Competency Framework Development Process Report

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14. ABSTRACT

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This document addresses the authoring processes used by AETC and Eduworks for developing competency frameworks. It does not address authoring activities for other Department of Defense (DoD) components or the entire Federal Government. The document captures the technical approach used by the Air Force and describes the key methods used to populate digital competency frameworks for the United States Air Force and the Eduworks corporation for other customers across industry, academia, and government.

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1 INTRODUCTION

This document is the final report for the Competency and Skills System (CaSS), contract number, W911QY-16-C-0002. As part of this work, Eduworks Corporation conducted interviews with AETC to gather knowledge on their processes and workflows for authoring competency frameworks that capture various Air Force Specialty Code (AFSC) knowledge, skills, abilities, and other attributes across a variety of ranks.

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CaSS is an open-source competency-management system prototype that manages digital competencies throughout their lifecycle. Over the last three years, the Advanced Distributed Learning (ADL) Initiative funded multiple research endeavors to develop a viable open-source software capability to support a range of Competency-Based Learning (CBL) initiatives across industry and the Federal Government. Eduworks is a small business specializing in the development of CBL solutions that use machine learning and artificial intelligence at their core.

The ADL Initiative's Total Learning Architecture (TLA) project seeks to create interoperable learning standards and prototypes that enable plug and play interoperability of learning technologies in the future. In 2018, the ADL Initiative identified Competency Management and related standards as a critical enabler to the TLA [1]. The contents of this report provide context and actionable information on enabling CBL across the DoD. The CaSS project creates data standards that enable competency frameworks to be represented in a digital state leading to interoperability and interchangeability between environments. This effort is underway and has multiple activities planned with Air Education and Training Command (AETC) in the future.

The CaSS open-source software platform provides a basis for experimentation but is not a fully accredited software application available for on U.S. Government or DoD networks.

CaSS [2] [3] [4] has three major components:

- A *competency repository* that stores and manages competency frameworks; a structured set of objects, generically called "competencies." Each competency can be defined by a wide range of associated metadata, such as description, type, scope, level and context, and associated resources, such as assessments, operations manuals, and training content.
- An *assertion store* that collects assertions about an individual's competencies. The term assertion is used in place of the term assessments because claims of competency may be based on many different factors (observers, assessments, operational systems)
- A *profile system* that gathers data from the assertion store, creates individual or team competency profiles and allows profiles to be managed and stored under TLA business rules.

See the *Appendix* for a full CaSS overview.

1.1 Report Contents

CaSS and other CBL-related initiatives deal with abstractions called *competencies*. From a CaSS perspective, a competency is anything that specifies knowledge, skills, abilities, and other aptitudes, abilities, motivations, and traits (KSAOs). Competencies may also include other human traits or behaviors that are relevant to education, training, or talent management. Within CaSS, competencies are organized into structured collections associated with a job, task, or subject. These competencies are referred to as *competency frameworks* or *frameworks.* A competency model [6] is another widely used term for the same thing and can be used interchangeably with the competency framework.

Organizations will often define competencies differently. CaSS was developed to ingest and normalize any competency definition and any valid competency framework, such as CASE, ASN, O*Net. CaSS also contains a mechanism for assigning a *type* to a competency so any competency object can be externally labeled based on organizational preferences.

This report includes the following:

- Overview of CaSS;
- Details on Eduworks' process for facilitating the development of competency frameworks
- Comments on the AETC process for developing competency frameworks;
- Detailed instructions for uploading competency frameworks to CaSS;
- User Interface mockups for entering competency frameworks into CaSS;
- Best practices to apply frameworks after storing in CaSS.

A section on the IEEE 1484.20.1 standardization project for Reusable Competency Definitions [5] and its role in the TLA was also added to this report after receipt of the initial draft.

