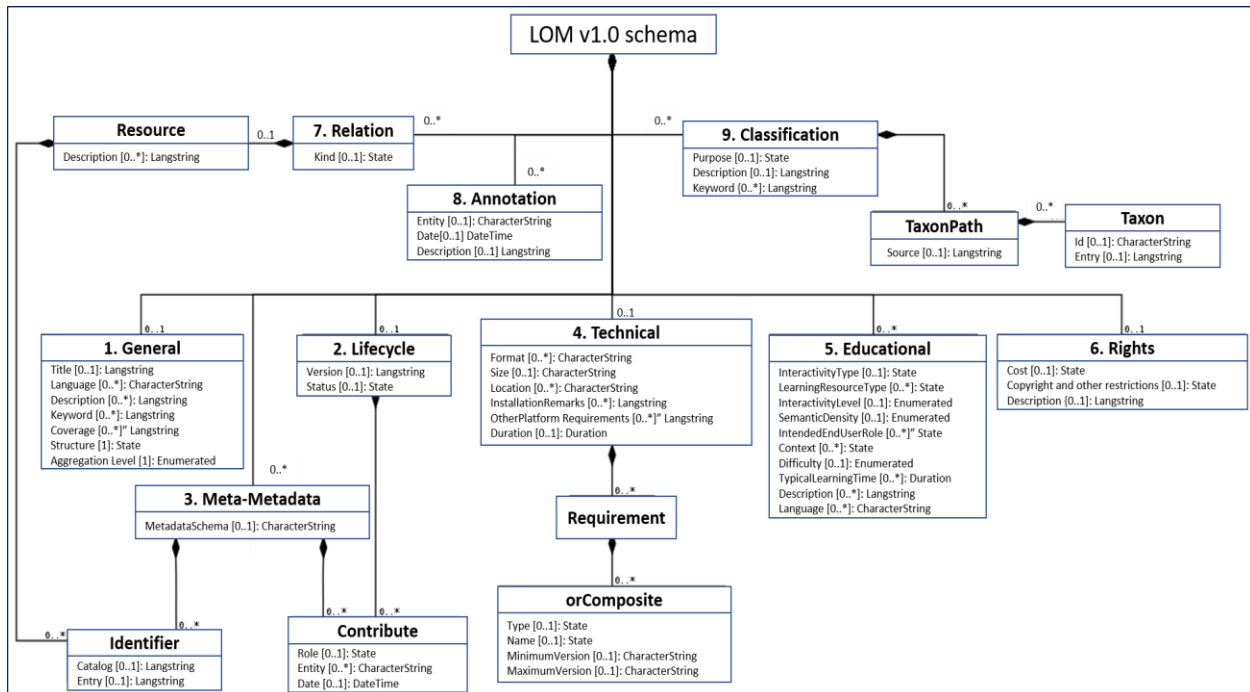
The LRMI specification includes an `AlignmentObject` as part of the specification. This object describes an alignment between a learning resource and a node in an educational framework. This feature was used extensively in the 2018 TLA Reference Implementation. The 2018 alignments included educational 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. The 2019 research effort needs to build out a minimum set of metadata requirements that should be implemented for any future learning activities or content.

---

<sup>1</sup> <http://lrmi.dublincore.org/>

### 2.1.2 IEEE 1484.12.1 Learning Object Model (LOM)

As shown below in **Figure 4**, Learning Object Model (LOM)<sup>2</sup> 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 learning objects, 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 these descriptions; it also defines how this data model can be amended by additions or constraints. The metadata is hierarchical, starting with a root and expanding to leaf nodes. Alignment of an object can be connected to a discipline, idea, prerequisite, educational objective, accessibility, restrictions, educational level, skill level, security level, or competency.



**Figure 4. Learning Object Metadata** – LOM comprises a hierarchy of elements that includes 9 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. <https://commons.wikimedia.org/w/index.php?curid=16026109>

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<sup>3</sup>, developed by the Medbiquitous consortium extends the LOM standard and provides custom vocabularies for some metadata elements.

<sup>2</sup> <https://ieeexplore.ieee.org/document/1032843/>

<sup>3</sup> [https://www.medbiq.org/working\\_groups/learning\\_objects/HealthcareLOMSpecification.pdf](https://www.medbiq.org/working_groups/learning_objects/HealthcareLOMSpecification.pdf)

The attributes defined by the metadata are clear and the rules surrounding the specification drive interoperability. The LOM specification (1484.12.1-2002) is very stable and has seen significant adoption. The ADL Initiative stakeholders have thousands of SCORM courses and other content that has been encoded with LOM metadata so any TLA component that relies on metadata needs to be compatible with LOM. As with most metadata formats, the consistency of quality metadata is a known issue.

### **2.1.3 Dublin Core Metadata Initiative (DCMI) Metadata**

The Dublin Core Schema<sup>4</sup> is a small set of vocabulary terms that describe digital resources (video, images, web pages, etc.), as well as physical resources such as books or CDs, and objects like artworks. The Dublin Core Metadata Element Set is a vocabulary of fifteen properties for use in resource description. It is part of a larger set of vocabularies and technical specifications maintained by the DCMI. Dublin Core metadata may be used for multiple purposes, from simple resource description to combining metadata vocabularies of different metadata standards, to 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 RDF, more recently in the context of the Linked Data movement. The DCMI assumed stewardship of the LRMI specification in 2014. The Dublin Core schema is relevant because it is widely used across the Internet. 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.

### **2.1.4 Schema.org Vocabularies**

Founded by Google, Microsoft, Yahoo and Yandex, Schema.org vocabularies<sup>5</sup> are 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 provides 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. Currently, *CreativeWork* properties include *educationalUse* and *educationalAlignment*. A more specific type of *CreativeWork* includes a *Course*<sup>6</sup> 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.

As shown in **Figure 5**, a learning activity is a schema.org→*Thing*→*CreativeWork* that inherits the properties that every schema.org *Thing* has and can be used to support multiple forms of alignment that are

---

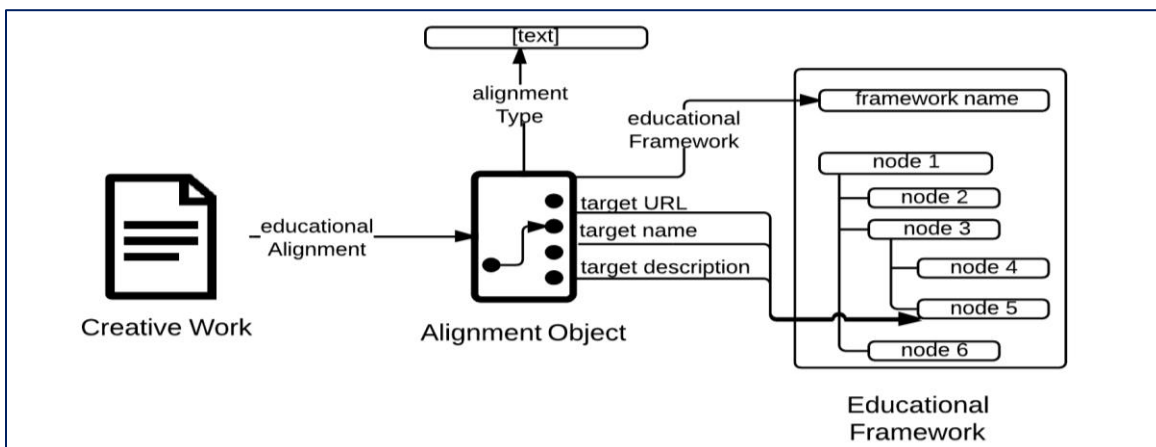
<sup>4</sup> <http://www.dublincore.org/specifications/>

<sup>5</sup> <https://schema.org/>

<sup>6</sup> <https://schema.org/Course>



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 a substantial corpus of paradata about how different types of content apply to different instructional domains and enables new insights into which content is more effective.



**Figure 5. Alignment between a Schema.org CreativeWork and a Node in an Educational Framework<sup>7</sup>** – *The 2018 TLA Reference Implementation used LRMI's AlignmentObject to reference a competency framework that provided a structured description of required knowledge, skills, abilities, and their interrelated relationships.*

## 2.2 ACTIVITY STREAMS

The future learning ecosystem will offer a wide range of learning content across the continuum of learning. One learner may spend time reading technical articles or writing a blog post while another interacts with video content and interactive exercises. Activity Streams are 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. 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.

<sup>7</sup> <https://blogs.pjtk.net/phil/explaining-the-lrmi-alignment-object/>

### 2.2.1 Experience API (xAPI)

The xAPI<sup>8</sup> specification is in the process of becoming a standard through the Institute of Electrical and Electronics Engineers – Learning Technology Standards Committee (IEEE-LTSC)<sup>9</sup>. 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, CPR dummies, serious games and simulations, and any number of other learning systems. The “xAPI Profile Specification”<sup>10</sup> 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.

A Learning Record Store (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 REST to ensure all data from xAPI can be stored and retrieved. It can share data and transcripts with other LRSs so learning experiences can follow you from one organization’s LRS to another. An LRS could be optionally integrated with any application such as an LMS, human resources (HR) 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.

### 2.2.2 IMS Global Caliper

The Caliper Analytics® Specification<sup>11</sup> defines a set of concepts, relationships, and rules for describing learning activities. Each activity domain is described in a metric profile that models a learning activity or any supporting activities. Each profile provides a shared vocabulary that developers use to describe user interactions in a consistent manner. Each profile is composed of one or more Event types (e.g., AssessmentEvent, NavigationEvent). Each Event type is associated with a set of actions undertaken by learners, instructors, and others. A Caliper Event describes the purposeful action undertaken by the actor within a given learning context. The data model is based upon the (Actor, Action, Activity) triple. Various Entity types representing people, groups, and resources are provided to describe the relationships established between participating entities and the contextual elements relevant to the interaction (e.g., Assessment, Attempt, CourseSection, Person).

Storage or data retrieval capabilities are not defined as a part of the specification; however, the defined data attributes about Events and Entities are clear and the rules surrounding the specification drive

---

<sup>8</sup> <https://github.com/adlnet/xAPI-Spec>

<sup>9</sup> <https://www.tagxapi.org/>

<sup>10</sup> <https://github.com/adlnet/xapi-profiles>

<sup>11</sup> <https://www.imsglobal.org/sites/default/files/caliper/v1p1/caliper-spec-v1p1/caliper-spec-v1p1.html>

interoperability. It is comparable to the xAPI specification but offers a more controlled vocabulary. It does implement ideal behaviors that xAPI has identified for future profiles. The Caliper specification appears to be gaining adoption across learning tool providers including Blackboard, Canvas, and others. Because other IMS Global standards are prevalent in K-12 education, it is anticipated that adoption will continue to grow.

### 2.2.3 W3C Activity Streams 2.0

The W3C Activity Streams<sup>12</sup> is an open format specification for activity stream protocols, which are used to syndicate activities in social web applications and services, like those in Facebook or LinkedIn. An *Activity* is a semantic description of an action. This specification describes a JSON-based serialization syntax for the activity vocabulary that conforms to a subset of [JSON-LD] syntax constraints but does not require JSON-LD processing. The Activity Streams 2.0 Vocabulary defines a set of abstract types and properties that describe past, present, and future activities. For example, the activity vocabulary defines five specific types of actors that include *Application*, *Group*, *Organization*, *Person*, and *Service*.

Every JSON object in an Activity Streams 2.0 document is either an object or a link. The object is the primary base type for the Activity Streams 2.0 Vocabulary. In addition to having a global identifier (expressed as an absolute Internationalized Resource Identifiers (IRI) using the *id* property) and an object type (expressed using the *type* property), all instances of the object type share a common set of properties normatively defined by the activity vocabulary. Object types are segmented into a set of eight core types, but external vocabularies can be used to express additional detail not covered by the activity vocabulary.

This specification presents opportunities for future TLA implementations. The W3C specification is already in use across many social platforms that are already part of the future learning ecosystem. Additional value may also be found in the way this specification implements *properties* and their ability to push/pull metadata about different objects referenced in the stream (e.g., information about places, content, other people). The capacity to include content metadata as a payload presents interesting possibilities in the way we catalog learning experiences and could have a huge impact on the way a competency management system makes inferences about learner competencies after interacting with a TLA learning activity.

### 2.2.4 SISO Human Performance Markup Language (HPML)

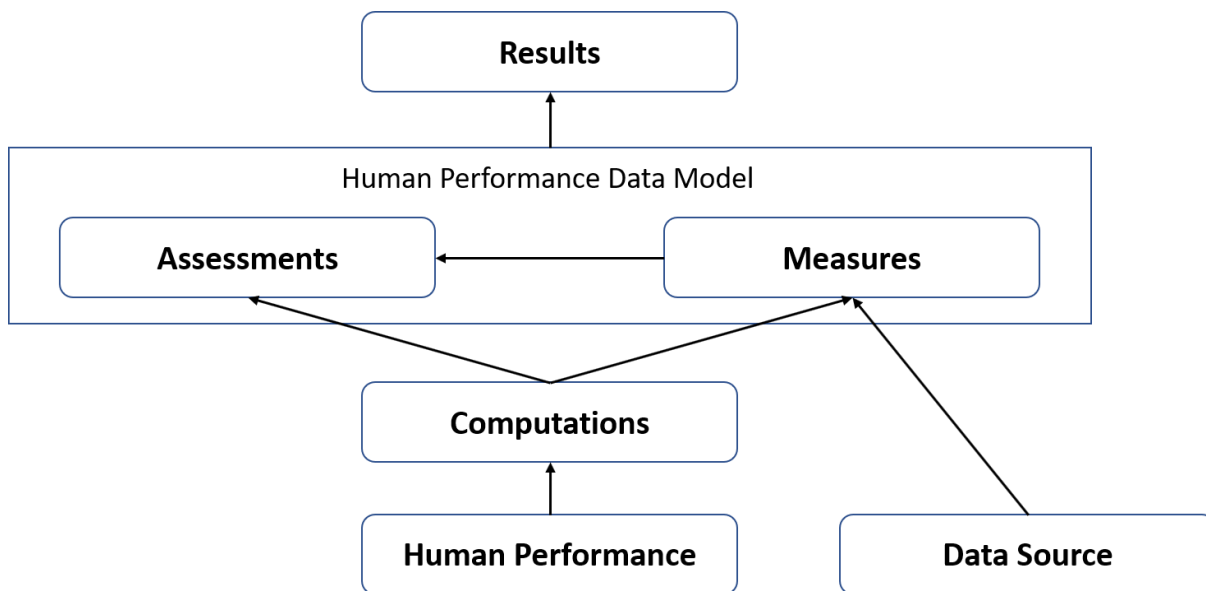
HPML<sup>13</sup> is an XML-Schema-based language intended to support trainers, instructors, leaders and others in the evaluation of individuals and teams as they perform their job functions. HPML provides schemas for organizing the information relevant to defining performance measurements, including 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 6**, HPML provides a flexible framework for configuring and executing performance measurement and assessments. The schema is separated into six distinct groups that make up the core components of HPML and can be added to or expanded with additional links in the schemas.

---

<sup>12</sup> <https://www.w3.org/TR/activitystreams-core/#documents>

<sup>13</sup> <https://discussions.sisostds.org/index.htm?A0=SAC-PDG-HPML>



**Figure 6. HPML High-Level Conceptual Architecture** – HPML includes a *Human Performance Data Model* that defines a set of rules that dictate how performance data is measures, computed, and assessed. It is agnostic about the kinds of data used to compute the measurements and assessments.

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. This is especially useful when considering approaches for collecting performance data out of live, virtual, and constructive simulations, but also provides immediate value to the TLA in formalizing a method for rolling up future learning ecosystem activities into meaningful assessments. More specifically, by externalizing the measurement and assessment specifications, these can be used with any data source (e.g., other activity streams).

### 2.3 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 (CBL) 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. Some of these competency specifications are included later in this section.

### 2.3.1 Achievement Standards Network™ (ASN™)

ASN™ provides access to machine-readable representations of learning objectives and curriculum standards<sup>14</sup>. It provides an RDF-based framework based on the Dublin Core Metadata Initiative's (DCMI) syntax-independent abstract information 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 BIBFRAME profiling.

### 2.3.2 Competencies and Academic Standards Exchange™ (CASE™)

The IMS Global Competencies created the CASE™ specification<sup>15</sup> to define how systems exchange and manage information about learning standards and competencies in a consistent and digitally-referenceable 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 or 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 Parent/Children statements like `Precedes`, `IsRelatedTo`, `Exemplar`, and `IsPartOf`. 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.

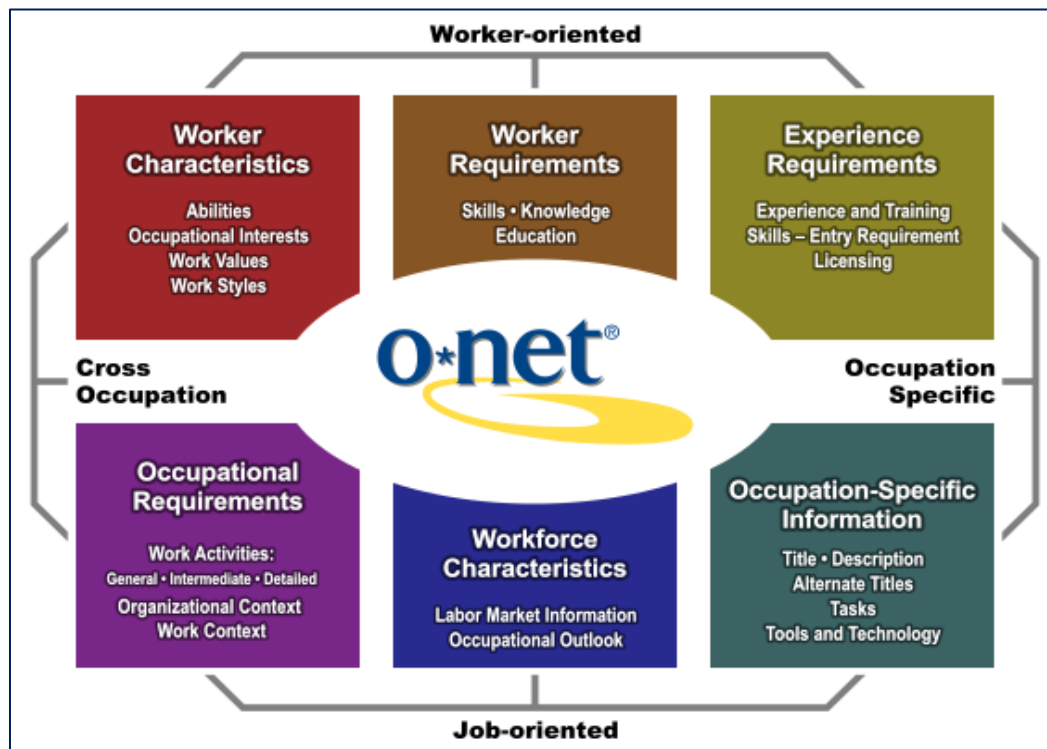
---

<sup>14</sup> <http://www.achievementstandards.org/>

<sup>15</sup> <http://www.imsglobal.org/activity/case>

### 2.3.3 O\*Net

The Occupational Information Network (O\*NET)<sup>16</sup> 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 7**, 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.



**Figure 7. O\*NET Content Model** – This model provides the framework that identifies and organizes the distinguishing characteristics of an occupation. The model defines the key features of an occupation as a standardized, measurable set of variables called descriptors. This hierarchical model starts with six domains that expand to 277 descriptors.

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<sup>17</sup>. 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 the COOL projects for [Army](#), [Navy](#), [Marine Corps](#), and [Air Force](#).

<sup>16</sup> <https://www.onetonline.org/>

<sup>17</sup> <https://www.onetcenter.org/crosswalks.html>

### **2.3.4 MedBiquitous Competency Framework**

The MedBiquitous Competency Framework<sup>18</sup>, 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 professions 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.

### **2.3.5 IEEE 1484.20.1 Reusable Competency Definitions (RCD)**

The current RCD standard<sup>19</sup> 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 Working Group (WG) 20<sup>20</sup> 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 will monitor this WG for progress.

## **2.4 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 encapsulates 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

---

<sup>18</sup> [https://www.medbiq.org/working\\_groups/competencies/index.html](https://www.medbiq.org/working_groups/competencies/index.html)

<sup>19</sup> <https://ieeexplore.ieee.org/document/4445693>

<sup>20</sup> <http://sites.ieee.org/sagroups-1484-20-1/>

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.

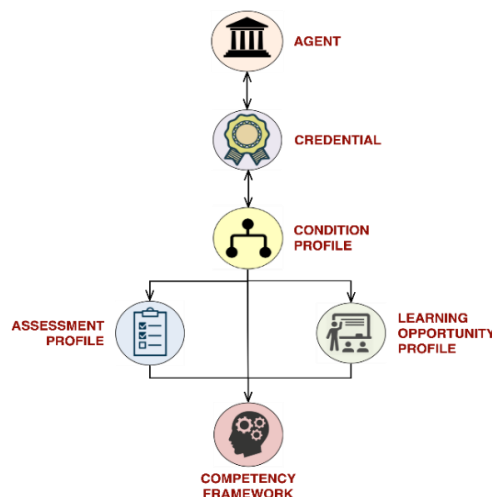
### 2.4.1. Credential Transparency Description Language (CTDL)

CTDL<sup>21</sup> 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 *Badges*.

The comprehensiveness and scope of this specification makes it ideal for defining TLA credentials. As shown in **Figure 8**, two super classes called `Agent` and `Credential` define sets of subclasses. The primary classes also include the `ConditionProfile` used to define sets of constraints on the credential described by an `AssessmentProfile`, `LearningOpportunityProfile`, or `CompetencyFramework`. These are used to express learning goals and outcomes.

### 2.4.2 Credential Registry

The Credential Registry<sup>22</sup> 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, third party approval status and more.



**Figure 8. CDTL Class Structure** – Six primary classes structure the data used to express learning goals and outcomes.

Credential Engine developers are using Dublin Core Application Profiles to create systems that communicate all aspects of credentials. The Technical Advisory Committee (TAC) promotes collaboration across different standardization initiatives that are developing data models, vocabularies, and schemas for credentials and competency frameworks. The Credential Registry uses CTDL to capture, link, update, and share up-to-date 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.

<sup>21</sup> <http://credreg.net/ctdl/handbook>

<sup>22</sup> <https://www.credentialengine.org/credentialregistry>



### 2.4.3 IMS Global Open Badges

Open Badges<sup>23</sup> 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 (*Assertion*, *BadgeClass*, and *Profile*) 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.

### 2.4.4 W3C Verifiable Claims

The mission of the verifiable claims<sup>24</sup> is to make expressing and exchanging credentials that have been verified by a third party easier and more secure. The basic components of a set of verifiable claims include a subject identifier, claims about the subject, claim set metadata, and a digital signature. Both the *Entity Profile Model* and *Entity Credential Model* consist of a collection of name-value pairs which will be referred to as properties in the data model. The link between the two is in the id property. The Entity Profile Model defines a subject identifier in the id property, while the claims section of the Entity Credential Model uses the id property to refer to that subject identifier. The first working draft of this specification was released in August 2017. Additional research is required to better evaluate its applicability to the TLA. However, the defined data model and structure of this specification implies that it could connect both semantically and syntactically. The data associated with verifiable claims are largely susceptible to privacy violations when shared with other TLA components so many of the verifiable claims *use cases* should be used to inform how PII centered on credentials should be protected within the security boundaries of the TLA.

## 2.5 LEARNER PROFILE

There are numerous 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?

Learner Profiles exist in many systems and are extremely diversified in nature. 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 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

---

<sup>23</sup> <https://www.imsglobal.org/activity/digital-credentials-and-badges>

<sup>24</sup> <https://www.w3.org/TR/verifiable-claims-data-model/>

Learner Profile may also include demographic data, student interests, learning preferences, descriptions of preferred learning environments, inter/intrapersonal 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.

While no formal specifications were used in the 2018 TLA Reference Implementation, numerous insights were learned that will influence future research. The 2018 TLA Test and Demonstration exposed a multitude of learner-related data was generated and consumed by different TLA components. This illustrates the need for a *Learner Profile Service* that allows different components and activities to exploit relevant information about each learner. To maximize the value these components can gain from the learner data, a broad and consistent taxonomy is necessary to describe and characterize the different attributes about each learner. Business rules are also needed to manage how this data is used across the *Future Learning Ecosystem*.

Existing Learner Profile specifications (e.g., LIP, PAPI) are somewhat dated. Their bindings are described in the XML language which is not appropriate for semantic interoperability. In some ways, these standards hinder the process of sharing and reusing Learner Profiles because it is difficult for applications to exploit profiles that are stored deep within various servers. Additionally, these specifications do not easily allow extensions to the schema with additional information that is relevant to other TLA components.

### **2.5.1 Comprehensive Learner Record (CLR)**

IMS Global led the development of the CLR<sup>25</sup>, 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, learning management systems (LMS), or other internal databases.<sup>26</sup> 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 Federal government stakeholders.

### **2.5.2 Learner Information Package (LIP)**

The IMS LIP specification<sup>27</sup> provides a standard means for recording information about learners. It is designed to allow information about learners, including their progress to date and awards received, to be transferred between different software applications. In this specification, the learner information is separated into eleven main categories of information that are: Identification, Qualifications/Certifications/Licenses (QCL), Accessibility, Activity, Goal, Competency, Interest, Transcript, Affiliation, Security Key, and Relationship. The LIP specification describes the data structures, XML binding, and best practices for the formatting, storage, and exchange of learner information.

---

<sup>25</sup> <https://www.imsglobal.org/activity/comprehensive-learner-record>

<sup>26</sup> <https://library.educause.edu/~media/files/library/2019/1/eli7164.pdf>

<sup>27</sup> <http://www.imsglobal.org/profiles/index.html>

The specification supports the exchange of learner information among learning managements systems, 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 future learning ecosystem will require real time learner services that can send and update records on the fly. An accessibility for LIP standard<sup>28</sup> 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.

### 2.5.3 IEEE Public and Private Information for Learners (PAPI Learner)

The PAPI Learner specification<sup>29</sup> 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 is the logical division, separate security, and separate administration of several types of learner information. This specification partitions the learner record 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 and addresses issues of privacy and security. The data models associated with this specification is 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*.

### 2.5.4 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 21<sup>st</sup> century. The ALR is a comprehensive record of all learning Airmen achieve during their career including educational transcripts, training records, performance reports, and ancillary training transcripts. The Airmen'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 Airmen's learning record will enhance the

---

<sup>28</sup> [https://www.imsglobal.org/accessibility/acclipv1p0/imsacclip\\_infov1p0.html](https://www.imsglobal.org/accessibility/acclipv1p0/imsacclip_infov1p0.html)

<sup>29</sup> [http://metadata-standards.org/Document-library/Meeting-reports/SC32WG2/2002-05-Seoul/WG2-SEL-042\\_SC36N0175\\_papi\\_learner\\_core\\_features.pdf](http://metadata-standards.org/Document-library/Meeting-reports/SC32WG2/2002-05-Seoul/WG2-SEL-042_SC36N0175_papi_learner_core_features.pdf)

ability to analyze the readiness of the air force by capturing an Airmen'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.

## 2.6 RECOMMENDATION ENGINE

A recommendation engine collects data, analyzes the data, filters the data, and makes a recommendation. While recommender algorithms are not likely to be standardized, they require computationally accessible data to reason over for which technical standards and specifications will play a role. Within the context of the TLA, a recommendation engine uses data filtering algorithms that make use of metadata and paradata<sup>30</sup> about learning resources, competency frameworks and the definitions of competence, Learner Profiles, and other data to inform a probabilistic ranking that guides learner interactions. Beyond the existing specifications and standards that a recommender must interface with, a recommender must be grounded in the science of learning.

This is substantially different from the recommenders most people are familiar with from their experience on Amazon or Netflix. These recommenders use collaborative filtering algorithms, content-based filtering algorithms, or a hybrid of the two. These algorithms make recommendations based on other similar user choices or on other similar content that someone might be interested in. Within the future learning ecosystem, recommendations need to be informed by learning theory. This adds complexity because not all people learn the same way which impedes the collaborative filtering approach. Additionally, the process of learning is a constantly moving target, so content-based filtering is not an ideal situation either, although both will certainly play a role.

### 2.6.1 Fast Learning from Unlabeled Episodes for Next-Generation Tailoring (FLUENT)

FLUENT<sup>31</sup> is an open source recommendation engine used in the 2018 TLA Reference Implementation. It utilized the LRMI metadata attached to various learning resources and information inferred about learners to make its recommendations. FLUENT supports the ability to utilize different instructional frameworks which provides the ability to deliver content recommendations based on different learning theories. This is important as different instructional domains require different instructional strategies.

### 2.6.2 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.

---

<sup>30</sup> Data about how content was being used that was collected.

<sup>31</sup> <https://github.com/soartech/tla/tree/master/learner-profile-interface/src/main/java/com/soartech/fluently>

### **2.6.3 Adaptive Instructional Sciences – IEEE (C/LT/AIS) P247.1)**

The purpose of the Adaptive Instructional Systems (AIS) Working Group<sup>32</sup> is to investigate the market need for standards across a group of technologies known as the AIS. The output of the working group will be one or more PARs identifying and generating specifications and standards that improve the interoperability across adaptive tools and technologies.

## **2.7 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.

### **2.7.1 xAPI Launch**

The xAPI Launch Specification<sup>33</sup> is a method of launching xAPI-enabled content by 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. 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 been widely adopted.

### **2.7.2 cmi5**

The cmi5<sup>34</sup> Profile replicates many of the features and capabilities associated with SCORM. The specification provides definitions, a launch process, a course structure, and runtime communications between a learning management system and learning content. The 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. The 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.

## **2.8 ASSESSMENT SERVICE**

Assessment within the future learning ecosystem will take many different forms. 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 or databases in use across the enterprise will continually be analyzed and assessed to measure the proficiency of individuals and teams within the organization.

---

<sup>32</sup> <http://sites.ieee.org/sagroups-2247-1/>

<sup>33</sup> <https://github.com/adlnet/xapi-launch>

<sup>34</sup> [https://github.com/AICC/CMi-5\\_Spec\\_Current/blob/quartz/cmi5\\_spec.md#content\\_launch](https://github.com/AICC/CMi-5_Spec_Current/blob/quartz/cmi5_spec.md#content_launch)

Many of the standards and specifications referenced in this document include rubrics for measuring performance (HPML, CASE™, Open Badges). Each has its own data structure, evaluation metrics, and format and each needs to be considered as part of the TLA assessment service. Controlled vocabularies are also required to ensure assessments are all speaking the right language and crediting the right competencies.

### **2.8.1 Question & Test Interoperability (QTI®)**

The IMS QTI® specification<sup>35</sup> 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 using UML to facilitate binding to a wide range of data-modelling tools and programming languages. 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.

## **2.9 IDENTITY MANAGEMENT**

The future learning ecosystem requires data exchange across different organizational boundaries and inherently different IT enclaves. The 2018 TLA Reference Implementation used Keycloak™, an open source single sign-on capability to manage individual access and permissions to all TLA components and activities used in the 2018 TLA Test and Demonstration. User names were anonymized through the creation of a universal user ID that each component used when communicating data (e.g., activity tracking) 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.

This is currently achievable at a minimal level through services like ID.me<sup>36</sup> and Login.gov<sup>37</sup>. 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 National Institute of Standards and Technology (NIST) SP 800-63 Digital Identity Guidelines.<sup>38</sup>

### **2.9.1 Privacy and Security for TLA (PS4TLA)**

The PS4TLA<sup>39</sup> research seeks to make recommendations for implementing a privacy by design model where privacy and security strategies are an inherent component of the future learning ecosystem. 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.

---

<sup>35</sup> <https://www.imsglobal.org/question/index.html#version2.2>

<sup>36</sup> <https://www.id.me/>

<sup>37</sup> <https://login.gov/>

<sup>38</sup> <https://pages.nist.gov/800-63-3/>

<sup>39</sup> <https://www.youtube.com/watch?v=opmiFzqfwXo>

## 2.10 MISCELLANEOUS

### 2.10.1 Learning Tools Interoperability (LTI)

The IMS LTI Specification<sup>40</sup> prescribes a way to connect learning applications and tools with platforms like learning management systems, 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.

### 2.10.2 Open Pathways

Open Pathways<sup>41</sup> has the goal to allow publishing and consumption of learning pathways across multiple services much like Open Badges. A learning pathway is an organized set of educational goals connected by specific digital credentials and a community's understanding of what people have accomplished in terms of competencies, or other measures. This model is published using standardized data formats and a common vocabulary across different stakeholder organizations. The Open Pathways effort is in the early stage of development and has little community adoption. However, it has potential to define a common taxonomy for TLA activities and could inform attributes and rules that TLA learning pathways should follow.

### 2.10.3 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 document titled "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 has to *find* the LMS. Once the content has found it, it can communicate through a series of *get* and *set* calls and an associated vocabulary. SCORM is entrenched in the traditional distributed learning community and is still widely used for managing online learning. It provides an important capability for the TLA in being able to deliver online content. The SCORM/xAPI wrapper provides additional capabilities to enable SCORM courses to report to an LRS.

### 2.10.4 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 ePub 3 specification, HTML5, Bluetooth, xAPI, and W3C packaging standards for interactive content. It appears work on this specification is no longer continuing.

---

<sup>40</sup> <https://www.imsglobal.org/activity/learning-tools-interoperability>

<sup>41</sup> <https://www.concentricsky.com/articles/detail/open-pathways-connect-badges-to-what-you-care-about>

### **2.10.5 ePub**

The ePub specification<sup>42</sup> defines a distribution and interchange format for digital publications and documents. 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 (eBooks), and with new versions continues to increase the format's capabilities to better support a wider range of publication requirements, including complex layouts, rich media, interactivity, and global typography features. The expectation is that the EPUB format will be utilized for a broad range of content, including books, magazines and educational, 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.

### **2.10.6 IEEE P1589 Augmented Reality Learning Experience Models (ARLEM)**

The purpose of the ARLEM specification<sup>43</sup> is to become an overarching integrated conceptual model that describes interactions between the physical world, the user, and digital information to establish the context for Augmented Reality (AR) applications used for learning. It will define the required 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. Therefore, a thorough review has not been possible. A review of draft documentation found that while ARLEM attempts to formulate a standardized taxonomy around Augmented Reality (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 to determine how these learning activities can integrate with the TLA.

---

<sup>42</sup> <https://www.w3.org/Submission/2017/SUBM-epub31-20170125/>

<sup>43</sup> <http://arlem.cct.brookes.ac.uk/>



## 3. 2018 TLA REFERENCE IMPLEMENTATION

---

This section describes the logical, physical, and operational implementation of the FY18 TLA demonstration. It introduces the interface definitions that will form the core of future TLA implementations, as well as full descriptions of the commercial items used to provide the current test implementation. The document is organized like the architectural elements defined in a system/subsystem design document (SSDD), albeit the requirements traceability section is tailored out. A research summary and lessons learned, from a technology standpoint, is added as Section 5. The research effort did not maintain detailed requirements, although high level functional requirements for the TLA implementation were collected and defined at a series of Technical Integration and Planning (TIP) meetings held throughout the year leading up to the 2018 TLA Test and Demonstration held at Fort Bragg in August of 2018.

### 3.1 LOGICAL ARCHITECTURE

The TLA Logical Architecture decomposes complexity by separating the TLA into a set of related technical services and principles that support the operation of the system. The service layer in *Figure 1* acts as the bridge between 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 TLA components. Each service includes control logic and user interfaces for a set of functions as depicted in *Figure 9*. 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 a TLA business function. 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.

Specific implementation of data interfaces is described in Section 3.3. The service layers include:

- **User Management:** Handles protection of Personally Identifiable Information (PII), login credentials and identification. In the 2018 implementation this was done primarily by Keycloak<sup>44</sup>. Keycloak™ is an open source Identify and Access Management solution. This service will typically be inherited from the parent organization implementing a TLA instance.
- **Resource Management:** For the 2018 event, the physical location and endpoints of TLA components were managed manually via a static index. Resource Management services are already used by the ADL Initiative stakeholders to manage dorm rooms, live training logistics, simulator schedules, and other capabilities. This data could be used to inform the TLA.
- **Competency Management:** Tracks overall competency state for selected goals and makes assertions based on evidence provided via xAPI. The Competency and Skills System (CaSS)<sup>45</sup> performed the competency service for the 2018 event. The CaSS project includes a Learner Profile as an internal data store that archives mastery estimates and user metadata for each learner.
- **Activity Management:** Manages the thread of assigning content to satisfy an identified goal. Activity management in 2018 included a recommender service that prioritized recommendations based on inferences made from the learners' performance. The FLUENT system performed the activity management functions in the 2018 TLA Reference Implementation. FLUENT also acted as the primary student interface for the TLA.

---

<sup>44</sup> <https://www.keycloak.org/index.html>

<sup>45</sup> [www.cassproject.org](http://www.cassproject.org)

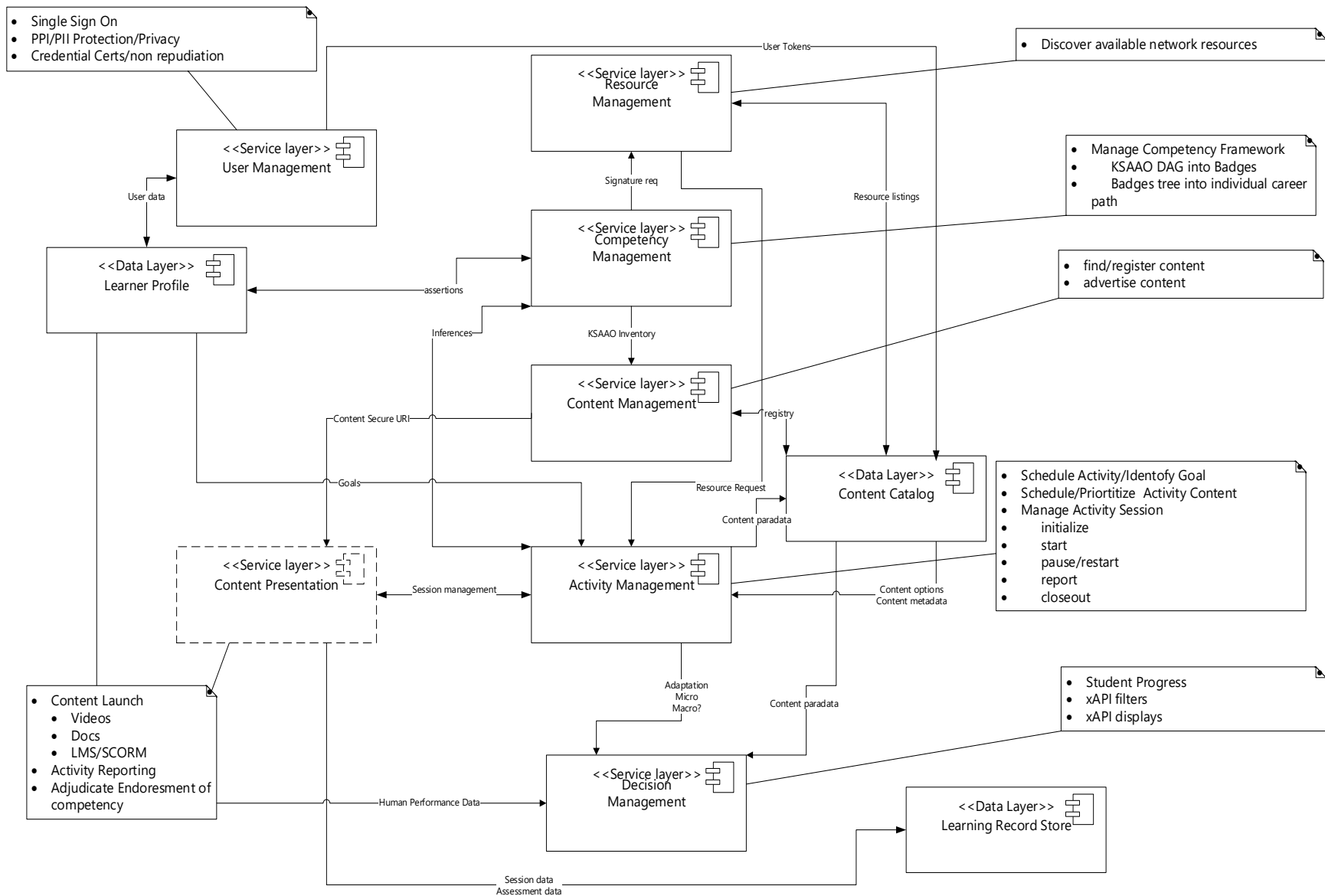
- **Content Management:** Manages the registration of content. In the 2018 Implementation, this was a static file called the Activity Index, which included metadata for all content in the 2018 content database. It was managed in an offline manual process, and physically co-located with the FLUENT instance.
- **Decision Management:** Manages the presentation and analysis of aggregate data for making learner, curricular, facility and other decisions. In the 2018 TLA Test and Demonstration, this was an offline process using commercial tools built into the LRS, or with exports in Microsoft Excel.

Within the logical services architecture, learning content is technically not part of the TLA, but the content was stored on TLA controlled servers for the purposes of the 2018 TLA Test and Demonstration, so it is included in this description. Content viewers establish data contracts with the TLA ecosystem by acting as “boundary objects.” The Content viewers and a Modified version of Moodle™ thus act as the Learning Record Providers (LRP), generating xAPI statements of user learning experiences, and managing content launch and user ID tokens. The LRPs generate xAPI statements that are streamed to the User LRS. These statements are the raw evidence that the CaSS uses to make assertions of competence.

These assertions are transformed into estimated levels of competency (mastery estimates) for each learner in the system. A recommendation engine (FLUENT) uses competency information and Learner Profiles schedule the delivery of activities through a series of prioritized recommendations. The ADL Initiative managed services include the LRS, authentication, identity management, content discovery (resource management), and launch services.

### 3.2 PHYSICAL ARCHITECTURE

The 2018 TLA Reference Implementation was installed on a set of seven virtual machines hosted by AWS. AWS provides the backend platform hosting, virtualization, and Domain Name Service (DNS) resolution functions. Six of the servers were procured under contract to USALearning, maintained by the ADL Initiative; the seventh was separately procured by the vendor on AWS under the prime CaSS contract. The specifications for each server are listed in *Table 4*. All seven servers used Ubuntu 16 LINUX as the operating system (OS). Web server configuration varied by vendor, with some teams utilizing traditional deployment and others using containerization frameworks. The Server instances communicate between themselves using HTTP over TCP/IP internally to the Amazon campus. The application ports and protocols used to access each service are listed in *Table 5* and described in Section 3.5.



**Figure 9. Logical TLA Services Architecture** – The TLA is implemented as a combination of multiple services (and microservices) and their interactions. Hence the communications between services and their coordination is vital for a successful realization of the architecture. Business functions within the TLA are often comprised of multiple services. Therefore, services cannot always be mapped directly to a specific TLA system or component.

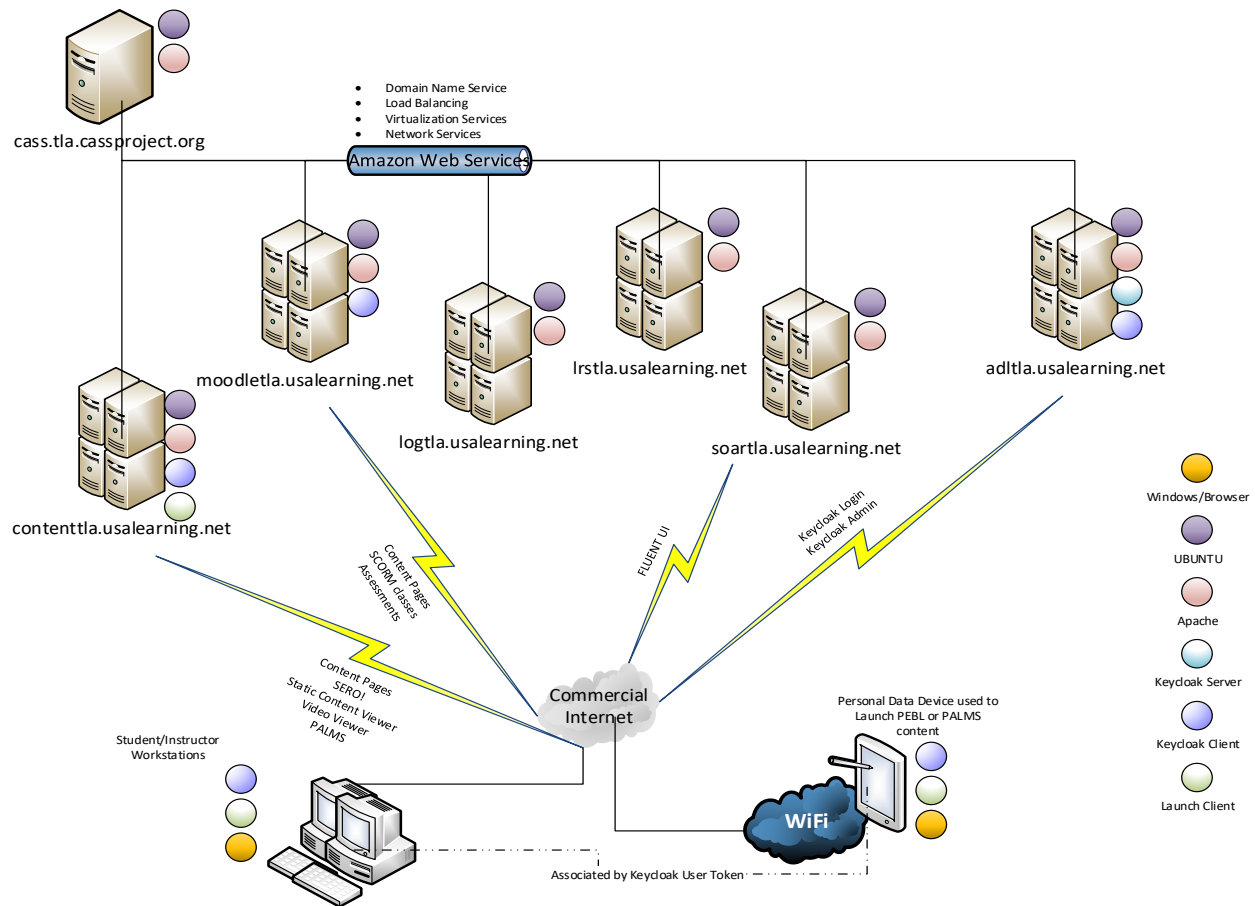
**Table 4. AWS Server Specifications** – The 2018 TLA Reference Implementation utilized a set of 7 virtual machines hosted by AWS. CaSS, FLUENT, Moodle™, and two instances of the Learning Locker LRS were set up to run with a content server and another server configured to run essential TLA services such as single sign-on authentication, launch, and discovery.