1.2 Competencies, Objectives, and Outcomes

Competencies define the KSAOs required to successfully do a job in an operational environment like the workplace. In the context of learning, competencies are often associated with learning objectives or outcomes. Multiple competencies or *Competency Objects* are represented within a competency framework. The framework may align with other frameworks and learning objectives. This document outlines the process for aligning competencies with the Terminal Learning Objectives (TLO) typically represented as part of a credential.

Learning outcomes explicitly state what a learner should be able to do after the successful completion of a *learning activity*. Competencies, in contrast, are independent of an activity and should be identified and defined before specifying learning objectives or outcomes.

Another significant difference between competencies and learning outcomes is that learning outcomes are observed and measured in the context of the learning activity, which is substantially different from the work environment where the competencies are applied. As depicted in ***Figure 1***, observing learning activities directly or observing related performance in the workplace generates evidence of competency. The evidence, when aligned to a competency framework, acts as an assertion of the learner's competency level.

An individual's evidence of competency is observed across multiple experiences, and some competencies are best assessed by performing tasks in the workplace [7]. As an example, a critical skill for a commercial vehicle driver is "*anticipating the actions of other drivers*." The skill is not part of a specific task thus, it may not appear in a task analysis used to develop learning objectives. If it does, the associated training may focus on issues, such as the distance one should maintain from other vehicles, how a driver scans and interprets the environment, or how to predict another drivers' behavior based on various sensory inputs. These issues support the competency however, they fail to address the real substance of the competency when viewed independently.

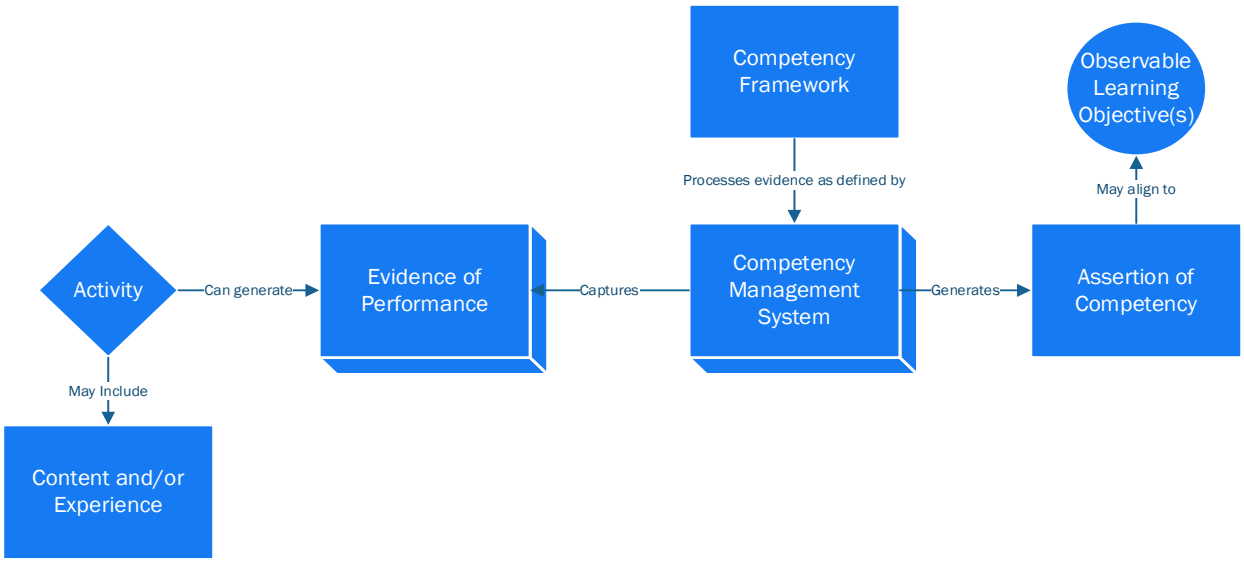

Figure 1. Relationship of Competency and Assertions. *Learning activities generate evidence of performance, which is processed by a Competency Management System. The Competency Management System aligns the evidence to the Competency Framework and asserts levels of proficiency for individuals or teams.*

2 EDUWORKS COMPETENCY FRAMEWORK DEVELOPMENT PROCESS

In 2017, Eduworks created a *Competency Framework Development* (CFD) process to help develop competency frameworks as part of the eXtension Foundation's effort [8] to transform its education and training programs to a CBL approach. The eXtension Foundation uses these frameworks to design new courses, analyze existing courses, and help learners find resources to meet training and professional development goals. These frameworks are also used to help credentialing bodies determine if learners have demonstrated the required skills to perform a task or function.