Description	EC2 Type	Disk Volume Type	Storage	IOPS	Base Throughput	Snap Storage
VM1-LRS	X-Large	General Purpose SSD (gp2)	200	150	128	150
VM2-LogLRS	X-Large	General Purpose SSD (gp2)	200	150	128	150
VM3-ADLServer	Large	General Purpose SSD (gp2)	50	100	128	0
VM4-SoarTech	X-Large	General Purpose SSD (gp2)	100	150	128	150
VM5-Content	Medium	General Purpose SSD (gp2)	200	150	128	50
VM6-Moodle	X-Large	General Purpose SSD (gp2)	100	150	128	100
VM7-CaSS	X-Large	General Purpose SSD (gp2)	100	150	128	100

While services and systems could be consolidated to run on fewer servers, the simplicity of this approach reduced risk and delineated clear boundaries for what will run on each system in the cluster. Moodle™ requires significant computational resources for each connected learner. Each LRS and the FLUENT recommendation engine also require significant resources for storing the different data elements about systems, learners, and content. A second LRS was added to support the logging of system components about different ongoing activities using xAPI (e.g., data about recommendations, competency assertions, learner inference, etc.). The six elastic IP addresses and 1000GB of data transfer per month was also added to AWS hosting requirements.

As shown below in **Figure 10**, the Student and Instructor Workstations communicated with the AWS servers over the commercial internet using the Hypertext Transfer Protocol (HTTP), accessed through a web browser. The Google Chrome™ 64-bit browser, version 69.0.3497.100, loaded on top of Windows 10 OS was used as the principal interface. The initial login page and credential management were provided by a Keycloak™ Server. Keycloak™ is a commercial, open source, single sign on application that also generates 28 key user tokens to protect PII by avoiding the passage of names, SSN, or other private data.

The FLUENT user interface (UI), hosted on the SOAR Technologies server, provided the main control panel page resources. Learning content pages used a set of browser-based content viewers to interact with learning content. A launcher application installed on the workstations, as well as the Moodle™ Server, managed launch of the individual content viewers of the selected type. A Keycloak™ client application installed on the workstations centrally manages logins. All content viewers except PEBL could launch in new browser sessions on the student and instructor PC workstations. The Personal eBook Learning (PEBL) application launched from an iPad™ personal data tablet device, using the user login to the Keycloak™ app to match user tokens to identify the correct device to launch. This overall physical architecture is depicted in **Figure 3** in the first section of this document.



**Figure 10. 2018 TLA Reference Implementation Physical Architecture** – The TLA’s physical architecture defines the system elements that can perform the functions of the logical architecture. The 2018 TLA Reference Implementation is built from systems, system elements, and all necessary physical interfaces between these elements.

### 3.3 SYSTEM COMPONENTS

#### 3.3.1 Activity Registry

An Activity Registry is an approach to 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 2018 TLA Reference Implementation, the Activity Registry combined cataloging information, usage, assertions, and analytical data into a single, sharable metadata repository. The Activity Registry has a trusted relationship with connected learning resources and other TLA services like launch and discovery. This growing collection of data about learning resources can be consumed by any TLA component. The Activity Registry was deployed as part of the FLUENT recommender; however, future versions will be implemented as a stand-alone capability.

A JSON metadata file was generated for each activity. Metadata was created following the LRMI specification and made specific use of the extension for educational alignments. Beyond the general metadata overhead (e.g., publisher, name, location), a very limited set of differentiators were implemented for 2018. The FLUENT recommender required 5 different metadata types for making its recommendations. Metadata was a semi-automated process using a spreadsheet to manually enter all metadata fields. A script formatted all fields into LRMI formatted JSON file that was uploaded to the Activity Index.

### 3.3.2 xAPI Activity Streams

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. These learning records can then be transmitted to the LRS. Within the 2018 TLA Reference Implementation, the xAPI was used exclusively to track individual learner experiences across different learning activities. System logs were also formatted into xAPI and sent to a separate LRS

### 3.3.3 Learner Record Store

The xAPI-enabled learning activities generate statements, or records of e-learning which include a basic “triple” structure consisting of actor, verb, and object. These statements are transmitted over HTTP or HTTPS to an LRS. The xAPI requires a central storage capability called a Learner Record Store (LRS). An LRS is a data store that serves as a repository for learning records collected from connected systems where learning activities are conducted. It is an essential component in the process flow for using the xAPI. The 2018 TLA Reference Implementation used the open source Learning Locker LRS<sup>46</sup>. Its main function is to store and retrieve the data that's generated from xAPI statements such that all other TLA components may access it without being dependent on direct communication with each other. With the statement structure of the LRS records, native Learning Locker dashboards were generated using a number of different actor, verb, and object combinations.

### 3.3.4 Competency Management System

A competency management system manages evidence of an individual skills, knowledge, abilities, attributes, experiences, personality traits and motivators to predict their value towards effective performance in a job. Competencies might include technical skills, business skills, leadership skills, people skills, ethics, professionalism, or any number of topics related to a job. Within the context of the TLA, the Activity Stream(s) stored in the LRS provide the evidence upon which *competency assertions* are made. Key to establishing assertions of competency from an Activity Stream, is the reconciliation between the Actor in a statement (stored in an LRS) and a persistent Learner Profile. As shown in **Figure 11**, the 2018 TLA Reference Implementation utilized the open source CaSS<sup>47</sup> to manage this evidence and infer competency against the competency framework.

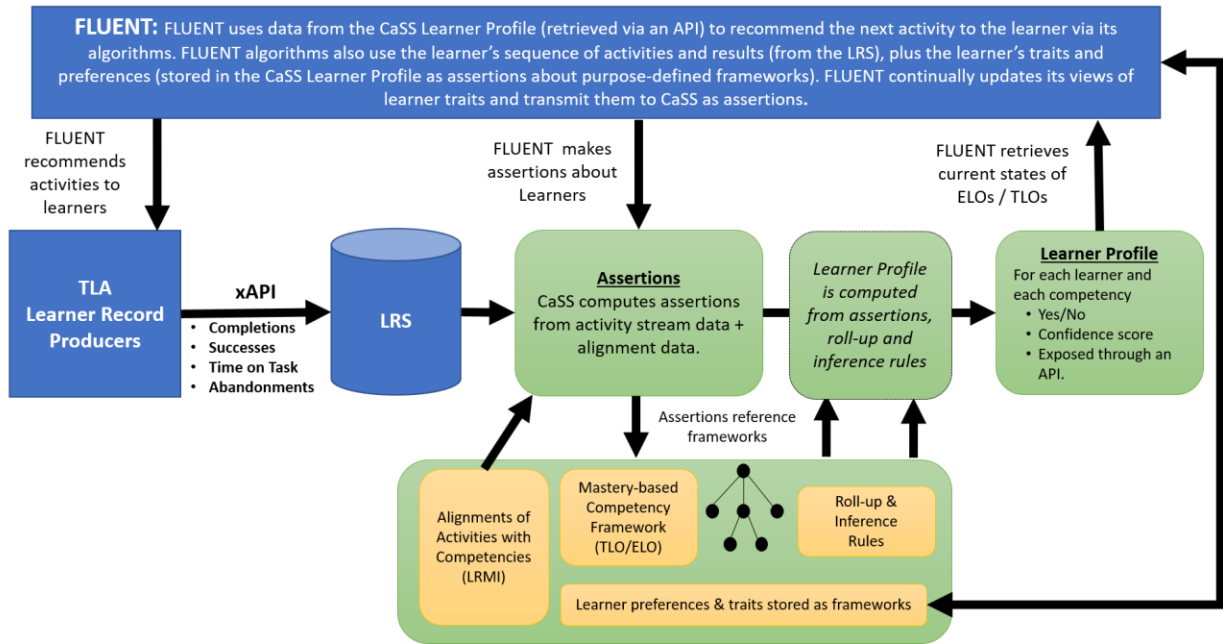
For the 2018 TLA Reference Implementation, CaSS pulled xAPI statements from the LRS and checked the verb to determine whether the statement claims any evidence of competency. For statements that *infer* competency, the ObjectID from the xAPI statement was compared to the *Activity Registry* to determine which competencies a statement is providing evidence for. The primary output from CaSS is a series of mastery estimates for an individual over time. This data is managed within a service layer that provides a common, semantic, and syntactically accessible network service for other systems to leverage. CaSS also enables assertions about an individual's competencies to be collected, processed, and incorporated into a machine-readable Learner Profile. Within the 2018 TLA Reference Implementation, AMQP was used to push this information to other TLA components and other TLA components were able to write to the Learner Profile by making assertions through CaSS.

---

<sup>46</sup> <https://www.ht2labs.com/learning-locker/>

<sup>47</sup> [www.cassproject.org](http://www.cassproject.org)

## 2018 TLA Competency Management Process



**Figure 11. Competency and Skills System** – The 2018 TLA Reference Implementation used CaSS to create, manage, and share information about competencies with other TLA components.

### 3.3.5 Learner Profile

In the 2018 TLA Reference Implementation, the Learner Profile was developed as part of the CaSS project. It primarily contains information about competencies, competency assertions, and credentials. Current and future ADL Initiative research is attempting to understand how different learner characteristics influence the intelligent delivery of content to optimize how a person learns. For example, the 2018 TLA test/demonstration populated the Learner Profile with additional learner inference data from FLUENT that helped the system rank and prioritize recommendations tailored to each learner. Future implementations will continue to explore how a Learner Profile might influence other TLA components.

### 3.3.6 Recommendation Engine

The open source FLUENT recommendation engine uses information about competencies, content, and learners to recommend different learning activities for a user to follow at a given point in time. For the 2018 demonstration, the competencies were divided into *knowledge* domains which were linear in nature and *ill-defined tasks* which required a higher level of understanding to apply the learned knowledge and skills. FLUENT also made use of a small subset of learner information that primarily included mastery estimates for each competency.

To make data-driven recommendations, FLUENT processes information about a learner including their history and context for learning. Learner inference data was derived from the Learner Profile, the LRS, and paradata from individual learners. FLUENT's Collaborative Filtering algorithms look at a user's past behavior and aligns that with the behavior of other users to make a recommendation. Any information derived about a learner was written back to the CaSS Learner Profile using xAPI assertions. FLUENT's content-based filtering algorithms utilize a series of discrete characteristics about an activity, as described in its metadata, to recommend additional items with similar properties.

### 3.3.7 Single Sign On

Single sign-on (SSO) is a property of the TLA's access control of multiple related, yet independent, software systems. With this property, a user logs in with a single ID and password to gain access to all TLA connected systems. While this is not a formal component of the TLA, the ADL Initiative expects that any TLA component will need to operate within an ADL Initiative stakeholder SSO environment. Within the 2018 TLA Reference Implementation, Keycloak™ was used for this purpose. This capability has been integrated to protect Personally Identifiable Information (PII) and to provide information security for learners, content, and organizations.

## 3.4 CONCEPT OF EXECUTION

The basic user thread of execution in the TLA demonstration system starts with the Keycloak™ LOGIN and proceeds otherwise through the FLUENT UI. Learners select goals, and then select from prioritized or un-prioritized content work towards that goal, launch the content, and closeout their performance. The experience closeouts, and any related assessments, are recorded as xAPI statements in the LRS. The goal – activity – content thread continues in a loop until the goals are all satisfied.

Two micro-services were used to communicate data between the different systems. A JSON/REST API was used to provide synchronous services between public facing components such as the recommender UI and the LRS. A RabbitMQ-based implementation of AMQP was used to provide immediate data transfer between server-side components, such as the mastery estimates coming from CaSS which needed to be communicated to FLUENT. Within the 2018TLA Reference Implementation, all data exchange APIs were required to support CRUD (Create, Read, Update, Delete) Operations with error messaging. System logs were embedded into xAPI statements and sent to a dedicated logging LRS, providing additional insight into the behaviors of each component.

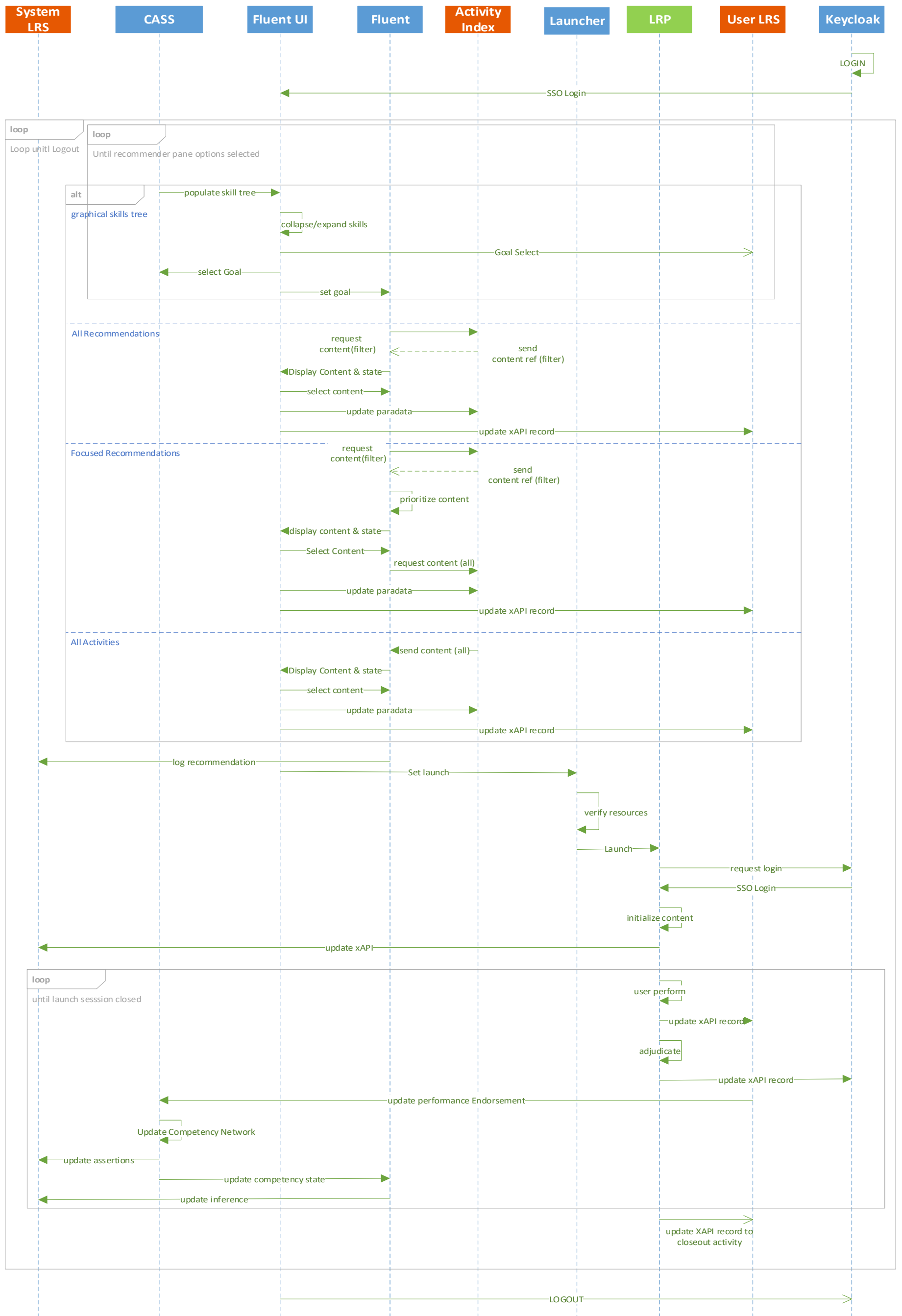
The 2018 Test and Demonstration showed that a pub/sub architecture is necessary for achieving the desired performance for the TLA. The quantity of messages and data that will be present when deploying at scale is very large. While AMQP demonstrated the effect push can have on end users at a small scale, it may not be adequate from a scalability standpoint. FLUENT reported latency issues with the use of linked data and identified it as a performance bottleneck when attempting to achieve real-time data sharing performance. Retrieving data involves following links many layers deep to retrieve sub-parts of the necessary data. If the linked data structure is complex, the number of interface calls required to retrieve the whole data structure can number in the hundreds or thousands. Other work-arounds need to be investigated.

The basic flow for the Run Time Mode is shown in the Unified Modeling Language (UML) sequence diagram of **Figure 12**. There are administrative and diagnostic modes using the native User Interfaces of Moodle™, CaSS, Keycloak™, and Learning Locker which are not shown in the diagram as part of the overall flow of execution. These interfaces were not intended to be accessed by learners. Administrative and diagnostic modes were used to:

- Modify the content discovery and metadata in the activity index.
- Unpin live-locked content by forcing a state change in Moodle™.
- Unpin live-locked competencies by forcing a state change in CaSS.
- Forcing global sign outs if Keycloak™ had an error.

Orange boxes represent system components in the data layer, blue boxes show components in the service layer, and green boxes represent the boundary object of the ecosystem, as depicted in **Figure 9**.





**Figure 12. TLA Reference Implementation Concept of Execution (COE)** – This describes the overall learner experience from their first-time logging into the 2018 TLA Test and Demonstration. The learner signs into the TLA via Keycloak™ and is then directed to the FLUENT User Interface where they remain in an infinite loop of receiving content recommendations until all competencies are completed.

## 3.5 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 next sections describe the interfaces used in the 2018 TLA Reference Implementation. These interfaces represent the operationalization of service contracts defined in the logical architecture.

### 3.5.1 Interface Identification and Diagrams

**Figure 13** shows the specific data interfaces between the low-level components of the System configuration items in the TLA Reference Implementation (which are shown along the top as swim lanes in the diagram. The FLUENT User Interface is the principle interface for the learner. It has the following functions:

- FLUENT launches via HTTP when the user logs into Keycloak™ successfully.
- FLUENT connects via REST calls to the recommender service within FLUENT to obtain the current state of competencies and set user selected goals,
- FLUENT sends launch requests to the launch service via AMQP, connects to Keycloak™ via AMQP, and launches the content viewers as second browser sessions.
- FLUENT connects to the CaSS using HTTP, shares assertions using AMQP and generates xAPI statements to the system LRS by sending JSON over AMQP.

The TLA launch services were embedded into FLUENT which provided the following capabilities:

- The user can launch content for static content viewer or xAPI video viewer via HTTP connected to launch client. This browser sends xAPI messages to the user LRS via JSON over AMQP.
- SCORM and assessment content launch in Moodle™, which loads in its own browser session with the launch function natively communicating through HTTP and generating xAPI statements to the user LRS in AMQP over HTTP.
- PEBL and PALMS content launches in their own browser session and generate xAPI to the user LRS natively using AMQP over HTTP, they host the launch function natively.

### 3.5.2 Advanced Message Queuing Protocol (AMQP)

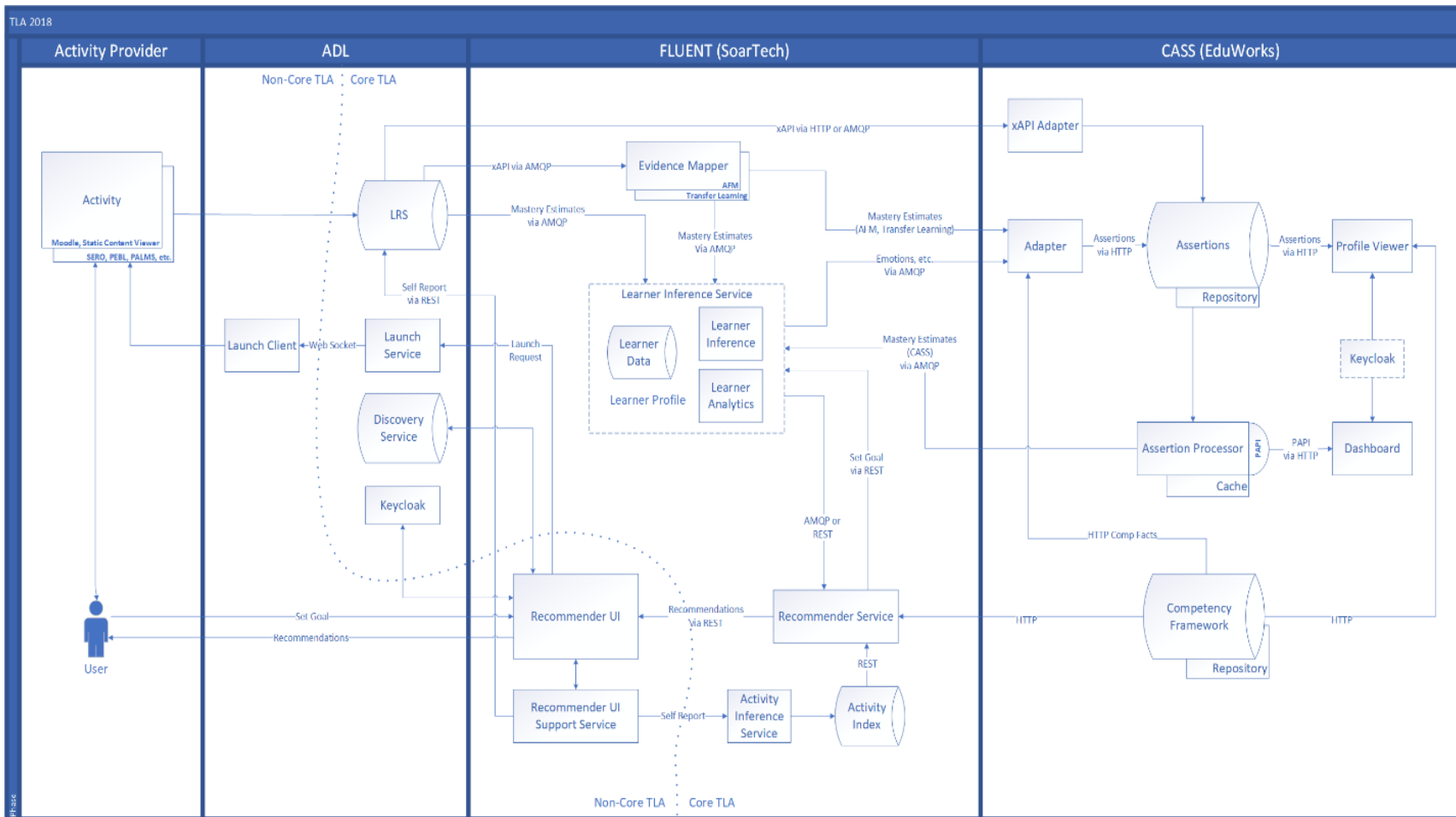
AMQP is an open standard application layer protocol for message-oriented middleware to enable a common messaging service between TLA components. It provides an extensible markup language (XML) based middleware application layer protocol for exchanging information via HTTP requests.

### 3.5.3 Representational State Transition (RESTful)

REST is an architectural paradigm that defines a set of constraints to be used for creating web services, which maintain data and control logic on the edges of communication and uses a series of HTTP based requests to a Universal Resource Locator (URL) or specified address for a network resource

### 3.5.4 Experience Application Program Interface (xAPI)

The xAPI is a specification currently going through the IEEE-LTSC standards development process (<https://www.tagxapi.org/>). 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.



**Figure 13. TLA Reference Implementation Components and Interfaces** – In its current form, the TLA follows a modular open systems architecture that leverages technical standards to support a loosely coupled and highly cohesive system structure. This allows TLA components to be added, modified, replaced, removed or supported by different vendors throughout their lifecycle. TLA components use carefully defined execution boundaries layered onto an integrated framework of shared applications, services, and data. TLA standards are published documents that establish key interface specifications, communication protocols, and data structures designed to facilitate interoperability between TLA components, enable compatibility with a wide range of learning content, and maximize the efficiency for how people learn throughout their career from “hire to retire.” These standards form the fundamental building blocks for life-long learning by establishing consistent protocols that can be universally understood and adopted by any TLA component to enable data exchange about learners, activities, and experiences.