The CFD process is built upon existing processes, methods, and techniques used in Instructional System Design (ISD), curriculum design, and skills-identification. The CFD process also borrows concepts and techniques from the *Developing a Curriculum*[1] (DACUM) process which is also used by AETC to develop their competency frameworks from. CFDs, as instances of the process are called, generate two artifacts: a competency framework and sample assessment methods to verify behaviors that show competencies within the framework.

[1] http://www.dacum.org

The CFD process is used to map learning activities to competencies, identify how and where competencies are assessed, and produce credentials associated with key milestones. The *alignment* [9] between a competency and various learning activities will generate evidence about an individual's proficiency level for the KSAOs represented within a specific competency object. The CFD produces tiered competency frameworks represented by a few top-level competencies and their required KSAOs. When applied to curriculum development, top-level competencies are often equated with TLOs but in many instances, a competency does not decompose into a learning objective.

2.1 Applications of the CFD Process

The CFD process was first used to create competency frameworks in 2017 by the eXtension Foundation for their "*Working Out Loud*" program based on the work of John Stepper [10] to promote social collaboration in the workplace. The CFD process was also used to create frameworks around agricultural science in urban environments. Another notable example is the "*4H common measures and a lesson study*" which includes 12 high-level competencies with over 80 sub-skills [11] for veterinarians who use health informatics technology at the University of Guelph in Ontario.

2.2 The CFD Process

The goal of the CFD process is to develop a competency framework for a specific job or work function. The CFD process is completed through a series of online meetings with practitioners, informed by distillations of pre-existing materials.

The CFD process includes the following key steps:

1. **Gather Materials**: Research sources of relevant competency framework information.
2. **Recruit Practitioners**: Arrange for 4-7 practitioners to participate in CFD.
3. **Distill Materials**: Use materials to develop potential competencies and assessments.
4. **Develop Competencies**: Facilitate structured online practitioner sessions to develop competencies.
5. **Develop Assessments**: Facilitate structured online practitioner sessions to develop assessments.
6. **Publish Framework**: Publish resulting competencies and assessment rubric.

If existing courses or learning activities are available, additional steps include:

7. **Develop a Competency Rubric for the Course**: Map course components to competencies.
8. **Modify the Course**: Change assessments and content to focus on competencies.
9. **Define Outcomes**: Establish key performance metrics.

The following sections provide details related to each of these steps.

2.2.1 Gathering Pre-existing Materials

The goals of analyzing pre-existing materials are to increase the facilitators' understanding of the job, start communication and collaboration among practitioners, establish a common taxonomy, create materials that make the process more efficient, and avoid conflicts with authoritative sources.

Materials should directly address the population, workforce, specialty, and position the framework is being developed to represent. Material are used to explicitly state job functions, tasks and required KSAOs. In addition to, quickly identify valid and reliable resources, such as learning objectives or learning outcomes that are currently used to train and educate practitioners. Other useful materials include the outputs of a DACUM process related to the job or function, certification standards developed by a legitimate professional association, well-designed instructional materials with objectives and outcomes, and the results from discussions with practitioners on the job or function from the framework in development.

The CFD facilitator is not required to be a domain expert to perform the CFD process. CFD facilitators should enlist the aid of practitioners in identifying credible sources and potential materials. The facilitator should not use materials that practitioners do not accurately represent the targeted population. All materials need to be reviewed with practitioners to understand their relevance to the job. This provides a method to collect practitioner input on the vital criterion that needs to be included in the competency framework and familiarizes the practitioners with the materials and helps refine a common taxonomy of terms and references.