### 3.6 COMPUTATIONAL RESOURCES

The ADL Initiative performed a load test of the server configuration listed in **Table 5** to determine the top end on the performance of the current TLA Reference Implementation. This test was run over the course of 90 minutes and simulated 1,000 instances of a single user signing in, viewing a course, opening and closing a SCORM course, taking a quiz, viewing all users enrolled in a course, and then signing out. The system failed at 10,000 users with Moodle™ unable to handle the load, failing on CPU overload. Memory is not provided as it did not represent a significant resource limit in any case. The network uplink limited component was the ADL Initiative server, likely Keycloak™ request for user ID.

**Table 5. TLA Reference Implementation Application Layer Protocol Port Usage** – Just as the IP address identifies the computer on a network, the network port identifies the application or service running on the computer. This allows TLA servers in the testing environment to run multiple applications and/or services.

HTTP Service	IP Address / URL	Port	Endpoint
CaSS	cass.tla.cassproject.org	80	<a href="http://cass.tla.cassproject.org/api">http://cass.tla.cassproject.org/api</a>
Moodle™	moodletla.usalearning.net	80	<a href="http://moodletla.usalearning.net">http://moodletla.usalearning.net</a>
Static content viewer	contenttla.usalearning.net	8000	<a href="http://contenttla.usalearning.net:8000">http://contenttla.usalearning.net:8000</a>
Video player	contenttla.usalearning.net	8001	<a href="http://contenttla.usalearning.net:8001">http://contenttla.usalearning.net:8001</a>
User LRS	lrstla.usalearning.net	8001	<a href="http://lrstla.usalearning.net:8001/data/xapi">http://lrstla.usalearning.net:8001/data/xapi</a>
Assessment	contenttla.usalearning.net	8002	<a href="http://contenttla.usalearning.net:8002">http://contenttla.usalearning.net:8002</a>
Static content	contenttla.usalearning.net	8003	<a href="http://contenttla.usalearning.net:8003">http://contenttla.usalearning.net:8003</a>
FLUENT UI	soartla.usalearning.net	8004	<a href="http://soartla.usalearning.net:8004">http://soartla.usalearning.net:8004</a>
PALMS	contenttla.usalearning.net	8004	<a href="http://contenttla.usalearning.net:8004">http://contenttla.usalearning.net:8004</a>
Keycloak™	adltla.usalearning.net	8081	<a href="http://adltla.usalearning.net:8081/auth">http://adltla.usalearning.net:8081/auth</a>
Launch client	adltla.usalearning.net	8081	<a href="http://adltla.usalearning.net:8081/application-launcher/client">http://adltla.usalearning.net:8081/application-launcher/client</a>
Launch	adltla.usalearning.net	8081	<a href="http://adltla.usalearning.net:8081/application-launcher/rest">http://adltla.usalearning.net:8081/application-launcher/rest</a>
Discovery	adltla.usalearning.net	8085	<a href="http://adltla.usalearning.net:8085/endpoints">http://adltla.usalearning.net:8085/endpoints</a>
FLUENT UI support	soartla.usalearning.net	8778	<a href="http://soartla.usalearning.net:8778">http://soartla.usalearning.net:8778</a>
FLUENT	soartla.usalearning.net	8979	<a href="http://soartla.usalearning.net:8979">http://soartla.usalearning.net:8979</a>
Activity Index	soartla.usalearning.net	8989	<a href="http://soartla.usalearning.net:8989/activity-index/activities">http://soartla.usalearning.net:8989/activity-index/activities</a>
Learner Inference	soartla.usalearning.net	8999	<a href="http://soartla.usalearning.net:8999">http://soartla.usalearning.net:8999</a>
System LRS	logtla.usalearning.net	80	<a href="http://logtla.usalearning.net/data/xapi">http://logtla.usalearning.net/data/xapi</a>

The point to point nature of all messaging within the 2018 TLA Reference Implementation was also a limiting factor in our ability to aggregate real-time data from different systems into a TLA-driven dashboard. The only analytics available within the 2018 implementation were those that were resident within the Learning Locker LRS. This limited the analytics to xAPI statements which did drive interesting statistics about content usage. However, the 2019 migration to a data streaming architecture enables a data strategy that utilizes data from multiple sources to drive analytics and visualizations.

### 3.7 LESSONS LEARNED AND FUTURE RESEARCH

The use of the system LRS to record assertions and inferences generated almost 75% of the xAPI statements. This is a performance bottleneck for the system as it scales. Since the assertions and inferences are developed continuously, this represents system data with a relatively high Quality of Service (QoS) requirement. This, along with several other concerns drives a desire to move to a streaming architecture for FY19, to ensure scalability and QoS.

The FLUENT application basically served as a singleton for the entire TLA 2018 Reference Implementation because it provides the primary user interface and manages the state space of the execution. The primary interface for the TLA will likely migrate to a common TLA portal. Moreover, a true SOA paradigm should be stateless between service boundaries. Moreover, the FLUENT application was single threaded and caused some performance delays during test and execution. Moving the recommender service to the system edge and improving its performance are goals for FY19 follow on work.

The CaSS calculations of convergence on competency is very sensitive to the weights assigned for the contribution of each content type for making assertions. These weights were determined without scientific rigor, and the FY19 architecture must move them to the edge to allow for human in the loop intervention. Moreover, some students ended up reaching an asymptote below the arbitrary 80% threshold set for competence and it was impossible to push the system farther forward.

The FLUENT recommender relied largely on the metadata assigned in twelve categories to select recommendations. It did not address learning path recommendations, as goals were selected manually by users. The FLUENT UI presentation of the CaSS maintained competency tree did not provide enough information for users to optimize their own learning path. This automation “surprise” should be addressed by the FY19 effort.

Keycloak™ was not implemented correctly, and while it was only chosen as one solution among many possible for SSO, the interface between the TLA services and the backend services used to protect PII and otherwise maintain information assurance should be addressed to facilitate future transition efforts.

The Static content viewer provides a very simple implementation for recording experiences with electronic publications. PEBL content required a full copy of the PEBL content repository and specially rigged content on each client. The ADL Initiative is reviewing the electronic publication technology strategy for FY19.

The Moodle™ version used was not the USALearning version, but required modifications for interoperability with Keycloak™, xAPI, and launch client. The CODIAC SCORM course did not allow fast forwarding to the appropriate point for the specific goal pursued and required the students to complete the entire course. The LMS migration and integration plan must be reviewed for FY19.

## 4. 2018 TLA TEST AND DEMONSTRATION

---

The ADL Initiative worked with the Institute for Defense Analysis (IDA) and the Special Warfare Education Group (Airborne) – SWEG(A), to plan logistics, scope, scale, and domain for the 2018 TLA Test and Demonstration. IDA designed the experiment using SWEG(A) students and the ADL Initiative integrated TLA systems and developed the course and its content. The ADL Initiative staff was augmented by vendors under contract to work on various TLA-related systems.

During the initial meeting with SWEG (A) representatives, a request was made to move away from the cyber and IT training used in the 2017 demonstration. They requested instruction that was more relevant to their mission. In order of preference, they preferred small unit training, 18D medical training, or 18E communications / radio training. The USJFCOM Combat Observation and Decision-Making in Irregular and Ambiguous Conflicts (CODIAC) course was ultimately approved as the foundation for the 2018 TLA Test and Demonstration. To assess the TLA, several research questions were posed. The 2018 TLA Test and Demonstration had the following research objectives:

- Assess the TLA functional requirements, does the TLA 2018 Reference Implementation demonstrate the intended functionality described below categorically?
- Assess the conformance to candidate specifications to allow TLA components and activities to communicate with each other.
- Assess successfully indexing, discovering (service discovery within the architecture), and launching a wide variety of learning activities across devices, operating systems, and modalities.
- Assess the ability of the TLA to track learner competence within a competency framework.
- Assess the ability to produce user learning activity recommendations based on the current state of learner competence.
- Evaluate the metadata strategies used within the 2018 TLA Reference Implementation.
- Assess the potential of the TLA for supporting cross-activity dashboards for instructors, learners, administrators, and others.
- Assess the TLA reference implementation for system-ilities (reliability, availability, maintainability, scalability, interoperability, portability, or others).
- Assess usability and user experience when interacting with the 2018 TLA Reference Implementation.
- Evaluate usability of the 2018 TLA Reference Implementation of the TLA by populations other than end users.
- Evaluate the technical viability of implementation and the diffusion potential compared to previous versions.
- Document system usage to determine whether the system functions as expected.
- Identify costs and potential benefits to different communities.
- Evaluate learning potential and the ability to enhance the learning experience.

A mixed-methods approach incorporating Delphi techniques, surveys, focus groups and a quasi-experiment was used for assessing the TLA. For assessing technical decisions, documentation quality, and diffusion potential, Delphi methods were used with panelists reacting to the API specifications, use-cases, and implementation aids. To assess the APIs, a testing implementation of the TLA was deployed and the functional and non-functional requirements tested with human subjects. To assess the functionality and non-functional requirements of the 2018 TLA Test and Demonstration system, the unit of analysis for examining behavior and results can no longer reside with human subjects but moves to the behavior of the components and APIs comprising the reference implementation and the results as measured by the integrity of the system's behavior compared to requirements. These levels will be assessed through the usage of 2018 TLA Test and Demonstration system level data to determine descriptively the behavior of the testing implementation, its potential, and experiences and levels of effort required to develop for and integrate with the test and demonstration system using the TLA architecture.

## 4.1 TECHNICAL PLANNING

Technical planning and integration meetings were held throughout the year in preparation for the overall 2018 TLA Test and Demonstration event. The first technical interchange meeting was held over 2 days in early March. The purpose was to bring TLA component developers, activity providers, researchers, and end-users together to plan logistics, scope, scale, and domain for the TLA demonstration at Fort Bragg in August 2018. The attendance of these events by representatives from the Special Warfare Education Group (Airborne) – SWEG(A), at Fort Bragg provided the opportunity for dialogue about IT requirements, target audience, instructional content, and other operating constraints. Other attendees included the ADL Initiative SETA staff, government personnel, the Institute for Defense Analysis (IDA), and vendors that are working on different elements of the TLA and the 2018 demonstration at Fort Bragg.

As shown in *Table 6*, numerous planning meetings were held. The first meeting focused on providing background information to build a common understanding of all relevant TLA components, activities, and the CODIAC Program of Instruction. Attendees were divided into three working groups based on their expertise. Risks were identified within each working group. Mitigation strategies were discussed, progress was updated, and a schedule of activities and dependencies was created and agreed upon by all participants within each working group. The three working groups included:

### 1. CODIAC Content Demonstration

- Decompose the 200-hour CODIAC course into a smaller subset that can be used to support the 2018 TLA Test and Demonstration.
- Create a related competency framework.
- Align/augment existing course content.
- Decompose and realign existing CODIAC source materials, identify new related content, design new activities.

### 2. 2018 TLA Technical Integration

- Technical development and integration of TLA components and services.
- Protection of PII and IA conformance.

### 3. CODIAC Content Instrumentation (This working group was eventually absorbed by the Content Demonstration working group)

- Define methods for instrumenting CODIAC learning activities for optimized reporting, analytics, and discovery by the TLA recommendation engine (FLUENT).

To help integrate the products from each working group, regular meetings provided the project team with an understanding of the technical underpinnings developed in each working group. A collaborative SharePoint site was established to help the team maintain a clear understanding of critical dates, milestones, objectives, and next steps for successfully executing the 2018 TLA Test and Demonstration in August 2018. A pilot test was scheduled for late July where a substantially completed walk-through of the course was performed. Numerous issues arose, and a second pilot test was more successful in early August. The ADL Initiative and IDA worked with SWEG(A) to handle all logistics including IRB approvals, IT setup and deployment, participant management and administrative tasks.

**Table 6. Key Planning Events** - Numerous in-person team meetings were held throughout the year. Working groups met weekly.

Month	Key Planning Event	Accomplishments
<b>February</b>	Initial Planning Meeting	The ADL Initiative and SWEG(A) staff meet at Fort Bragg to discuss all aspects of the 2018 TLA Test and Demonstration
<b>March 6-7</b>	Technical Integration and Planning Meeting #1	In person planning meeting focused on engineering efforts for the 2018 TLA Reference Implementation, ISD efforts for the curriculum/course development, and implementation guidance for associated activities
<b>May 7-8</b>	Technical Integration and Planning Meeting #2	In person planning meeting focused on engineering efforts for the 2018 TLA Reference Implementation, ISD efforts for the curriculum/course development, and implementation guidance for associated activities
<b>July 21-24</b>	Pilot Test	In person testing of the 2018 TLA Reference Implementation with representative sample of learning resources connected and substantially complete
<b>August 13-17</b>	TLA Test and Demonstration	One-week course provided to SWEG(A) students. Pretest and surveys completed by students prior to the course. A post-test, surveys, and focus groups were completed by students on the last day of the course.

## 4.2 TLA CONTENT DEMONSTRATION

A key emphasis was placed upon the content demonstration aspects of this event in addition to the instructional relevance of the 2018 TLA Test and Demonstration event. From this perspective, instructional content had to be presented in a logical and intuitive way that maximized our ability collect, analyze and display learning data to the relevant target audience (student, instructor, administrator). By instrumenting a wide array of related content, the demonstration was expected to generate a large amount of inter-connected human performance data (based on individual performance) that can be used to demonstrate the potential of the TLA for observing learner progress across learning modalities.



The TLA is content agnostic; it should be able to equally support any-and-all subject areas. However, to enable empirical testing of the reference implementation, the Combat Profiling domain as taught in the CODIAC course shown in **Figure 14** was selected. Major work efforts included the decomposition of an existing course into approximately 14 hours of instruction, building a related competency framework, establishing levels of mastery, and the alignment of learning resources with specific competency objects. The intention of the working group was to expand the aperture for the types of content the TLA can utilize by going beyond traditional DL content and making use of serious games and simulations, live exercises, eBooks, and other adaptive content that participants may encounter in their lifetime.



**Figure 14. CODIAC** – Inspired by the US Marine Corps’ Combat Hunter program, CODIAC was used as a foundation for the 2018 TLA Test and Demonstration.

#### **4.2.1 CODIAC Course Description**

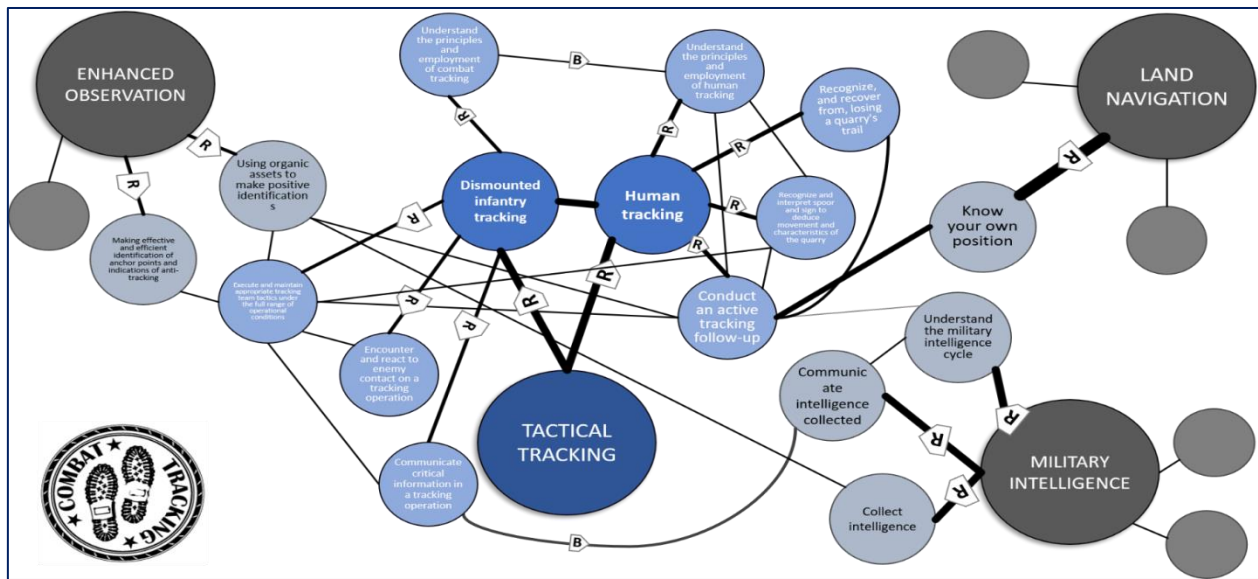
The CODIAC Program of Instruction (POI) includes systematic training designed to improve cognitive skills, showing personnel how to read the human terrain, establish a baseline, detect an anomaly, and make decisions “left of bang.” The CODIAC course is presented as a 200-hour course that includes nine modules with the last module consisting primarily of scenario-based exercises. Of the eight remaining modules, each has explicitly defined Enabling and Terminal Learning Objectives (ELOs/TLOs). Multiple courses of action were discussed by the working group about how to structure the course for the 2018 TLA Test and Demonstration. Initial thoughts were to find content that skimmed across all CODIAC modules to lightly provide an understanding of the entire CODIAC POI. However, after further reviews and discussion, the decision was made to provide a more robust curriculum around the entire course.

The 2018 TLA Test and Demonstration focus on delivering instructional content and learning activities that support a competency-based approach to delivering the CODIAC program of instruction. This course has well-defined learning objectives, instructional activities, and available learning content including structured exercises, activities, and assessments. To successfully learn the required content contained within this module, numerous learning objectives from the different CODIAC modules were analyzed. Supporting knowledge, skills, and abilities were defined, cataloged, and decomposed into their own competency network. **Table 7** on the following page shows the how the ELOs and TLOs were structured for the original course. These were augmented with ELOs and TLOs from other related courses. The modified CODIAC course used for the 2018 demonstration was supported by other educational resources from across the services including the following:

- CODIAC POI, including several hours of edited video – permission received from JSJ7
- Combat Hunter eLearning course – permission received from USMC
- PercepTS Small Unit Leader Kit – Permission received from U.S. Navy

**Table 7. CODIAC ELOs and TLOs.** *These ELOs and TLOs derived from the existing course structure presented a guide for identifying, reviewing, and aligning content with an overall CODIAC Competency Framework.*

Module	Name	Description
<b>TLO1</b>	Left of Bang	This module is about positioning to out-fight the enemy, specifically out-think them too. At the end of this module, learners will explain the importance of operational tempo, of making sense of the situation faster than our opponents to anticipate their actions and be able to act “left-of-bang.”
<b>ELO1.1</b>	Define Consequences	Define consequences of being reactive versus proactive on the battlefield
<b>ELO1.2</b>	Incident Timeline	Explain incident timeline and Left-of-Bang.
<b>ELO1.3</b>	Benefits	Describe benefits.
<b>ELO1.4</b>	Response	Describe when and how to respond Left-of-Bang
<b>TLO2</b>	The OODA Loop	At the conclusion of this unit, trainees will be able to explain the cognitive processes associated with the OODA-Loop, including how these processes are impaired by stress and how decision-making limitations can be mitigated, such as employing the five combat multipliers.
<b>ELO2.1</b>	Cognitive Processes	Explain cognitive processes associated with the OODA loop.
<b>ELO2.2</b>	Define Steps	Define steps in the OODA loop.
<b>ELO2.3</b>	Decision-making	Given various scenarios, explain the process for OODA loop decision-making.
<b>ELO2.4</b>	Behavioral Cues	Effect of behavioral cues on OODA loop and decision-making
<b>TLO3</b>	Baseline + Anomaly = Decision	This module introduces the concept of baseline and anomaly, and how together they require a decision. Upon completion of this module, learners will be able to describe baseline, an anomaly, and how anomalies to the baseline require a decision.
<b>ELO3.1</b>	Describe Baseline	Describe the concept of a baseline.
<b>ELO3.2</b>	Describe Anomaly	Describe the concept of an anomaly.
<b>ELO3.3</b>	Explain Decision-making	Explain why a decision is required when there is an anomaly
<b>ELO3.4</b>	Decision-making Process	Given various scenarios which include anomalies, explain the process for decision-making.
<b>TLO4</b>	Reading the Human Terrain	This unit introduces techniques for interpreting human behavior cues. At the conclusion of this module, learners will be able to describe the six domains of profiling in detail and will be able to demonstrate the six domains’ use.
<b>ELO4.1</b>	Biometrics	Describe biometrics; list several biometric cues and their interpretations. There are 11 specific biometric cues discussed. We may want to decompose further.
<b>ELO4.1.1</b>	Explain Biometrics	Explain the biometrics domain.
<b>ELO4.1.2</b>	Interpret Biometric Cues	Given specific biometric cues, explain what they might mean.
<b>ELO4.1.3</b>	Apply Biometrics	Describe how to apply biometrics in the battlespace.
<b>ELO4.2</b>	Kinesics	Describe Kinesics; list several kinesic cues and their interpretations. There are 8 specific kinesic cues discussed; we may want to decompose further.
<b>ELO4.2.1</b>	Explain Kinesics	Explain the kinesics domain.
<b>ELO4.2.2</b>	Interpret Kinesic Cues	Given specific kinesic cues, explain what they might mean.
<b>ELO4.2.3</b>	Apply Kinesics	Describe how to apply kinesics in the battlespace.
<b>ELO4.3</b>	Proxemics	Describe proxemics; list several proxemic cues and their interpretations. There are 11 specific proxemic cues (4 groups) discussed. We may want to decompose further.
<b>ELO4.3.1</b>	Explain Proxemics	Explain the proxemics domain.
<b>ELO4.3.2</b>	Interpret Proxemic Cues	Given specific proxemic cues, explain what they might mean.
<b>ELO4.3.3</b>	Apply proxemics	Describe how to apply proxemics in the battlespace.
<b>ELO4.4</b>	Geographics	Describe geographics; list several geographics cues and their interpretations. There are 5 specific geographics cues discussed. We may want to decompose further.
<b>ELO4.4.1</b>	Explain Geographics	Explain the geographics domain.
<b>ELO4.4.2</b>	Interpret Geographics Cues	Given specific geographic cues, explain what they might mean.
<b>ELO4.4.3</b>	Apply Geographics	Describe how to apply geographics in the battlespace.
<b>ELO4.5</b>	Atmospherics	Describe atmospherics; list several atmospheric cues and their interpretations. There are 5 specific atmospheric cues (4 groups) discussed. We may want to decompose further.
<b>ELO4.5.1</b>	Explain Atmospherics	Explain the atmospherics domain.
<b>ELO4.5.2</b>	Interpret Atmospherics	Given specific atmospherics cues, explain what they might mean.
<b>ELO4.5.3</b>	Apply Atmospherics	Describe how to apply atmospherics in the battlespace.
<b>ELO4.6</b>	Heuristics	Discuss heuristics and explain how heuristic matches are made.
<b>ELO4.6.1</b>	Explain Heuristics	Explain the heuristics domain.
<b>ELO4.6.2</b>	Explain Dangers of Heuristics	Explain the dangers of the heuristics domain.
<b>ELO4.7</b>	Icons, Colors, and Symbols	List and interpret the relevant icons, colors and symbols in one’s own area of operation. There are 4 specific image-types discussed; with colors having 7 different significances. We may want to decompose further.
<b>ELO4.7.1</b>	Explain Iconography and Symbolism	Explain the importance of iconography and symbolism.
<b>ELO4.7.2</b>	Interpret Icons and Symbols	Give examples of specific icons, color and symbols, and their meanings.