In rare instances, there is a lack of suitable materials to aid the creation of a competency framework. In these instances, the facilitator will work with practitioners to capture the current body of knowledge following DACUM processes. Capturing the information directly increases the relevance of the final product and can be used as a foundation to build upon in the future.

2.2.2 Practitioner Recruitment and Commitment

Practitioners are at the core of the CFD process. Each session in the CFD process will ideally include 4 to 6 practitioners. If there are too many participants, it becomes unwieldy online however, if the facilitator can access a larger group, practitioners not taking part in online sessions can act as reviewers. Each practitioner should expect to spend approximately 15 hours on the CFD process over 2 weeks.

2.2.3 Analysis of Materials

As materials are analyzed, the facilitator should begin the development of a candidate set of competencies. A spreadsheet should be used to document successful workplace behaviors and their associated indicators. The spreadsheet should have the following features:

- Define a unique identifier for each competency at the project or global level.
- Identify different components of competency, such as KSAOs and TLO.
- Allow the description of an Action Verb, Object, and Modifier when referring to KSAOs.
- Delineate the difference between knowledge and ability.
- List Proficiency Indicators.

The facilitator should engage with practitioners on calls or online sessions to begin identifying higher level competencies, sub competencies, and other related KSAOs that embody the core components of each job or responsibility. The facilitator should be careful not to place hidden biases into the list of indicators and should avoid relying on a single practitioner's opinion. The objective is to translate authoritative information into a format that can be used in the CFD process rather than define new competencies.

2.2.4 Session Guides

Facilitators use CFD guidebooks to explain the CFD process and to guide practitioner sessions. Most of the content in a session guide is generic and remains unchanged with the job being analyzed. On-the-job examples should be used to facilitate discussions among practitioners when available. These can be derived either from the existing materials and the competency spreadsheets or the practitioners can generate them.

2.2.5 Practitioner Sessions

All sessions are consensus-driven and are generally scheduled for 2 to 4 hours but may be scheduled for shorter periods at the facilitator's discretion.

Introductory Session: The first practitioner session introduces the CFD process. The facilitator goes through the introductory material to clearly define what is and what is not a competency and how to define KSAOs. Competency frameworks will be discussed, and the interdependent relationships between competencies, competency frameworks, and assessment criteria will be explained. No competencies will be defined during this session. The CFD guidebooks also include quizzes to help determine if learners understand competency concepts, KSAOs, and assessment techniques.

Competency Development Session: Competencies are developed using a consensus process where practitioners receive encouragement to recommend competencies. The facilitators run these sessions as brainstorming efforts to ensure total participant engagement and to enable discussions that move the group toward consensus. The discussion focuses on practical aspects of a job rather than theoretical requirements.

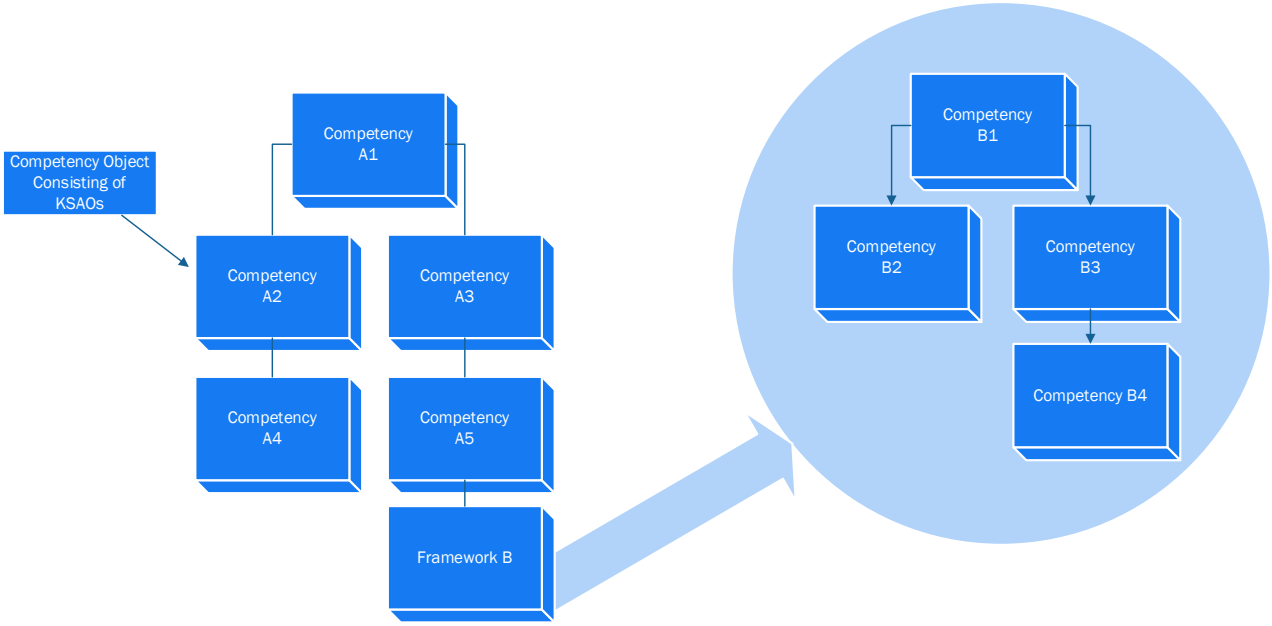

Figure 2. Typical Structure of a CFD Framework. *Top-level competencies are identified and then expanded to include supporting competencies. The hierarchical nature of this allows one competency framework to include the entirety of another competency framework as a supporting competency.*

A typical framework has 6 to 15 top-level competencies. If applicable, TLOs from existing courses may be used or modified to provide the high-level competencies. Practitioners may also make suggestions for high level competencies based on their experience. One CFD session is enough to develop the top-level competencies, but additional sessions may be scheduled as needed. Only top-level competencies should be developed in the initial sessions. If other competencies are identified they should be documented and stored for later use. A suggestion process is used to identify and organize competencies. Typically, the facilitator will limit the time spent on each top-level competency so that all top-level competencies can be addressed. This may require 1 or 2 sessions, depending on the number of the competencies.

Additional Competency Development Sessions: During these sessions, each top-level competency is decomposed into sub-competencies. Lower-level KSAOs may appear in more than one competency. As depicted above in ***Figure 2,*** some competencies may encompass another framework. In managing these sessions, the facilitator will start with top-level competencies and use their associated KSAOs to derive supporting competencies. Sometimes practitioners agree upon new suggestions and information but do not incorporate the suggestions into the framework, so they re-route the information into a competency spreadsheet to revisit later.

Offline Review: Each practitioner must review the framework by commenting on the competencies, suggesting indicators for each competency, and recording these indicators. Indicators are discussed further in section 2.4.1.