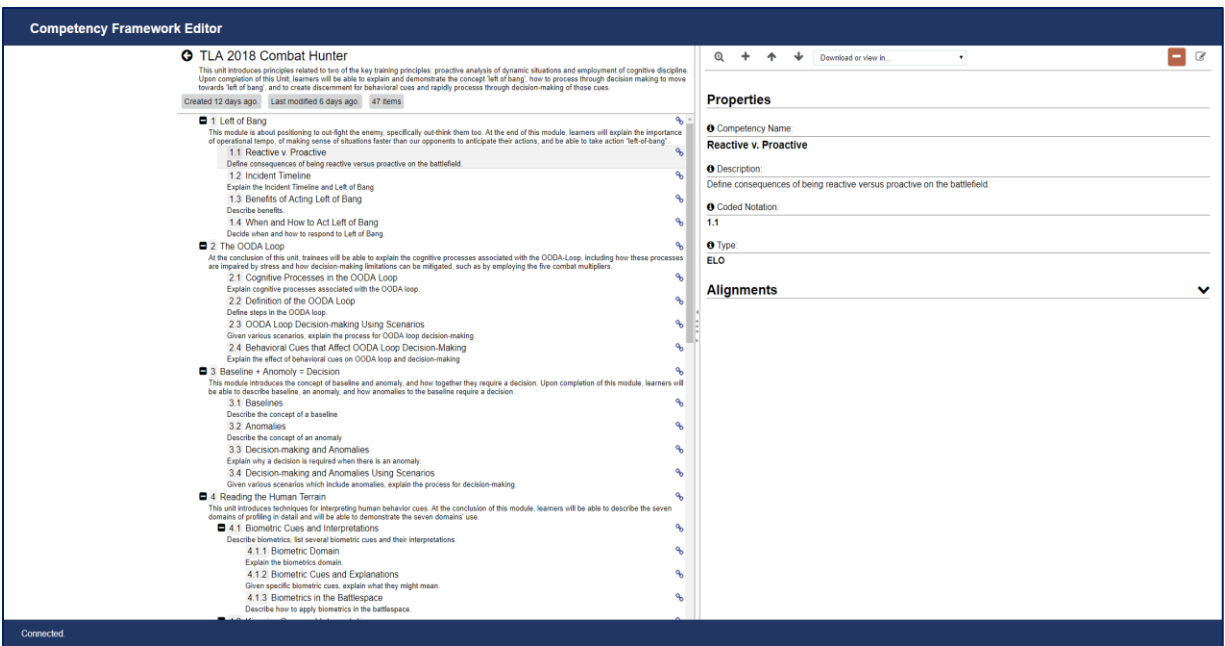
**Figure 15. CODIAC Competency Framework** – The CODIAC course structure provided the foundational ELOs and TLOs that informed the creation of a related Competency Framework. This is an example Competency Framework created around the Combat Tracking TLO.

#### 4.2.2 CODIAC Competency Framework

As shown *Figure 15*, the competency framework developed to support the 2018 TLA Test and Demonstration was largely defined by each competency’s many-to-many relationship with other competency objects. This is complicated by the need to weight the inferred relationship between competencies which are different depending on the context (e.g., job, role, and periodicity) of how they are applied. The discussion highlighted some of the inherent challenges in migrating to a competency-based education system.

The CODIAC ELOs and TLOs were written succinctly so they can be measured and assessed; however, it was determined that the simple mapping of ELOs and TLOs to competencies did not adequately reflect the entirety or potential of what a competency model should include in its definition. Competencies and learning objectives are two related educational terms that can create confusion. Competencies define the applied skills and knowledge that enable people to successfully perform their work while learning objectives are specific to a course of instruction. Learning objectives describe what the learner should be able to achieve at the end of a learning period. There may be more than one measurable learning objective defined for a given competency. While competencies and learning objectives can be written similarly, a competency is obtained or developed during the process of learning and is intended to describe the desired knowledge, skills, and behaviors we want students to walk away with after taking the course.

Due to time constraints, three cross-cutting competency frameworks comprised of 234 interrelated competency objects were created to illustrate how different competencies can be inferred from different assessment activities. Three clusters of competencies were created to include Combat Awareness, Combat Profiling, and Combat Tracking. As shown in *Figure 16*, CaSS was used to encode the frameworks. As assertions are made from existing assessments, they are applied to the relevant competencies included in these three frameworks via a unique identifier for each competency. For example, as a student evaluates an image, the specific act of analyzing the image might demonstrate proficiency with the proxemics ELO that traces back to both Combat Awareness and Combat Profiling.



**Figure 16. Competency Framework** – The CaSS Competency Framework Editor was used to encode the CODIAC competency frameworks used within the 2018 TLA Test and Demonstration. CaSS was used to define the basic elements of each competency and its relationships to other competencies. Each competency object has a unique numerical identifier that was referenced using the LRMI alignment object.

### 4.2.3 CODIAC Content Discovery and Alignment

One goal of the 2018 TLA Test and Demonstration was to go beyond traditional DL content to demonstrate the breadth of learning activities that can be connected into the TLA. As shown in **Table 8**, the 2018 TLA Learning Record Providers span the range of learning activities from traditional eLearning content (e.g., SCORM courses) to emerging technologies like serious games and mobile learning applications.

After encoding the Competency Frameworks, the content obtained from CODIAC, Combat Hunter, and PerceptTS was reviewed, cataloged and aligned to each competency included in the framework. An initial assessment revealed existing content that included video-based lectures, reading assignments, instructor activities/handbooks, assessments/quizzes, interactive web-based training lessons, and written, scenario-based exercises. A gap analysis was performed to determine how many learning activities were available to support each competency object. It was discovered that most of the available DL content and assessment activities were appropriate to support knowledge and comprehension, but were not adequate for demonstrating the application, analysis, or synthesis of the required knowledge, skills and abilities associated with many of the competencies. These were necessary to support the novice, intermediate, and advanced levels of mastery within each competency.

Further, to differentiate between recommendations, numerous learning activities and assessment activities were required for each identified competency in the framework. A search was performed to identify additional formal and informal learning activities including non-digital content (e.g., Combat Hunter card game), serious gaming applications, and scenario-based live exercises. Other courses were also identified from the Army Distance Learning Program (TADLP) and Joint Knowledge Online (JKO). These courses ultimately were not used; however, the ADL Initiative staff did create six serious game vignettes using the Unity3D game engine. Numerous reference materials including articles, handbooks, lessons learned, and other materials were also collected and mapped to each competency.

**Table 8. 2018 TLA Learning Record Providers** – The 2018 learning activities included many different types of learning content that were instrumented with xAPI statements that are then transmitted to an LRS.

TLA Learning Record Provider (LRP)	Short Description	Related Standards
<b>Live Exercises</b>	Instructor-led exercises and group activities were used as <i>Capstone</i> assessments for receiving a <i>badge</i> and to assess for other higher-level competencies.	xAPI
<b>Moodle™ LMS</b>	MarineNet Combat Hunter e-Learning Course: Three SCORM lessons that consisted of a single large Flash® file that encapsulated all interactions and behaviors. These files had very limited reporting capabilities.	SCORM, xAPI
<b>Moodle™ LMS</b>	Multiple choice and short answer quizzes implemented throughout the program of instruction.	xAPI
<b>PALMs</b>	Perceptual Adaptive Learning Modules.	xAPI
<b>PEBL eBook</b>	Content in the form of an e-publication has the characteristics of a book but is augmented by the technologies included on each device.	xAPI, ePub3/ADB
<b>Sero! Concept Maps</b>	Open Source Concept Map toolkit used to create capstone exercises to demonstrate understanding about key concepts. Used for assessment.	xAPI,
<b>Static Content Viewer</b>	An ADL Initiative-developed viewer that allows a learner to <i>self-report</i> whether they've completed viewing/reading assigned content. A big limitation of this platform is that it is only able to collect initializes and completes data.	xAPI,
<b>Unity3D Serious Game</b>	Situational Judgement Trainers: Content delivered in the context of a digital, interactive judgement trainer where scenarios are presented to each learner and they are assessed on their responses.	xAPI, Serious Games xAPI Profile, WebGL
<b>xAPI Video Player</b>	Web-based utility that plays any number of video formats and tracks viewer usage (e.g., pause, play, skip, focus, etc.)	xAPI

To measure the transfer of learning, a pre-test and post-test were created. Each test consisted of multiple-choice questions, matching exercise, true/false questions, and free-response short answer questions. Other assessment activities were integrated into the various activity providers, and in some cases, a single assessment was aligned with multiple competencies. A minimum of six assessment activities were desired for each competency with at least two of those assessment activities capable of evaluating the higher orders of Bloom's taxonomy. Situational Judgement Trainers and concept maps were created to allow learners to demonstrate their understanding of different competencies. Live, scenario-driven exercises were performed with an instructor as a capstone event to receive a badge for each of the three competency frameworks (Combat Awareness, Combat Profiling, Combat Tracking).

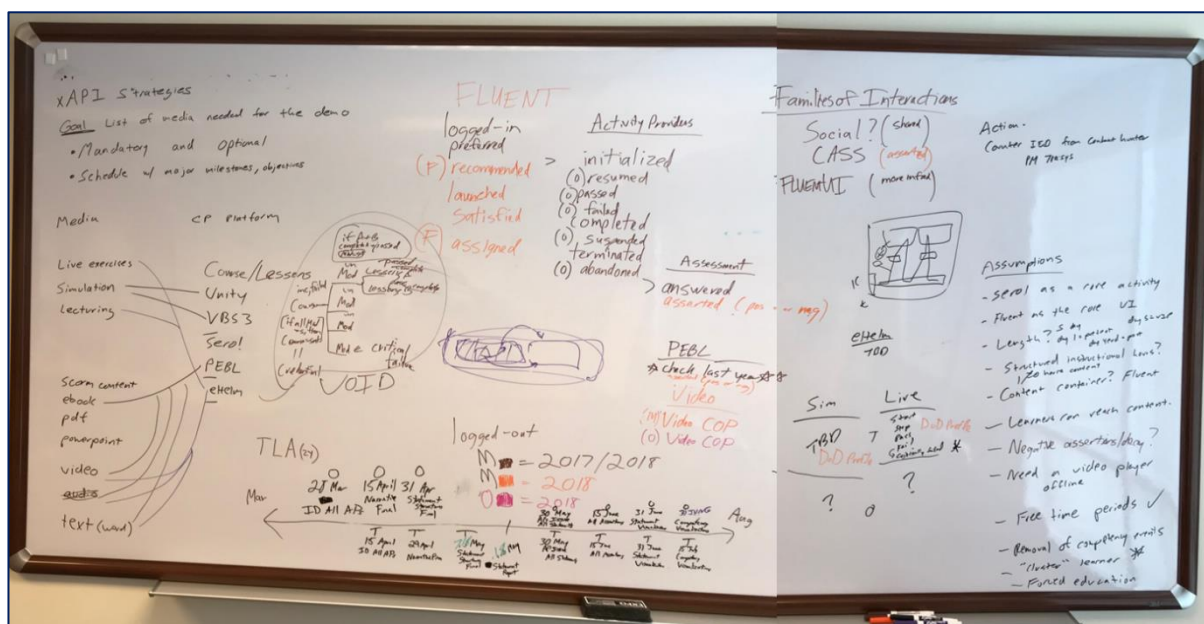
#### 4.2.4 Instrumenting CODIAC Content

CODIAC learning activities were initially aligned to competencies using an Excel spreadsheet. Decisions had to be made about which TLA Activity Providers will deliver which content, where different pieces of content will reside, and how each piece of content will be launched, tracked, and managed over the course of the one-week test and demonstration.

A primary focus of the 2018 TLA Test and Demonstration was to demonstrate the instrumentation, collection, aggregation,

*A working group was originally established to focus on this topic; however, this working group was absorbed by the Content Demonstration*

analysis, and visualization of learning data. To meet this goal, a data strategy was created to define how each activity would be described using metadata and an xAPI profile was created to enable a shared vocabulary for consistently tracking learner performance across all activities. Metadata is used by FLUENT to help inform recommendations to the learner and the CaSS to help inform the meaning behind different assertions being processed. Mandatory and optional xAPI statements were created for each media type used in the 2018 demonstration. These were derived from the types of performance data that each media type can generate, the roles of each user that needs to visualize this data, and the type of data that needs to be generated to support each user.



**Figure 17. xAPI Statement Mappings** – The xAPI working group began identifying basic xAPI statements that will be required across all media types. Additional statements will be needed as the different types of content/media are confirmed for use in the 2018 demonstration.

As shown in **Figure 17**, numerous strategies were discussed for how and when to instrument the different learning activities. Dashboards and data analytics strategies ranged from instrumenting learning activities with xAPI statements to the fusion of data from other TLA sources. Other data types include competency data and Learner Profile information created by CaSS, metadata for content/activities, and learner inference data derived from FLUENT. A TLA data requirements document was authored to clearly define all activity tracking requirements for each learning activity. This document provided guidance for those implementing xAPI to ensure data interoperability across learning activities, but also provided a foundation to inform the types of dashboards that would be available in the 2018 event.

An overarching xAPI profile was created for the 2018 TLA Test and Demonstration that was comprised of numerous other xAPI profiles and a shared vocabulary that allowed disparate TLA services and content providers to track data consistently, facilitating a common language for analytics and visualization services. However, it was not implemented consistently across all 2018 activities and components. The xAPI actors were defined by the participants UUID (assigned by Keycloak™). Statement templates were created for specific learning activities and experiences that were delivered to learners. Client-based services like the video player or PeBL integrated quickly; server-based services like PALMS, Unity3D, and Moodle™ required special helper services to facilitate full integration.

Activity Name	Activity Description	Competency #	Weight	Challenge Level	Shiny?	Learning Resource Type	Educational Uses	Learning Stage	Interactivity Type	Est. Time
CODIAC Lesson: Atmospheric	Watch this short video explaining how to read atmospheric.	2.1.2.A.5, 2.1.2.B.5,	0.4, .2	Simple	No	Video	FirstTime	InformOrRecall	Passive	3 Minute
CODIAC Lesson: Baseline Anomaly Decision	Watch this short video detailing how to use anomalies to stay left of bang.	1.1.2.A.1, 1.1.2.A.2, 1.1.2.B.1, 1.1.2.B.2, 1.2.4.A.4, 1.2.4.B.1	0.3, 0.3, .2, .2, .2, .2	Simple	No	Video	MoreContent	InformOrRecall	Passive	3 Minute
CODIAC Lesson: Biometrics	Watch this short video detailing how to use biometric cues to assess the situation.	2.1.2.A.1, 2.1.2.B.1	0.4, .2	Moderate	No	Video	MoreContent	InformOrRecall	Passive	12 Minute
CODIAC Lesson: Combat Multipliers	Watch this short video about planning ahead based on 5 combat multipliers.	1.1.3.A.2, 1.1.3.B.2	.4, .2	Moderate	No	Video	FirstTime	PresentOrModel	Passive	20 Minute
CODIAC Lesson: Decision-making	Watch this short video about processes for making good decisions.	1.1.1.A.2, 1.1.1.B.1, 1.2.1.B.3, 1.2.2.A.1, 1.2.2.B.2, 1.2.4.A.1	.4, .2, .2, .4, .2, .4	Simple	No	Video	FirstTime	InformOrRecall	Passive	8 minute
CODIAC Lesson: Ethical Decision-making	Watch this short video detailing why its important to make ethical decisions.	1.2.2.A.1, 1.2.2.B.2	.4, .2	Simple	No	Video	FirstTime, MoreContent	InformOrRecall	Passive	3 minute
CODIAC Lesson: File Folders	Watch this short video explaining what File-Folders are and how to use them to catalog your observations.	2.1.1.A.3, 2.1.1.B.1, 2.1.2.B.6, 2.1.3.A.1	.4, .2, .2, .4	Moderate	No	Video	MoreContent	InformOrRecall	Passive	14 Minute
Report: Cognitive Readiness	Are you looking for more information about cognitive readiness? Read this report from the Institute for Defense Analyses.	1.2.1.A.1, 1.2.1.B.2	0.4, .2	Simple	No	Text	Reference	InformOrRecall	LimitedParticipation	40 Minute
Journal article: Situation Awareness	Read this review of Mica Endsley's 1995 "Articles on Situation Awareness Theory and Measurement" to understand how it impacts decision-making.	1.2.1.A.1, 1.2.3.B.2, 1.2.4.A.1	0.4, .2, .4	Simple	No	Text	MoreContent	InformOrRecall	LimitedParticipation	7 Minute
CODIAC Lesson: Geographics	Watch this short video explaining various methods to profile geography to empower situational awareness.	2.1.2.A.4, 2.1.2.B.4	.4, .2	Simple	No	Video	FirstTime	InformOrRecall	Passive	14 Minute
Report: Critical Thinking and Military Decision Making	Report from Naval War College about how critical thinking shapes Military decision-making.	1.2.1.A.1, 1.2.1.B.2, 1.2.3.B.2, 1.2.4.A.1	0.4, .2, .2, .4	Simple	No	Text	Reference	InformOrRecall	LimitedParticipation	20 Minute
Report: Critical Thinking Training for Army Officers	Are you interested in learning more about critical thinking? This report goes through an extensive literature review on critical thinking that might be of interest.	1.2.1.A.1, 1.2.1.B.2, 1.2.3.B.2, 1.2.4.A.1	0.4, .2, .2, .4	Simple	No	Text	Reference	InformOrRecall	LimitedParticipation	20 Minute
Report: Impact of Culture on Moral and Ethical Decision-making	Moral and ethical decision-making isn't just for U.S. Forces. See this report from the Canadian Armed Forces about the impact of culture on their moral and ethical decision-making.	1.2.2.A.1, 1.2.2.B.2, 2.2.1.A.1, 2.2.1.A.2, 2.2.1.B.1	.4, .2, .4, .4, .2	Simple	No	Text	Reference	InformOrRecall	LimitedParticipation	20 Minute

**Figure 18. TLA Metadata Spreadsheet** – An Excel spreadsheet captured the 23 fields used to describe each learning activity. The Activity Name and description were used verbatim by the recommender’s interface to provide the learner information about how the activity applies to the competencies it is aligned with. As learning activities were added to the spreadsheet, a script pulled data from the relevant cells and automated the process of creating an LRMI formatted JSON file. The JSON file was uploaded to the Activity Index which acted as a common repository that all TLA components used to understand relevant information about learning content and activities.

Using the LRMI format, the 2018 metadata schema included 23 properties describing the activity, including its location, associated competency alignments, associated thumbnail, and a 140-character description of the learning activity. The metadata files also included human-readable text fields (e.g., name and description) that FLUENT used to display to the learners as part of the recommender interface. As shown in **Figure 18**, the approach was a labor-intensive process that required human data entry into an Excel spreadsheet that included all metadata fields.

This data was then exported and brought into a script that could generate JSON files that were conformant with the LRMI specification. The JSON files were aggregated into an Activity Index which was resident inside the FLUENT boundary. The Activity Index was used by FLUENT content filtering algorithms to make basic recommendations. CASS also used the Activity Index each time it received an assertion from an activity. CaSS would use the activities metadata to align to a specific competency and to inform mastery estimates.

#### 4.2.5 Sequencing and Delivery

While the original CODIAC course was an established program of instruction, the 2018 Test and Demonstration took other courses such as Combat Hunter and PerceptTS and merged this content with other available content that was never considered in the original development of the CODIAC course. This presents the challenge of reassembling the content in a way that makes pedagogical sense to learners and instructors. Often, this is because the fundamental elements of instruction (objectives, content, instructional events, activities, and assessments) are not aligned with sound learning principles or instructional strategies.

While the CODIAC course was being migrated into the TLA competency framework, instructional designers reviewed the domain and found that the course contains both well-defined and ill-defined tasks. **Table 9** and **Table 10** show a breakdown for how different instructional activities will be divided for the 2018 TLA Test and Demonstration.

**Table 9. Well Structured Tasks.** *Instructional framework and sequencing of activities for well-structured tasks and problems.*

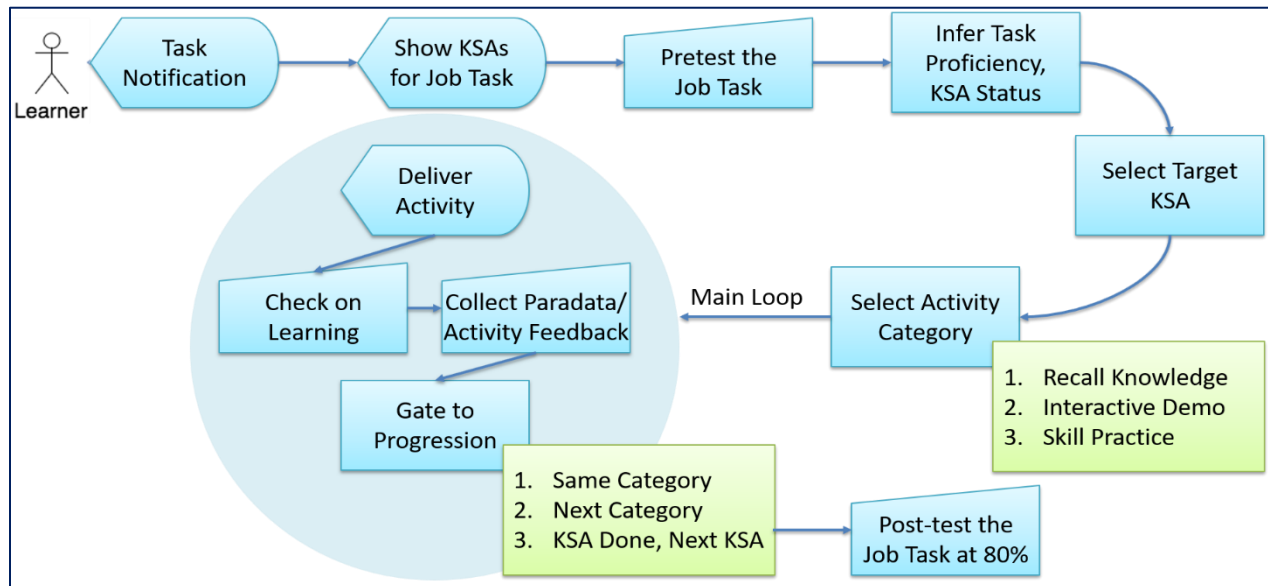
Activity Type	Sample Activities
1. Presentation	<ul style="list-style-type: none"> <li>• Tell me (verbal information, concepts, procedures, principles)</li> <li>• Show me (demonstration)</li> <li>• Copy me (demonstration with active participation)</li> </ul>
2. Practice	<ul style="list-style-type: none"> <li>• Locate, name, identify, list, match (information, concepts, procedures, principles) followed by correct answer or corrective feedback</li> <li>• Discuss verbal information, concepts, procedures, principles</li> <li>• Do next or you do it with correct answer feedback</li> <li>• Given conditions, predict consequences with correct answer feedback</li> <li>• Given outcome, specify conditions with correct answer feedback</li> </ul>
3. Support	<ul style="list-style-type: none"> <li>• Motivational, cognitive, and metacognitive adaptations</li> <li>• Corrective feedback</li> <li>• Explanation of what happened and why</li> <li>• Discussion of verbal information, concepts, procedures, principles</li> </ul>



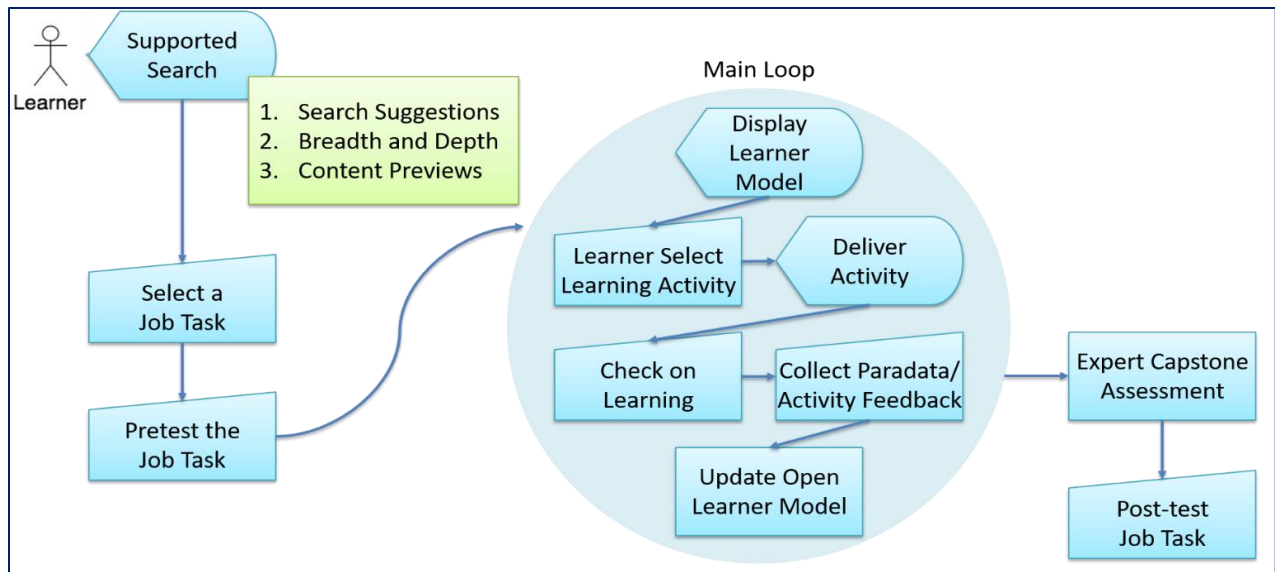
**Table 10. Ill-Defined Tasks.** Problem-centered framework and sequencing of activities for ill-defined tasks and problems.

Activity Type	Sample Activities
1. Authentic Problem	<ul style="list-style-type: none"> <li>• Ill-structured learning tasks (e.g. CODIAC Unit 5, Lessons 5001-5006 – Meaning of cues, image, 5008 – Profile environments)</li> <li>• Practical experiences (e.g. CODIAC Unit 8, Lessons 8005, 8006, 8007, 8010, 8013)</li> <li>• Practical Applications (e.g. CODIAC Unit 9, Lessons 9001-9010)</li> </ul>
2. Demonstration	<ul style="list-style-type: none"> <li>• Show me (demonstration)</li> <li>• Copy me (demonstration with active participation)</li> </ul>
3. Practice	<ul style="list-style-type: none"> <li>• Do next step or you do it with correct answer feedback</li> <li>• Given conditions, predict consequences with correct answer feedback</li> <li>• Given outcome, specify condition with correct answer feedback</li> </ul>
4. Support	<ul style="list-style-type: none"> <li>• <i>Tell me and Show me</i> (verbal information, concepts, procedures, principles covered in unit 1-7 and lessons 8001-8004, 8008, 8009, 8011, 8012)</li> <li>• Locate, name, identify, list, match (information, concepts, procedures, principles) followed by correct answer or corrective feedback</li> <li>• Discuss (or videotaped discussion of) verbal information, concepts, procedures, and principles covered in Unit 1-7, and lessons 8001-8004, 8008, 8009, 8011, 8012</li> <li>• Motivational, cognitive, and metacognitive adaptations</li> <li>• Corrective feedback and explanation of what happened and why</li> </ul>

The FLUENT recommendation engine was developed to accommodate multiple *instructional frameworks* to guide recommendations according to established instructional strategies that are commonly used today. This allows future implementations to tailor the instruction according to the domain being taught and other considerations where different instructional strategies are desired. For the 2018 TLA Test and Demonstration, FLUENT was instrumented with two frameworks that were best suited to deliver recommendations for which content a user should encounter next. **Figure 19** and **Figure 20** below show how content was delivered to support well-structured and ill-defined tasks.



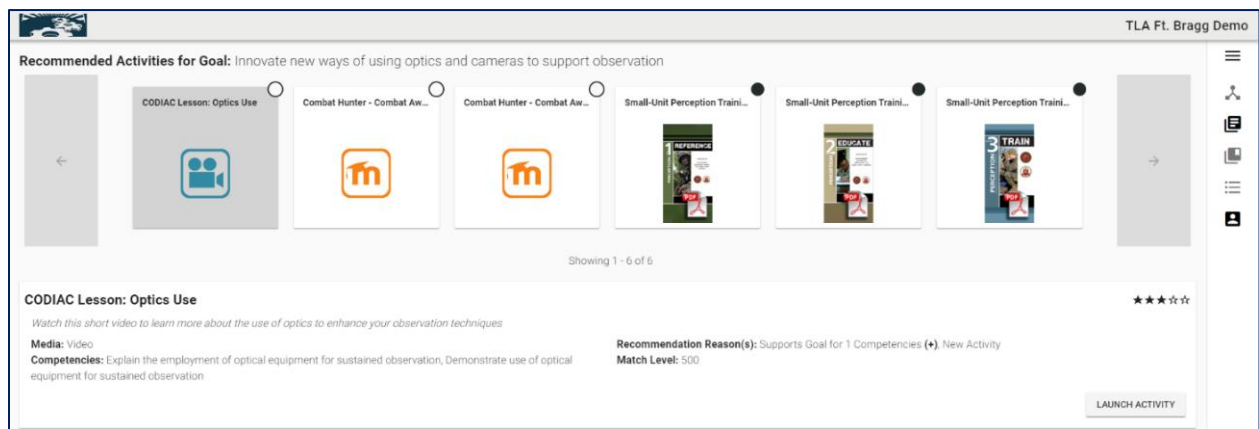
**Figure 19. Well Structured Tasks** – This represents an instructional framework for delivering content in support of well-structured tasks. Content is presented in a linear fashion where knowledge, Skills, and Abilities (KSAs) are structured hierarchically and the user cycles through learning content while using the checks on learning to progress to each consecutive level.



**Figure 20. Ill-Defined Tasks** – This represents an instructional framework for delivering content in support of ill-defined tasks such as understanding the meaning of cues inside different images. For these types of tasks, the user cycles through content and a learner behavior model is updated and used to determine the appropriate content the user should encounter next.

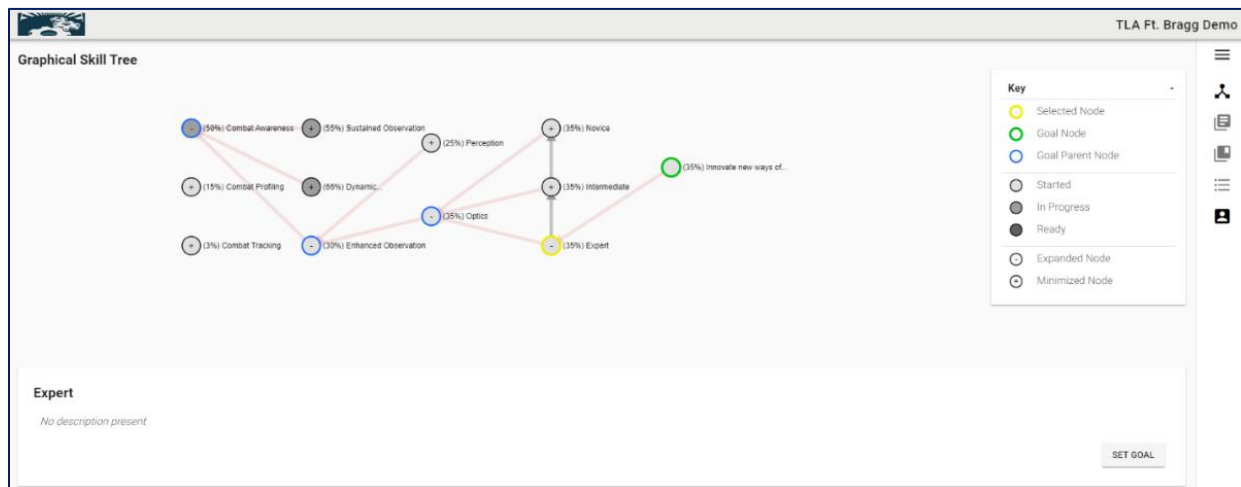
### 4.3 TECHNICAL INTEGRATION

After an initial registration with Keycloak™, the FLUENT recommendation engine provided the primary interface to the learner through a browser based HTML5 application. Upon log-in, users were sent to the home page seen below in **Figure 21**. This is the primary interface for the students and offered a few different methods for accessing content. Basic functionality included the ability for each learner to set his or her goals and visualize progress through an interactive skill tree. Based on selected goals, FLUENT would direct learners to different LRP including the Moodle™ LMS, PeBL, PALMs, Sero!, and live exercises. Each LRP was capable of delivering different learning activities that were tracked and used to make future recommendations.



**Figure 21. Home Page of 2018 TLA Test and Demonstration FLUENT Interface.**

Instructional content had to be presented in a logical and intuitive way that maximized our ability collect, analyze and display learning data to the relevant target audience. By instrumenting an array of disparate content, the 2018 TLA Test and Demonstration generated a large amount of inter-connected human performance data (individuals and teams) that could be used to demonstrate the potential of the TLA for observing learner progress across learning modalities. The recommended activities generated by the FLUENT system were based on the goal selected by the user on the screen shown in **Figure 22**. For this event, instructional content was organized into skill trees with three top-level nodes (badges): Combat Awareness, Combat Profiling, and Combat Tracking. This structure was solely for content organization, not to restrict users to a predefined path. Learners could begin at any level of a skill tree and there were no restrictions on what goals learners could select or how often they could change goals.



**Figure 22.** FLUENT Interface Showing the CODIAC Skill Tree Structure and Goal Selection

As students worked through the content, xAPI statements were generated to record their interactions with the system. These statements were captured in the Learning Locker LRS. One LRS was set up to capture learner actions (e.g., answering a question), while another was set up to capture system actions (e.g., making a competency assertion). Each TLA component published their system log files via xAPI statements to store a ledger of what was going on internal to each system. xAPI system logs were housed in a separate LRS and were used to provide additional insight into the computational resources and data dependencies in the 2018 TLA Reference Implementation. In addition, non-xAPI learner inference data were stored in the CaSS. This resulted in three data sets:

- Learner data: a 77 MB JSON file with 57,381 xAPI statements
- System log data: a 1.8 GB JSON file with 353,746 xAPI statements
- Learner inference data: a 90 MB JSON file (non-xAPI format)

**xAPI Data Structure:** The xAPI is a technical data specification that enables flexible and customizable tracking of learner performance and behaviors across different learning activities. The xAPI statements are constructed in a JavaScript Object Notation (JSON) format with three important properties: Actor, Verb, and Object. In sequence, these pieces of data produce a clear recording of the learning experience. These data can also be cross-referenced with performance data to map the training to performance. The xAPI specification is open-source and maintained by the ADL Initiative. In addition to the three data fields mentioned above, the following properties were also used in the demonstration:

- **ID:** a unique identifier for each xAPI statement
- **Version:** the statement's associated xAPI version
- **Timestamp:** when the event described by the statement occurred
- **Stored:** when the statement was recorded by the LRS
- **Result:** further details representing a measured outcome (e.g., assessment score)
- **Authority:** agent or group behind assertion; verified by LRS via authentication
- **Context:** further details of recorded event (e.g., altitude of flight simulator)

**Competencies and Badging:** Badges represent a way of acknowledging achievements or skill acquisition in a granular fashion. The CODIAC course was organized into skill trees with three top-level nodes:

- Combat Awareness
- Combat Profiling
- Combat Tracking

These nodes were deemed badges and arbitrarily given internal codes 1, 2, and 3, respectively. Expanding each node revealed more layers of content, up to a maximum of five layers (e.g., competency code 3.1.3.B.3). Each competency's unique ID was a URL that contained further text information about it, including its weight, description, and internal code.

**Learner Inferences:** CaSS used each learner's data to estimate their proficiency for each node of the skill tree. This information was stored in JSON format, but it did not follow the xAPI structure. As such, these data were not logged by an LRS but were instead stored locally in CaSS. These data included:

- Number of attempts and timestamp of last attempt for each activity
- Mastery estimates (novice, intermediate, expert) for each competency
- Mastery probabilities, assertion source, and timestamp for each competency (the CaSS assertion processor maintains a list of systems that can provide assertions)

**Activity Index:** The Activity Index was stored as an LRMI-formatted JSON file located inside the FLUENT application boundary. The metadata drives the filtering algorithms used in the prioritization of recommended learning activities. The metadata model also included paradata, assertions, analytical data, identities, and reputations that flow through the distribution network. CaSS also has a service that goes into the Activity Index and retrieves a mapping from the xAPI assertion statement to the appropriate metadata for the activity generating the statement. Each competency has a unique identifier in the competency framework. This is referenced in the metadata through the LRMI Alignment Object.



**Figure 23. SWEG(A) Classroom at Fort Bragg** – The classrooms for the TLA 2018 Test and Demonstration were reconfigurable and allowed the team to support all participants at once for completing the initial pre-test and surveys.

## 4.4 TLA TEST EVENT AT FORT BRAGG

Learners valued the content, the team collected an enormous quantity of data, event administration ran smoothly and timely, no system outages occurred, and the vision for the future learning ecosystem was realized to an enthusiastic audience. The event itself took place from August 13-17, 2018 at Fort Bragg in Fayetteville, North Carolina. As shown in **Figure 23**, the 2018 TLA Test and Demonstration was delivered in collaboration with the John F. Kennedy Special Warfare Center and School (JFKSWCS), with participants from its Army SWEG(A). Roughly 60 volunteer active duty personnel from SWEG(A) interacted with the TLA Reference Implementation for 14 hours over five days.

On the first day, participants were briefed on the purpose of the event and provided an overview of the tools and technologies they would encounter throughout the week. Upon completion of the briefings, participants signed the informed consent forms and began completing a survey that collected demographic information about each participant. Upon completion of the surveys, each participant took a pre-test that was intended to measure their current state of proficiency across the 234 competencies identified for use in this course. The pre-test was graded, and the results were used to initialize the participant's Learner Profile so that the different TLA systems could tailor recommendations based on each individual's current level of understanding. The pre-test results were also compared to the results of a post-test taken after the event to measure the immediate transfer of learning after taking the course.

As participants navigated through the course, observers continually collected data about what each participant was working on, and several focus groups were held after the course to poll participants on various aspects of their experience in the course. Using this data, coupled with the digital data collected throughout the event, seven areas of the TLA were evaluated:

1. **Functionality:** TLA features and proposed benefits were documented, and the reference implementation was assessed against the defined functional requirements. As participants interacted with the system, basic system metrics, user behaviors, and system behavior were gathered to determine functional performance and whether design goals were met. Some of the measures used for assessing functionality included a comparison of systems actions taken as a result of corresponding event data and the comparison of recommendations to competency data per user.
2. **General System -ilities:** Related to the functionality assessment, the system's general technical performance was captured; this includes criteria such as latency, composability, technical reliability, and modularity. System interruptions, downtime, and stress load failures were also monitored.
3. **Specific System -ilities:** This involves documentation and assessment of the idiosyncratic technical performance criteria, such as how varied learners' trajectories are from one another (i.e., system adaptability). System logs about operational performance were also reviewed to help understand how and why different actions occurred.
4. **Usability (End Users):** This assessment included learners' satisfaction, engagement, and subjective experiences using the system. Data was captured using existing instruments (i.e., *System Usability Scale* [Brooke, 1996] and *User Experience Questionnaire* [Turner, 2011]).
5. **Usability (Developers):** This assessment focused on the satisfaction and experience of those who interact with the system for design and development purposes, such as content developers and instructional designers; this involved both the reference implementation and the viability and quality of its technical documentation in terms of clarity, functionality and diffusion.

6. **Learning Outcomes:** Although the transfer of learning was not a focus for this test, the system's learning potential was assessed to provide a baseline for future experiments. This was determined primarily by measuring learning gains using a pre/post-test design.
7. **Cost Factors:** Finally, initial development cost data (to eventually inform return on investment analyses) was captured from the system designers and developers. Data collection includes both qualitative and quantitative data.

Upon completion of the course, all collected data, including the results from the surveys, pre and post-tests, and the three primary TLA data stores were cleansed and packaged in support of a TLA data hack-a-thon. This event invited engineers, data scientists, and others to get an in-depth understanding of what data was collected and made available during the 2018 TLA Test and Demonstration event. The hack-a-thon provided detailed results about the potential for how learning data may be used to power data-driven dashboards that support a variety of different roles and purposes across the continuum of learning.

#### ***4.4.1 Logistics and Administration***

Leading up to the August 2018 event, the ADL Initiative worked with SWEG(A) and IDA to create surveys, orientation briefings, and coordinate the exchange of materials required to obtain all the various permissions for holding the event. The ADL Initiative coordinated staffing, travel, hardware/software implementation, and overall management of the event. IDA created the research plan, and SWEG(A) provided 30 desktop computers, 3 classrooms, student participants, and instructor/observer participants as needed to help facilitate the 2018 demonstration. Prior to the start of the demonstration, the ADL Initiative staff and vendors spent the week with SWEG(A) staff preparing the classroom, computers, and devices for the demonstration. The team partitioned the classroom into two areas: a large area for learners and their working areas, and a smaller area for developers and support staff. A small meeting room was also provided to support focus groups and other ad hoc meetings.

The Research Plan submitted through IDA followed all policies required for the protection of human research subjects. With concurring approval by the Department of Defense Personnel and Readiness Research Regulatory Oversight Office, this project received an exemption. Participants were divided into groups of 30. This allowed for a 4-hour class in the morning and one in the afternoon. SWEG(A) confirmed participant availability and provided all the primary points of contact for JFKSWCS and Fort Bragg policies, permissions and access. Participants worked in a computer lab with Internet connected desktop computers, iPad devices, and WIFI access for iPad Internet connectivity. Public Internet was accessed through Fort Bragg's LangNet. SWEG(A) reviewed all instructional content and ran scans on all network-connected hardware to monitor ingoing/outgoing network traffic.

#### ***4.4.2 Hardware and Network Connectivity***

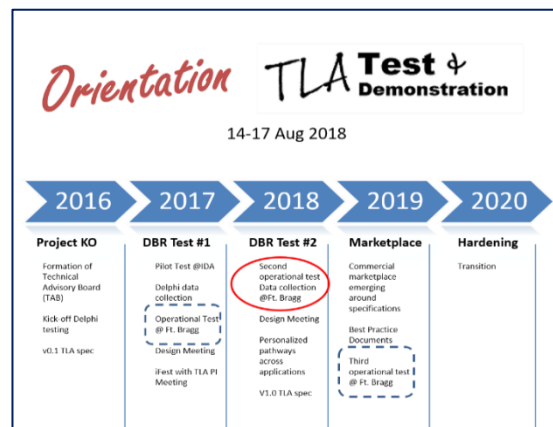
The TLA's AWS infrastructure met all requirements. With over 30 concurrent users streaming video, reading PDFs, and using Moodle™, the team and learners observed no system outages. Networking, memory, and CPU metrics were well below their limits, rarely reaching even 50% capacity. Rather than configuring 30 laptops individually, the SWEG(A) engineers requested the team provide a single, pre-configured master hard drive that could be cloned across all classroom computers. SWEG(A) used their Master Drive Cloning System to rapidly deploy preconfigured operating systems, applications, and settings on each desktop computer. The lead time for this system is 30-60 days (ideal). SWEG(A) delivered a single desktop computer at the end of June from the 25<sup>th</sup> to the 28<sup>th</sup>. The ADL Initiative engineers received the desktop and configured it to run the required software components.

With 30 concurrent learners using two devices each, network latency and bandwidth limits were a concern. The team used two Netgear Nighthawk routers broadcasting two frequencies<sup>48</sup> each, allowing up to 128 simultaneous connections – satisfying connectivity requirements for the learner devices and allowing network access for developers and administrators. After setting up the routers, network connections for each device were configured with fallbacks to the developer network if necessary. Devices typically maintained their connection, but wireless settings required the team confirm connectivity each morning. For security reasons, SWEG(A) did not broadcast the wireless networks, so the team established each connection manually across devices. Any loss of connectivity was only temporary as the backup network took effect, but a building-wide power outage did impair connectivity for roughly 30 minutes during one session.

Computers, iPads, and peripheral hardware functioned without issue. The desktops were preconfigured with the software preloaded through SWEG(A)'s cloning process. Minor changes were made to the software as some TLA components were updated after the cloning process. On the desktops, very few issues arose. System permissions from SWEG(A) prevented the team from resolving some issues with browser caching<sup>49</sup>, so the team changed the learners' web browsers from Google Chrome to Mozilla's Firefox during the demonstration resolve this. Initial system usage on the first day (Tuesday) uncovered a performance issue with the LRS responsible for collecting system logs. The server was upgraded and its corresponding DNS registration by midnight. The machine resumed function Wednesday morning.

#### 4.4.3 Pre-Tests, Post-Tests, Surveys, and Focus Groups

Upon arrival Tuesday morning, all students gathered to sit through an orientation brief, signed their informed consent forms, and completed a series of surveys. Upon entering the classroom, SWEG(A) staff randomly assigned a UUID to each participant to ensure future anonymity in analysis and reporting. Log-in accounts had previously been created with the UUIDs and only SWEG(A) and IDA had access to Soldier identities. As shown in **Figure 24**, the Orientation provided an overview of the multi-year initiative and walked participants through the intended purpose and justification for this research. The CODIAC course was introduced and the various delivery platforms were described to show participants how to use the system.



**Figure 24. Orientation Briefing – The 2018 TLA Test and Demonstration is the culmination of the second spiral of Design Based Research.**

The first survey was a Basic Demographic Questionnaire consisted of 16 items including name, gender, age, service, duty station, office, assignment, military grade, military occupational specialty code, education, and background. The target populations for this study are U.S. Army active duty or reserve military personnel with military grades spanning mid and senior enlisted, non-commissioned officers, warrant officers, and non-field grade officers. They are stationed at Ft. Bragg and are all under the US Army Special Operations Command (USASOC) with Psychological Operations and Special Forces military occupations

<sup>48</sup> Each router broadcast its 2.4 GHz and 5 GHz frequencies.

<sup>49</sup> Caching is a process employed by modern web browsers to reduce page load times. These browsers keep local caches of certain files from webpages that they expect to rarely change (like style sheets and images). While this improves user experience, clearing these caches often requires administrator permission on the machine itself.

represented. The age span is approximately 20-26 years with gender skewed mostly toward males. A User Experience (UX) Questionnaire was also presented for collecting data about system usability and the user's experience interacting with the system. A 24-item UX Questionnaire was developed to collect data on usability and user experience. These surveys helped evaluators understand more about the participants and for stratification in analysis.

Researchers were also on site to collect observational data of the interactions in correlation with the collection of system performance and behavioral data from TLA systems over the interaction period. These data should enable a unit of analysis at the individual level as well as the group and provide descriptive data on learner individualization and system level performance.

To capture initial and final knowledge of the subject matter, the team administered pre-tests and post-tests. Pretest scores were used to seed the initial user competency values in the system. Though originally planning to use Moodle™ for serving these assessments, the team utilized paper copies because the final pre- and post-test included short answers and essay questions which required manual grading outside of Moodle™. Two separate tests were developed; one for the pre-test and one for the post-test. All learners went through and took their pre-tests at the same time Tuesday morning. Eight team members with knowledge of the CODIAC material graded each test manually. As the experts finished grading these pre-tests, results were transferred to an Excel spreadsheet, and run through a script to import those results into CaSS to initialize the participant's TLA Learner Profile. Each paper test was digitally scanned upon completion and again after grading was completed. The lack of automation required considerable resources.