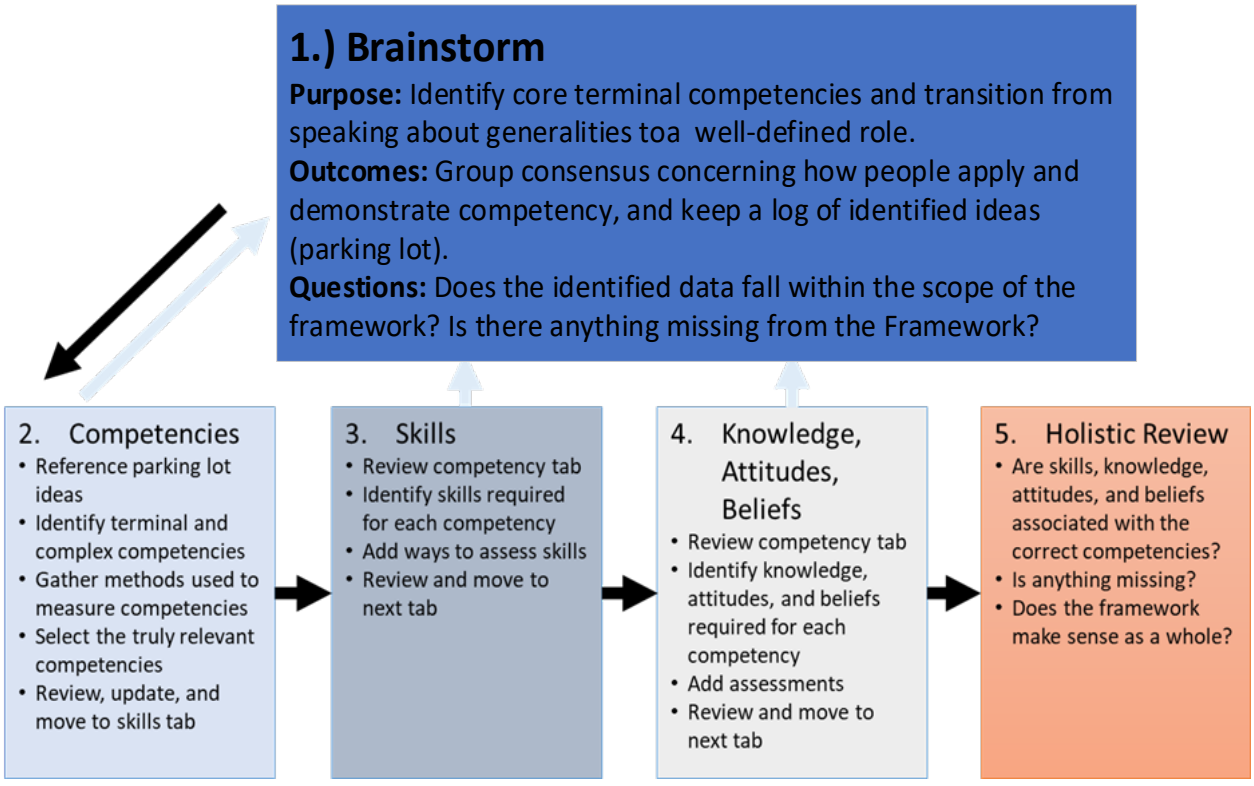

Figure 3. CFD Process Workflow. *The CFD process starts with a higher-level discussion about how people apply and demonstrate competencies in the workplace. This informs the identification of candidate competencies that are further decomposed into KSAOs. Once top-level competencies are defined, they are decomposed into sub-competencies and aligned with evidence of proficiencies through various learning activities and assessments.*

Assessment Sessions: These sessions develop assessment methods for each competency. The facilitator reviews how to derive assessments from competencies, how to express each assessment, and how to identify performance indicators. Assessment methods must be defined for each competency and any evidence of proficiency must be derived from key indicators identified earlier in the CFD process. Assessment methods must also be well-defined and measurable. Discussions should also determine whether the competency is assessed separately from its sub-competencies or if the competency and all its sub-competencies needs to be assessed. Assessment strategies should not use a single measure of evidence. Instead, they should incorporate a robust estimation of proficiency from numerous data sources into their assessment strategy. As shown in **Figure 3**, the competency framework developed through the CFD process should undergo a holistic review across a community of practitioners to periodically update and refine the resulting competency framework.

2.3 What is Knowledge, Skill, or Ability?

In a CFD, a competency is defined *as a collection of Knowledge, Skills, Abilities, and Other attributes (KSAOs).* Competencies have been traditionally applied to training environments designed to develop knowledge and skills. However, CBL has the potential to explore more complex measures of mastery by allowing individuals to demonstrate mastery in an operational setting.