To understand more about each participant's context of use, insight into thoughts and feelings about their experience, and other individual/group dynamics, post intervention focus groups were held. The focus group protocols called for a short social and warm-up period, followed by the open-ended questions and conversation, and finally a wrap up. Questions were created ahead of time and were intended to draw out experiences and perceptions concerning expectations of learning, expectations of interaction, actual experiences of interaction, contrasts between expectations and actual system performance, and participants' feelings about use. Focus groups were closed between the researchers and the participants and will be recorded for analysis.

Lastly, the research team recorded learner, administrator, and engineer feedback about the event through surveys and focus groups. Small groups of learners were led through focus groups while other the ADL Initiative staff and IDA discussed the event with SWEG(A) administrators and instructors. Interviews were also held with the ADL Initiative and vendor engineers to document their experiences. In addition to face-to-face focus groups, participants also completed paper surveys for both administrative and engineering efforts.

#### ***4.4.4 Learner Management and User Experience***

Prior to the event, the ADL Initiative created 90 TLA accounts to be used by learners at Fort Bragg. Each participant received login credentials for a UUID they kept and used throughout the event, allowing the system to track their individual performance without collecting any Personally Identifiable Information (PII). Learners were asked to preserve their login credentials between days, although these credentials could be given to a learner upon request.

After login credentials were distributed and all in-processing activities were complete, instructions were provided on how to access and use the system, learners logged into their designated accounts and began using the FLUENT User Interface (UI). Learners will interact with the CODIAC content for approximately



four hours per day over a four-day period with the first and last day limited to two hours to allow for in-processing and out-processing the participants. Fixed groups of 30 participants alternated at designated times throughout the week. When using the FLUENT UI, learners had difficulty knowing which competencies had not been achieved due to a scaling issue<sup>50</sup>. By default, the tree view expanded nodes with a fixed font size and did not reconcile tightly grouped elements for visibility, making large groups of activities unreadable.

As the TLA is designed to empower personalized learning, everyone experienced a different learning path through the CODIAC content. Overall, the system and content kept learners engaged and allowed them to progress through the content in a logical fashion. Since the learner was the sole pivot point for all recommendations, they alone chose their learning goals and corresponding activities. While many learners began with the SCORM content (presumably because its relationship to so many competencies almost guaranteed its recommendation), their activity paths began diverging after those were completed.

Participants viewed the relevance of CODIAC content as a positive experience and especially called out the live activities and capstone exercises as having value to their near-term learning goals. It is important to note that the human readable descriptions included in the metadata for each activity and the custom thumbnail images also contributed to a positive learner experience by explaining why each activity was related to different competencies. The research team observed some learners intentionally change their goals to seek out an interesting or fun activity being performed by their neighbor.

#### ***4.4.5 Data Collection and Management***

Automated data collection efforts produced a significant quantity of data. The system collected over 450,000 xAPI statements during the 4-day event, which were anonymized and distributed for the iFEST hack-a-thon. Approximately 400,000 of these were generated through the system log LRS and the other 50,000 were generated through learning activities to reflect participant behaviors. The “2018 TLA Data Requirements” document defined the meaning, structure, and requirements for the xAPI statements produced within the TLA. Other than xAPI statements, the system captured each learner’s final competency profile, their activity history, and statistically significant pre-test and post-test differentials. Additionally, the surveys and focus groups provided a wealth of objective information about TLA usage, user interface, instructional content, value proposition, and overall user experiences. All data was collected and put under positive control by the ADL Initiative and IDA at the end of the event.

An objective third party evaluation of the raw data by an ADL Initiative vendor that was not part of the 2018 event concluded that the dataset collected at Fort Bragg had limited value for the purpose of true analytics. This is a result of many factors including inconsistent usage of terms due to inconsistent usage of the TLA’s xAPI profile. Some of the content providers used different verbs or did not include the result extensions as outlined in the Data Requirements document. The result of numerous misalignments between data expectations, metadata intents, and statements produced resulted in performance measurement gaps from some learning activities. In most instances, enough data was generated by other activities to minimize the impact of the missing data.

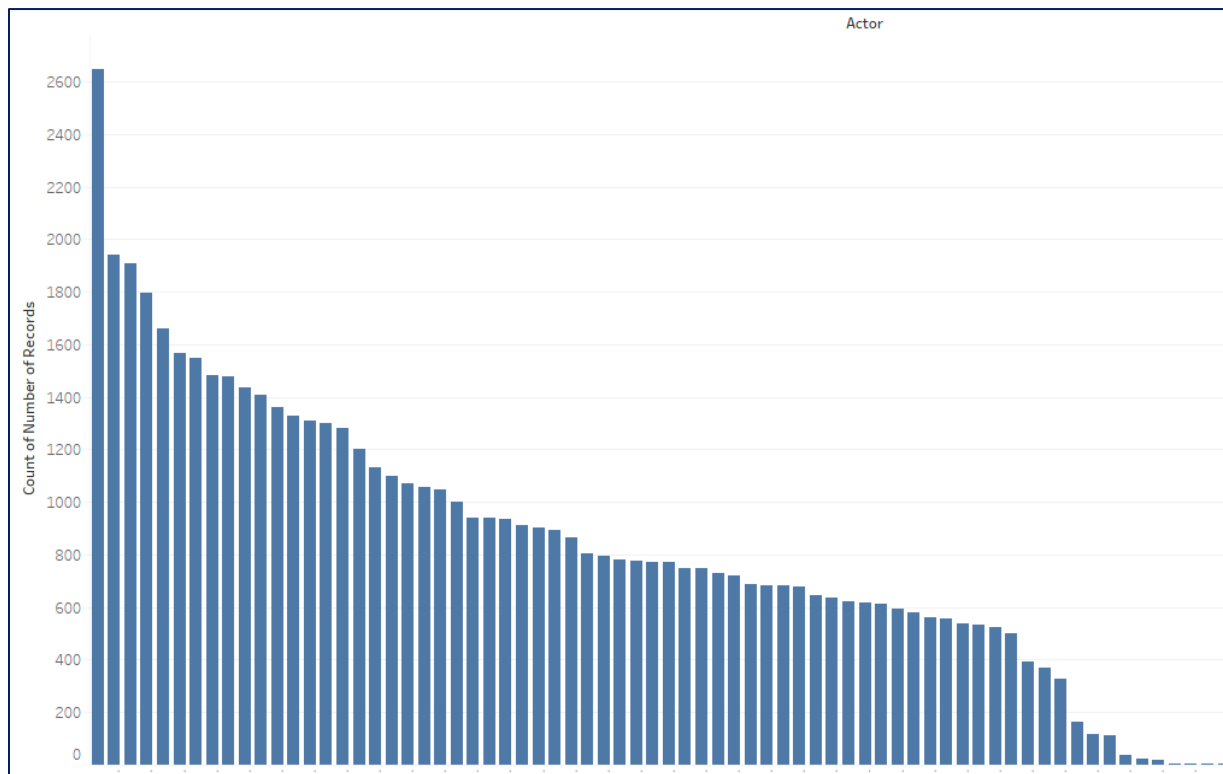
---

<sup>50</sup> The tree view did not utilize vertical screen real estate, staying confined to roughly the top third of the page. This caused competencies with large numbers of activities to produce dense packs of associated activities, making it difficult for learners to see what was being displayed.

#### 4.4.6 Data Analytics and Visualization

Analytics is the discovery, interpretation, and communication of meaningful patterns in data. It relies on the simultaneous application of statistics, computer programming and operations research to quantify performance. A variety of visualization techniques are used to communicate insights into the data being collected.

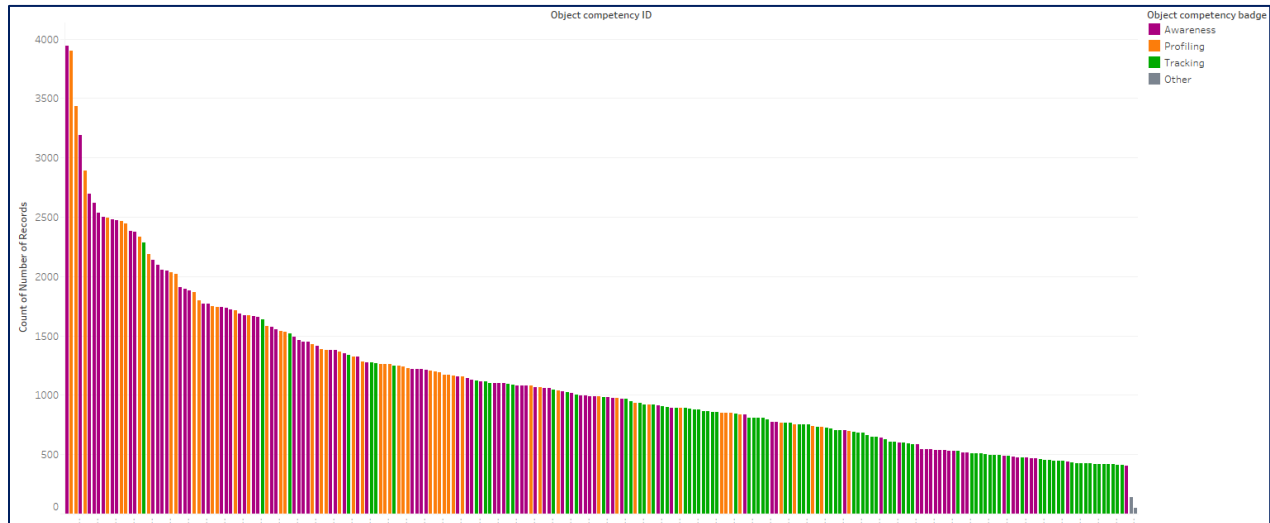
Native LRS dashboards were used to support real time visualization of the Activity Streams as they entered into each LRS (system log and participant actions). These dashboards allowed non-technical users to participate and understand the analytics process by compiling data and visualizing trends and occurrences. The dashboards also provided participants an objective view of performance metrics and served as an effective foundation for further dialogue. The 2018 TLA 2018 Reference Implementation exposed numerous limitations with the *point-to-point* messaging that took place between TLA components. This approach specifically presented challenges in providing real time dashboards because the data was being passed between different localized data stores which required numerous *listener* services to collect and aggregate the data.



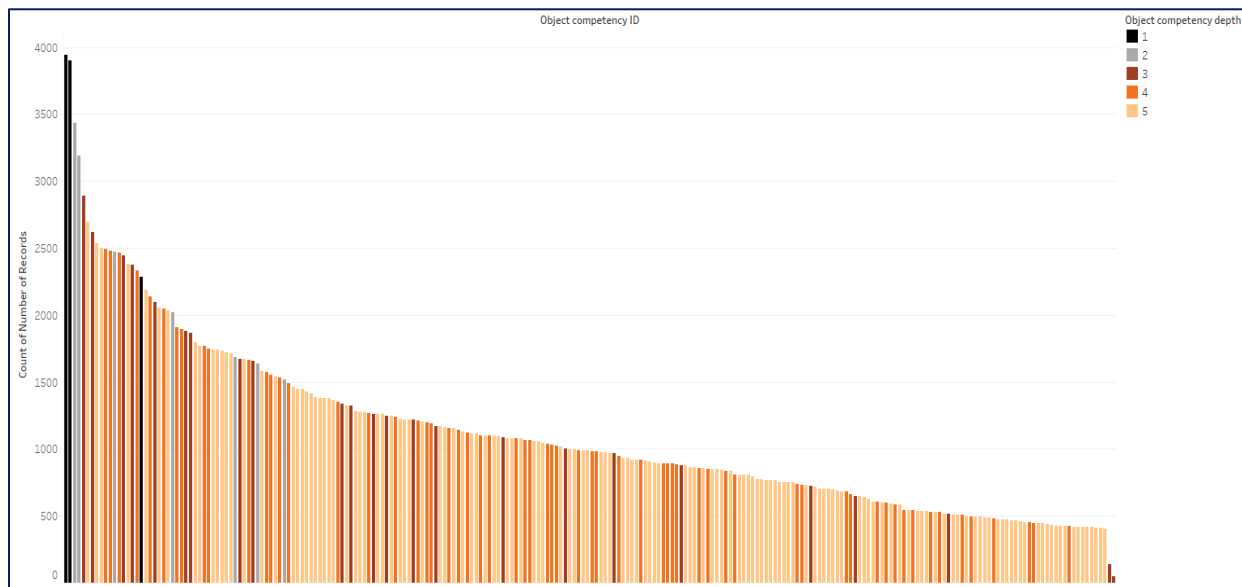
**Figure 25. Activity Levels of All Learners.**

In addition to the LRS dashboards, a hack-a-thon was held that promoted further exploration of the data generated throughout the week. Hack-a-thon participants performed an exploratory analysis on usage patterns across all learners within the TLA 2018 Test and Demonstration. To this end, attendees created a variety of charts to explore patterns in user behavior, new ways to use xAPI data, and methods to refine the data collection process. As shown in **Figure 25**, each bar represents a learner, and the height of the bar indicates the number of xAPI statements associated with that account. Besides one outlier at the top end and many low-activity accounts at the bottom, the distribution is reasonably smooth.

The next step was to analyze usage patterns across competencies. Each competency is shown in **Figure 26**, along with the number of xAPI statements associated with it. The color of the bar represents the badge that the competency was placed under. Users were free to work on any competency at any time, but the chart below suggests that many may have chosen to begin with the badge positioned at the top (Combat Awareness), even though there was no order between the three separate skill trees.



**Figure 26. Statements Generated per Learner.** – Color Indicates the Specific Competency Framework (Badge)

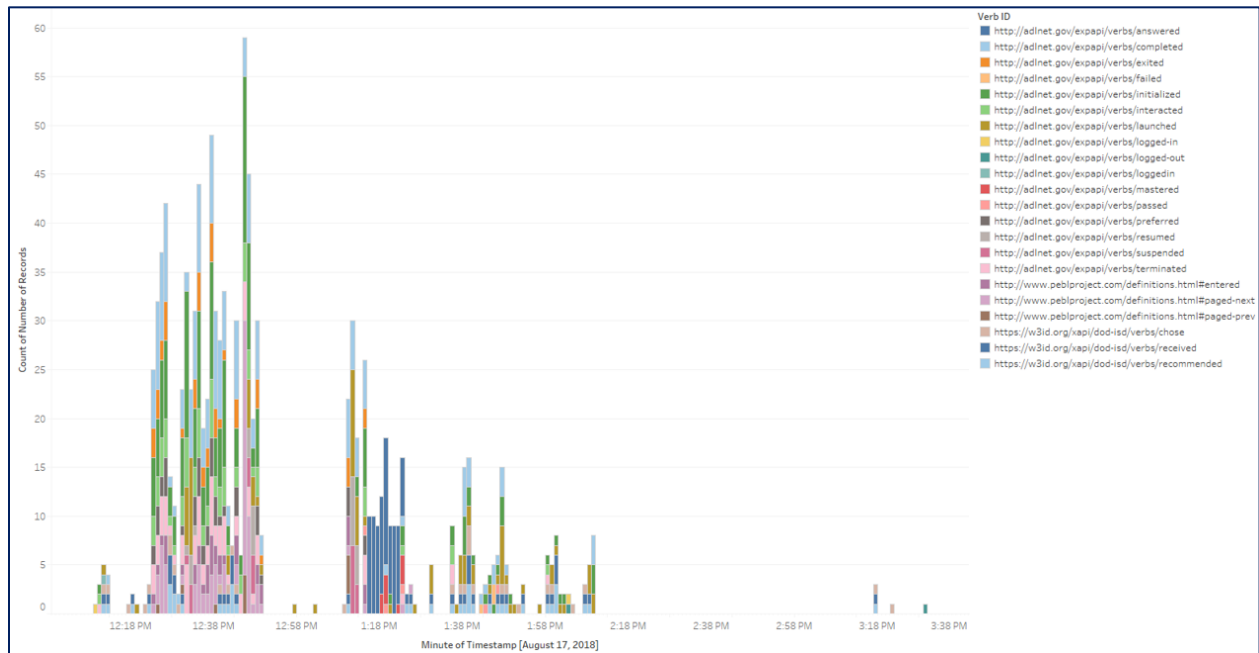


**Figure 27. Statements Generated per Competency** – Color Indicates Depth.

In addition, the same data were examined but with respect to competency depth. Each skill tree in the FLUENT UI included five level parent-child hierarchy that reflected the CODIAC competency frameworks created for this course. **Figure 27** provides a chart that shows that the higher-level nodes generated more statements, perhaps because they were more easily accessible to learners. To reach a competency at the deepest level, users had to click through several parent nodes, whereas the depth 1 competencies were immediately visible upon loading the page.

**Research Question:** Were students engaged during their hours with the system?

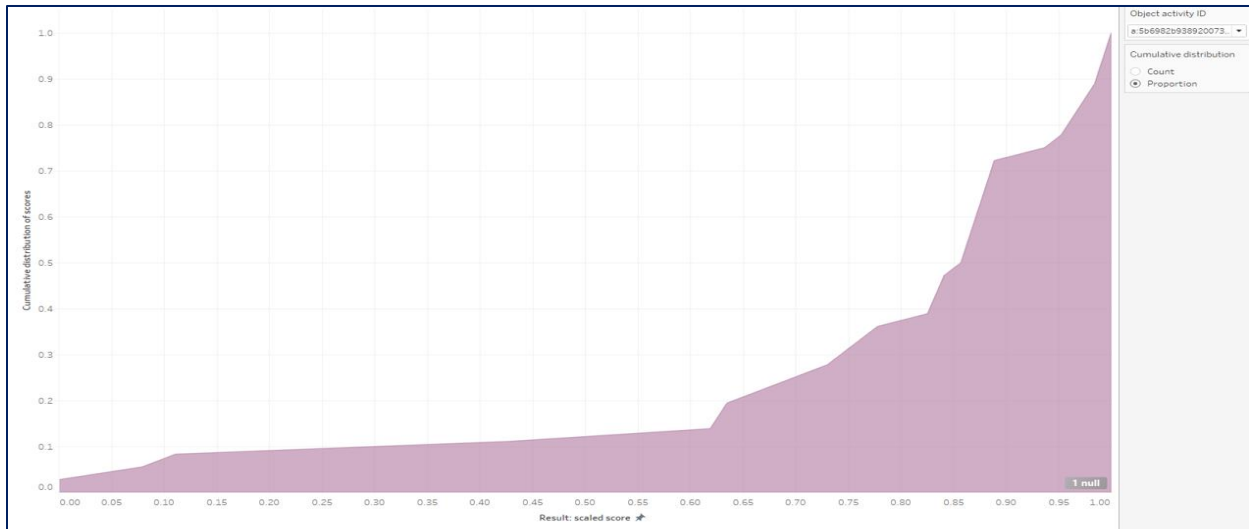
**Answer:** One key advantage of xAPI over older standards is that learner activity can be tracked in much greater detail. In addition to completions, successes, and failures, we can now also record actions such as turning a page, indicating a preference, or pausing a video. As shown in **Figure 28**, this allows for a nearly perfect reconstruction of a learner’s experience over any span of time. To illustrate this, a prolific user was chosen and all associated xAPI statements plotted on a timeline. For each minute of the four-hour period from noon to 4:00 PM on Friday, August 17<sup>th</sup>, 2018, we can see the count of statements generated for that user. This is further broken down by color-coding to indicate the verb ID in each statement.



**Figure 28. Statements per Minute** – This chart shows statements by minute for an individual participant, along with a color-coded breakdown of the verbs associated with these statements.

**Research Question:** Which assessment questions are the most difficult?

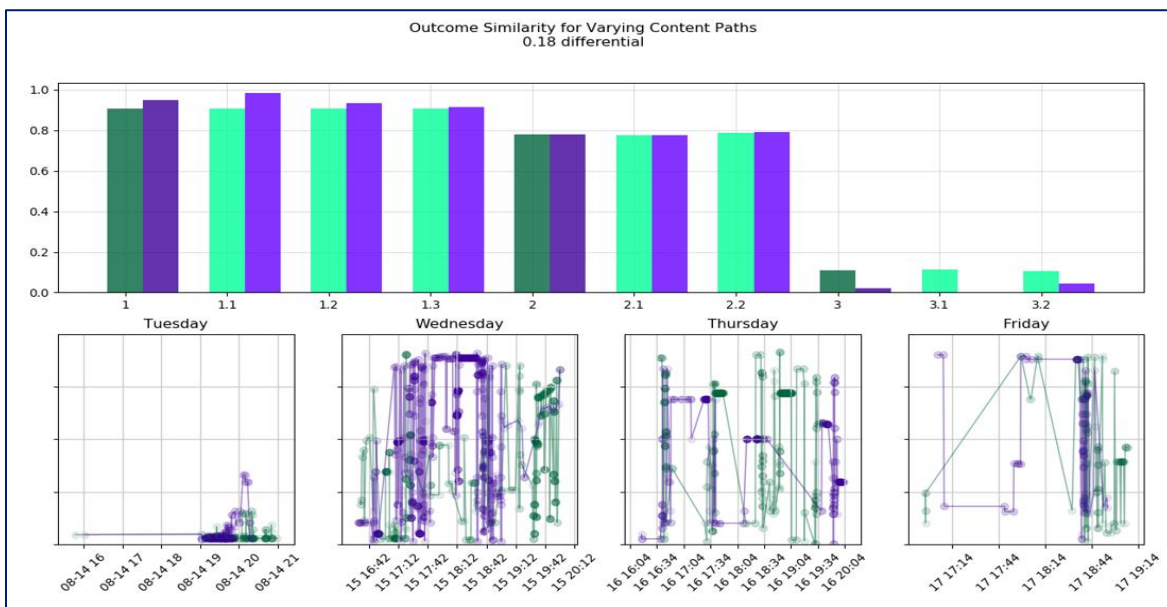
**Answer:** Another frequently discussed research topic is gauging the difficulty of each task. For longer assessments with a wide variety of possible scores, a simple mean or median calculation may not provide enough information. Instead, we can examine the distribution of scores to see how different learners have performed. One way to do so is to plot the proportion of all learners who achieved a given score (i.e., a percentile). As shown in **Figure 29**, 50% of learners earned a scaled score of 86% or less.



**Figure 29. Empirical Distribution Function** – For a chosen assessment activity.

**Research Question:** Can we visualize the learning pathway of a single learner over time? Can multiple student pathways through the learning activities be determined, contrasted, and visualized?

**Answer:** As shown in **Figure 30** the team generated a preliminary visualization for learner paths. Given the short duration of the TLA demonstration, most participants were unable to make significant progress toward all three badges, so this learning path comparison focused on pairs of students whose final competency states were similar. To calculate this similarity, each user’s final competency state for each badge and terminal learning objective (TLO) was extracted into a vector. Then a difference vector was constructed for each pair for learners by subtracting one learner’s vector from the others. Finally, the norm (length) of each pairwise difference vector was calculated (a smaller norm indicating less distance between their final outcomes, hence greater similarity).



**Figure 30. Competency States and Learner Paths** – The top chart compares two participants in terms of their final competency states. The bottom charts show the learning paths taken by the two users. The chosen users were the two most similar ones in the demonstration.

#### 4.4.7 Lessons Learned

Data quality is of utmost important for analytics. The 2018 TLA Reference Implementation exposed numerous issues that inhibited analytics and data visualization, both with the data sets themselves and the way the data travel through the TLA. The 2018 demonstration did not reach full compliance with the guidelines laid out in the *2018 TLA Data Requirements* document. Compliance with the established standards is crucial for data consistency and component interoperability. Data issues included the following:

- **Non-conformant usage of context Activities object.** Parent and object were frequently the same activity. This object should maintain the relationship between the content and its competency node.
- **Reuse of statement IDs.** It is crucial to have a unique identifier for each xAPI statement. Per the specification, statements should not be overwritten, but instead voided if they must be invalidated.
- **Lack of functionality for YouTube video pages.** For video content hosted on YouTube, there was no way to track the user's platform, how the user was directed to video, or how the video linked to the competency framework. This resulted in malformed xAPI statements.
- **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 being used as unique identifiers.** It is essential to have at least one unique identifier for each entity type, and uniqueness must be maintained.
- **Inconsistency in verb language.** For example, some statements used “en” for the English description of a verb, while others used “en-US.”
- **No established timestamp format.** Timestamps were recorded to varying levels of precision. Some contained time zone information while others did not. As this can cause significant disparities between components, a standard timestamp format should be established.
- **Inconsistent labeling of competency levels.** Internal competency data (micro, macro, competency) did not match external documentation (ELO, TLO, badge), and varying sources describe different relationships between these terms.
- **Poorly formatted objects.** Different objects followed different schemes for capitalization, space padding between fields, and field order.

One of the biggest challenges that arose was that FLUENT object IDs used a 24-digit hex-identifier that was non-conformant with the object identifiers used within an xAPI<sup>51</sup> statement. This inhibited CaSS from generating assertions for the xAPI statements and required modifications to the approach for processing competency assertions from different activities. This had downstream effects as other systems tried to access the nonconformant data (e.g., LRS to LRS communications). There is also concern that many of the operations within FLUENT were updated in place (e.g., the Activity Index and metadata fields like popularity and emotional rating) which resulted in the loss of valuable time-series data. Had these values been incorporated into the xAPI statements, the statements would have served as an immutable record of these changes and could have been the basis for iterative feedback loops where it would be possible to report on the correlations between content properties, learner preferences, and performance.

---

<sup>51</sup> an xAPI object ID needs to be a URI

**Assessment:** As an Activity Stream, xAPI has no rubric for rolling xAPI statements up into meaningful assessment data. Future reference implementations should investigate how an xAPI profile might map to HPML's Human Performance Data Model as evidence of competency. The CASE™ rubric is also suited for establishing the criteria and performance levels for earning *Credentials*. Both may be relevant to different types of competencies.

**Granularity of Data:** The granularity of data being collected from different LRPs was inadequate and often consisted of data like that being generated from a SCORM course delivered via an LMS. Increased granularity will enable more robust analytics that each platform can deliver. The use of an xAPI Profile Server will help create conformity through controlled libraries and extensions.

**xAPI Data Storage:** A separate LRS was used to store system log data due to performance concerns. The second LRS mitigated the risk of high network traffic slowing down a single LRS. The use of two different LRSs presented difficulties for real-time analytics because the two data streams must be merged before analysis can be performed. When real time dashboards are required, all data used in those dashboards should be stored in a single LRS.

**Competency Organization:** Instructional content was organized into skill trees. This allowed competencies to be placed at any desired level of depth, but each node could only have one parent. This prevented the many-to-many relationships that competencies are expected to have in a framework. Moving forward, competency frameworks should be structured into acyclic directed graphs to preserve directionality and eliminate the single parent constraint.

**Learner Profiles:** The Learner Profile was used to house *mastery estimates* for the competencies each participant was obtaining throughout the week. It was closely coupled to CaSS but FLUENT used xAPI assertions to write learner inference information to the Learner Profile. This approach proved successful and warrants additional exploration as a mechanism for collecting assertions about a learner from authoritative sources within the DoD.

**Search:** No search service was provided in 2018. Participants desired the ability to find the different pieces of information they required to supplement the existing learning materials. Searches could be scripted to occur through internal DoD database structures or across all content associated with a TLA instance.

**Content Categorization:** The number of required LRMI metadata fields used did not create enough differentiation between activities for the recommender. For example, different types of text documents such as peer-reviewed journal articles, field manuals, guide books, technical reports, and others were all listed as a text document. Schema.org presents a vocabulary that can be utilized to add this specificity to the 2019 Reference Implementation.

**Weighting:** All content was treated the same and incremental increases in competency were assigned for each completed activity. Weighting was included in the metadata generation spreadsheet; however, weighting was not included in the 2018 TLA Data Requirements document so some systems were not able to support this capability. Future implementations will require the weighting of evidence based on the metadata.

**Service Separation:** Many distinct applications and services were run on the same AWS instance with no separation. This resulted in undesirable side effects, such as resource contention. Services should be decoupled.

**Data Types:** While many of the data elements were known, there were still many undefined data types included within the 2018 TLA requirements document. Data types such as activity metadata, relations of competency objects, and elements of the Learner Profile need to be better defined so that dashboard requirements can be defined.

**Messaging:** Multiple messaging formats including REST and AMQP were used to pull and push messages between TLA components. Messages were not optimized or organized which resulted in poor data discipline by creating multiple instances of the same message. This had a secondary impact of creating more network traffic than was necessary and impeded the ability of the 2018 architecture to scale.

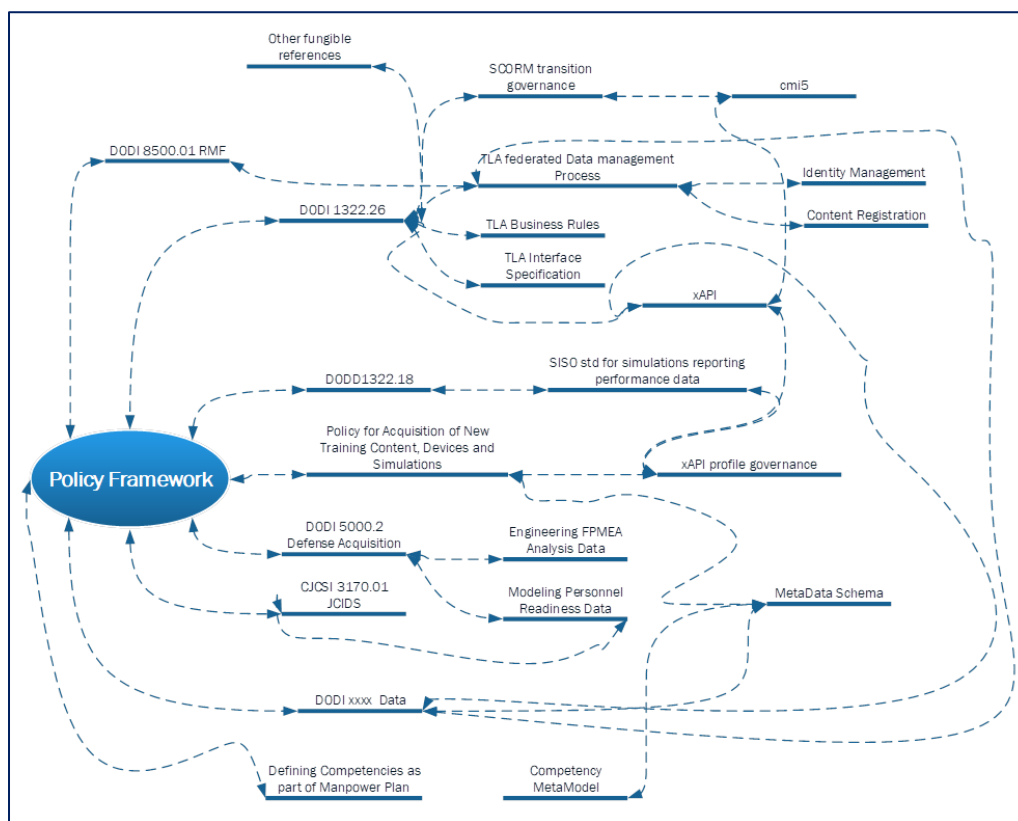
**Service Discovery:** A service discovery mechanism used either a REST API or an admin portal to register endpoints for each TLA service. The service was under-utilized and many TLA components in 2018 used hard-coded IP addresses inside their software. This was problematic when trying to set up a development environment that is separate from the live production servers after the production servers were locked down prior to the event. For future instances of the TLA, a dynamic Service Discovery Protocol (SDP) will be investigated to help reduce the configuration efforts required by TLA developers.



## 5. CONCLUSION AND NEXT STEPS

The 2018 TLA Test and Demonstration, coupled with the 2018 TLA Reference Implementation, the CODIAC content, and the 2018 technical specifications proved successful in demonstrating the potential of competency-based learning, the viability of existing technical standards, and the amount of relevant data that can be generated through the TLA. The 2018 TLA Test and Demonstration also exposed technical gaps in the way the TLA was implemented and revealed numerous lessons learned on the complexity involved with migrating a single course from a linear program of instruction into a competency-based learning system. One of the biggest challenges faced was the attempt to demonstrate the value of data analytics and lifelong learning in the context of a single, one-week course.

Future events should better represent the complexities of different learning environments, different learning activities, and student behavioral changes that occur throughout their career. One big revelation during this year's event was the reliance on the training and education community to generate evidence of competency within CaSS. From the perspective of competency-based learning, evidence needs to be collected from numerous sources including the operational work environment. The 2018 experiment showed this is possible from a technical perspective, but that there are many policy issues that need to be changed to enable this capability for the future.



**Figure 31. 2019 Technical Specifications and Standards** – This figure shows the preliminary specifications and standards being investigated for inclusion in the 2019 TLA Reference Implementation. These show the breadth of scale and the scope of impact in migrating away from simply collecting performance data from a learning activities and places additional focus on the collection of evidentiary data from operational systems and mission outcomes that include key performance indicators that are aligned to the myriad of different competencies in a framework.

As shown in **Figure 31**, the 2018 TLA Test and Demonstration informed the team on new potential standards and specifications that should be explored and evaluated for potential inclusion in the future. Many of these technical standards are not the atypical learning standards that the ADL Initiative has traditionally worked with. Instead, they tie into other areas of the DoD including Failure Modes and Effects analysis (FMEA), business rules and logistics, the JCIDS requirements development process, and even the way we acquire learning tools, systems and content. Many of the candidate specifications shown above are being investigated with the overall intention of positioning the xAPI as a Global Information Grid (GIG) standard to enable it to be used to pull data about learner performance from the same work system being used on the job.

The 2018 TLA Reference Implementation showed that while technically feasible to collect and process data derived from any system, the policy issues are a limiting factor in the DoD today. One example is during a hack-a-thon leading up to the event where a 911 database from NYC was instrumented with xAPI so all calls over a specific time frame would be decomposed, quantified into meaningful data, and streamed to an LRS for further review.

Another area of 2019 TLA Test and Demonstration research should focus on creating *vocabularies* and *classifications* of competencies that can be attached as metadata to each competency object. This would allow for commonality and reuse of competency objects and descriptors across organizations. It would improve the ability to build assessment strategies that predict the influence of different activity *types* applied to specific competency *classifications*. Metadata vocabularies might include descriptors that inform whether a competency includes psycho-motor skills, fine motor skills, cognitive skills, skill decay, or relevant environmental factors that impact or inform the description of a competency. Some competencies are linked to the environment in which the competency is expressed, and others are motivated by objectives (knowledge, skills, abilities). **Table 11** below shows one approach for creating competency classifiers that demonstrate how different competencies might be grouped together

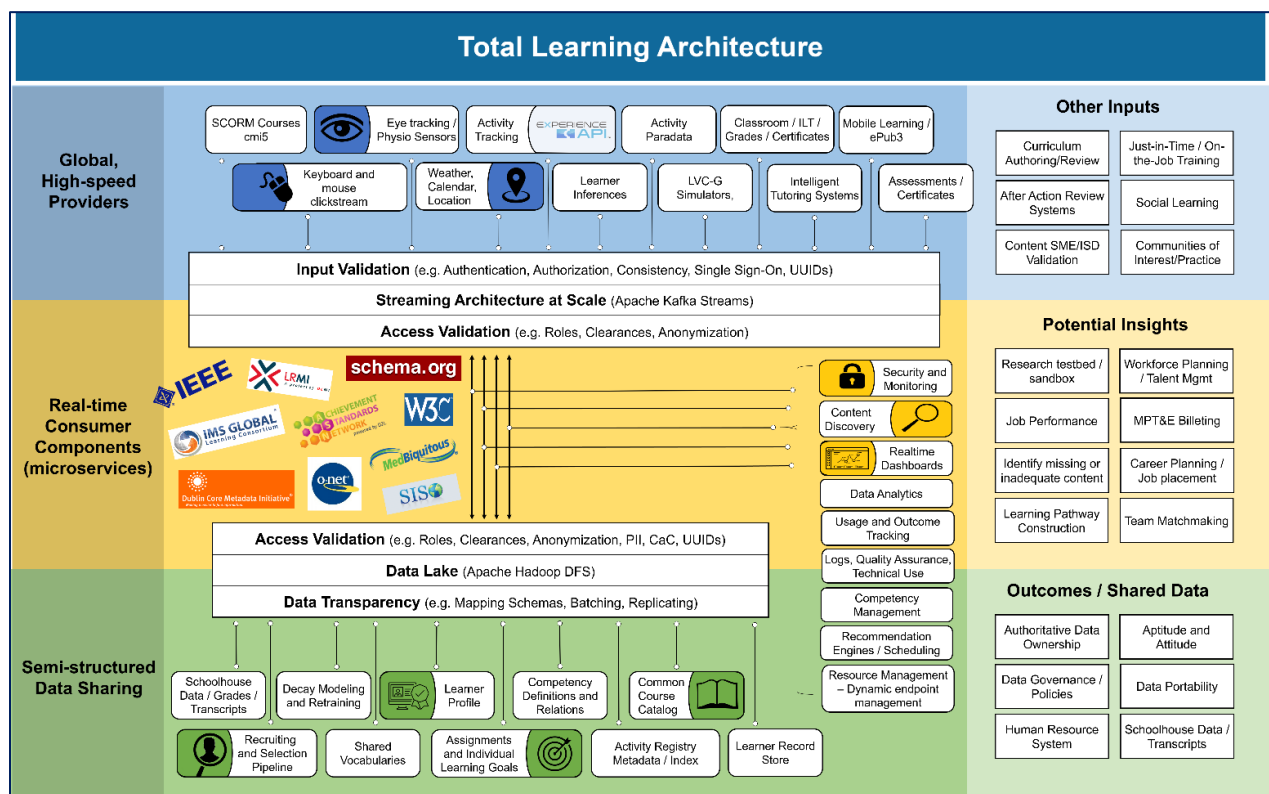
The 2019 TLA Test and Demonstration research should also investigate approaches for formalizing how assessment rubrics can be defined, managed, consolidated and shared. Many competency frameworks include rubrics, performance levels, or other data that can be used to evaluate proficiency. The Human Performance Data Model provides similar capabilities. A TLA Assessment service using common vocabularies could provide a common approach for integrating these rubrics into the TLA.

**Table 11. Competency Classifications** – This table shows a small number of competency classifications pulled from Wikipedia at [https://en.wikipedia.org/wiki/Competence\\_\(human\\_resources\)](https://en.wikipedia.org/wiki/Competence_(human_resources)).

Classification	Description
<b>Organizational Competency</b>	These competencies describe the mission, vision, values, culture, and core competency of the organization that sets the tone and/or context in which the work of the organization is carried out (e.g., customer-driven, risk taking, cutting edge).
<b>Core Competency</b>	Capabilities and/or technical expertise unique to an organization. These competencies differentiate an organization from their competition (e.g., the technologies, methodologies, strategies, or processes or that organization that create competitive advantage). An organizational core competency is an organization’s strategic strength.
<b>Technical Competency</b>	Depending on the position, both technical and performance capabilities should be weighed carefully as employment decisions are made. For example, organizations that tend to hire or promote solely based on technical skills, (i.e. to the exclusion of other competencies) may experience an increase in performance-related issues (e.g. systems software designs versus relationship management skills).

Classification	Description
<b>Behavioral Competency</b>	Individual performance competency is more specific than organizational competencies and capabilities. As such, these competencies are defined in a measurable behavioral context in order to validate applicability to the work environment and the degree of expertise.
<b>Functional Competency</b>	Functional competency is job-specific competency that drives quality results for a given position. They are often technical or operational in nature (e.g., backing up a database).
<b>Management Competency</b>	Management competency identifies the specific attributes and capabilities that illustrate an individual's management potential. Unlike leadership characteristics, management characteristics can be learned and developed with the proper training and resources.

To mitigate the limitations of the point to point architecture used in the 2018 TLA Reference Implementation, a real-time stream-processing software platform is needed to handle the numerous data feeds in the TLA. As shown in **Figure 32**, Apache's open-source Kafka platform is one such solution. This migration will provide consistency in how data is accessed and communicated throughout the TLA. TLA components will subscribe to relevant TLA data streams (topics), pull from various data stores within the TLA data lake, and publish new TLA data streams that other components will subscribe to. In the future, this exploration may identify new capabilities and potential for managing data about learning.



**Figure 32. 2019 Data Streaming Architecture** – The 2019 TLA Reference Implementation is migrating into a more modern data streaming architecture using Apache Kafka. Data producers are along the top and may include learning activities, biometric feedback devices, mastery estimates, Learner Profile updates, or any other types of data that need to be collected in support of education and training.

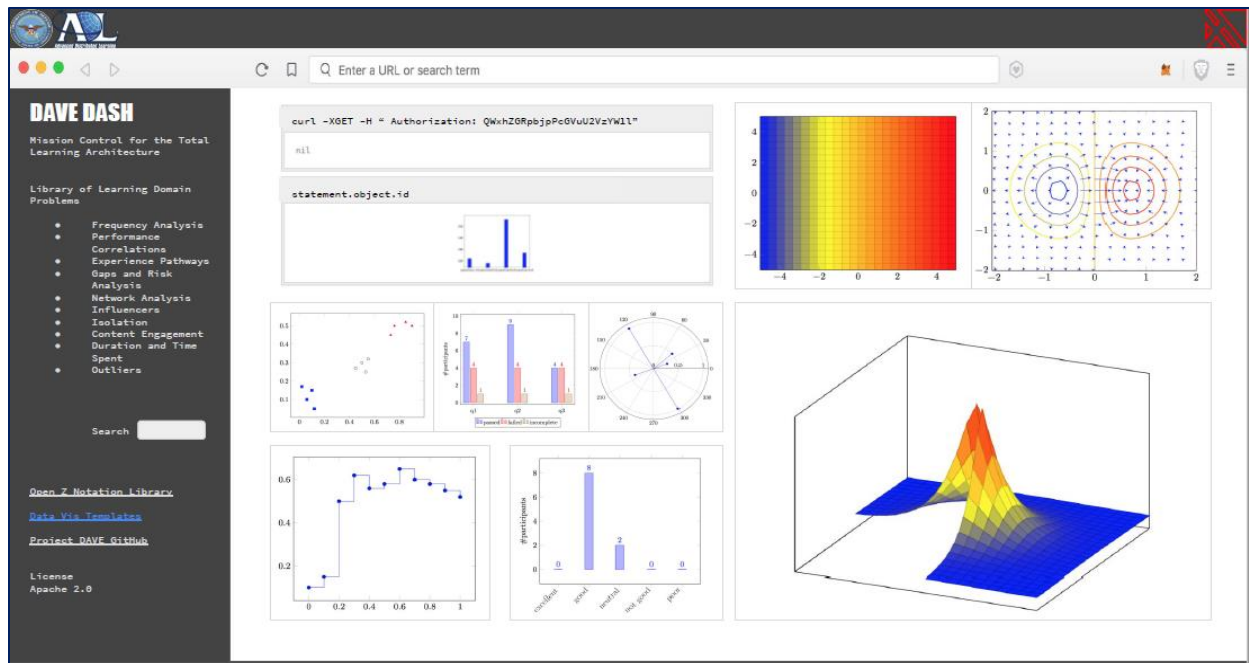
Using the streaming architecture, we will be able to stream numerous types of data in any number of formalized data schemas that represent the numerous types of data that a typical learning ecosystem might generate. The concept is to forward all data to a brokerage service that validates the messaging format and sends the appropriate data topics to the appropriate endpoint in the data lake. This provides a single collection point that all other TLA components can publish or subscribe to in real time while also providing the ability to pull in historical data from the data lake.

The vast increase in the quantity of personal information that is being collected and retained, combined with the increased ability to analyze it and combine it with other information, is creating valid concerns about the ability of different TLA components to manage these unprecedented volumes of data responsibly. There is an urgent need to strengthen the underlying systems, component products, and services that make learning data meaningful. Data labeling will enable the implementation of artificial intelligence, recommendation engines, and adaptive tutors by creating a uniform approach for labeling data within the future learning ecosystem. In addition to a data labeling strategy, an exploration into simulated datasets will present the opportunity to start exploring other relevant topics such as the data lifecycle, periodicity of required updates, and pattern discovery techniques.

As previously mentioned, the 2019 TLA Reference Implementation will also instantiate the Learner Profile as separate entity from CaSS. The promise of new TLA applications stems from the ability to create, collect, transmit, process, and archive information on a massive scale. The vast increase in the quantity of personal information that is being collected and retained, combined with the increased ability to analyze it and combine it with other information, is creating valid concerns about the ability of different TLA components to manage these quantities of data responsibly. This work will identify best practices for managing a Learner Profile across the continuum of lifelong learning while also defining approaches, processes and methodologies for creating, managing and storing Learner Profile data and describing lifecycle considerations for each data type including authoritative sources where each data type can be discovered.

An Activity Registry is an approach to capturing, connecting and sharing data about learning resources available to an organization. Key features include the ability to generate and manage content metadata, manage taxonomies and ontologies, alignment of content with competencies, generate and manage paradata, perform semantic search services, and create machine-actionable metadata for AI-based recommenders. Organizations that consume a learning resources will also capture information about how a resource is used including context, user feedback, user ranking, rating, annotations, etc. Over time, this paradata (usage data) and third-party analytical data may become more valuable and more useful than curated cataloging metadata for discovery and understanding which learning resources are effective.

A big effort as part of the 2019 TLA Reference Implementation work includes enhancing the metadata strategy using the LRMI specification to build out required, recommended, and optional metadata attributes for each learning activity. Additional research needs to identify an approach for describing various learning activities a learner will encounter across the continuum of lifelong learning. Best practices will also be identified for managing, updating, and versioning this information in an intuitive way that can also drive the development of a common course catalog across the entire DoD. The Data Analytics and Visualization Environment (DAVE) Framework provides an open-source means of creating domain-based learning data dashboards that is extensible to new learning problems, instructional strategies, technological realities, and metrics objectives. As shown in **Figure 33**, each topic in the DAVE Framework features a domain problem, an algorithm designed to solve the problem, and a recommended data visualization.



**Figure 33. 2019 Data Analytics and Visualization Environment** – The migration to a Data Streaming architecture in 2019 will enable a common approach for accessing TLA data through micro-services that publish and subscribe to different TLA data streams. This approach allows TLA dashboards to pull data from the different streams and transform that data into meaningful reports, visualizations, and analytics.

The migration to the new architecture also provides the ability to subscribe to data from any TLA component to produce specific data-driven visualizations that represent data and/or analytic results in concise, graphical ways. These analytics are intended to go beyond static charts and graphs to produce real-time reporting capabilities. While these reports can be used to provide an answer to a specific question, they should also promote further inquiry and exploration of the vast amount of data collected about different elements of training and education. Within the TLA, a data dashboard is expected to be an information management tool that visually tracks, analyzes, and displays key performance indicators (KPI), metrics, and key data points about an individual, class, a training event, or other TLA-related information. This requires data to be aggregated from across TLA components. TLA dashboards will combine data from an LRS with learner data, content paradata and metadata, competency frameworks and other relevant data to provide insights and reports.