When following the CFD process, it is useful to have clear and precise characterizations of what defines KSAOs and how they differ. The capture of KSAOs related to a generalized proficiency level does not express the uniqueness of an individual's talent or capability. When documenting KSAOs, subject matter experts may offer insight that represents the optimal characteristics of a practitioner besides their required KSAOs. For this reason, the CFD process uses the following definitions:

- **Knowledge** *comprises facts, principles, and beliefs*[2] *to be expressed as declarative statements, to transmit to others, and to acquire from others through communication*.
- ***Skill*** *is the capacity to effectively apply knowledge and abilities to perform a physical or mental task [13].*
- ***Ability*** *is the capacity relevant to performing a task a set of tasks.*
- **Other *Characteristics*** are the most complicated contributors to competence and the most difficult to measure. These may include aptitude, attitude, self-confidence, interests, inclinations, and more [14]. Personal traits like self-confidence or emotional intelligence may indicate a disposition to handle challenges more effectively. Characteristics come naturally to individuals. While they cannot be taught, these characteristics can be influenced. Identifying and including these characteristics in competency frameworks can prove invaluable in selecting candidates for different jobs or roles. Though difficult to measure directly, characteristics often manifest themselves in measurable behaviors [13].

[2] There is no inherent requirement for knowledge to be correct, as a competency framework for the Flat Earth Society may argue the *fact* that the Earth is flat. However, in practice, it is assumed that knowledge in a framework is correct as far as the owner of the framework is concerned [12].

During the introductory CFD session, the facilitator will present these definitions and go through short exercises to ensure everyone helping to develop the competency framework understands the definitions and distinctions. The facilitator will also reinforce the principles that learners hone their skills based on behavior and behaviors are not equal to knowledge. The relationship between skills, behaviors, and knowledge are expressed in the form of a skill statement[3]. Each skill must be teachable, and an individual or organization must be able to obtain it through education or training. The skills must also be measurable, meaning there must be an assessment that can determine whether an individual or organization has the skill [12]. Abilities may improve with training and practice, but they cannot always be acquired through training. For example, abilities are often expressed as nouns, such as "20-20 vision" or "dexterity" or "strength."

Example: Rideshare companies typically require their drivers to use their mobile app. These companies also educate their drivers on the danger of inebriated passengers. However, the knowledge required to use a rideshare app differs from the knowledge required to recognize inebriated passengers. In either case, it is unlikely that the knowledge gained by reading through these courses will immediately translate into skills. Skills for a rideshare driver might include "Use the rideshare service's app," "Enter a destination into the rideshare service's app," "Determine the most profitable times to drive," "Obey traffic rules," and "Recognize inebriated passengers." These skills can be learned, practiced, and assessed but not from reading a book or watching a video.

The focus of these sessions should be on those competencies that when combined, contribute to successful performance within a role, position, or job. Top-level competencies comprise multiple KSAOs, and sub-competencies typically constituent elements of a discrete and measurable activity or assessment. In ISD terms, top-level competencies should be at the level of TLOs, and the rest should be at the level of Enabling Learning Objectives (ELOs) as defined by a trusted analysis. When intended for training and education, CFD discussions should remain at a granular level to define or analyze assessments with evidentiary chains to enable proficiency. For assessments that focus on demonstration of skills in an operational environment, assessment strategies should be at a granular level that reflects the availability of trusted performance data.

2.4 Assessment of Competencies

CFD competencies must be measurable and assessable. The appropriate assessment methods for KSAOs may vary but can typically be related to appropriate learning taxonomies (Bloom, Krathwohl, Kirkpatrick, et al.). They tie the critical method to maximize CBL benefits to capturing data, both in the learning environment and under the actual performance of activities aligned to competencies.

Knowledge is assessed by recall or explanation when demonstrated in a manner that reflects the ability of an individual to realize information within the context of a defined environment. Typically, knowledge checks include questions that ask whether some variation of the declarative

[3] The definition of a skill statement is derived from the work of SkillsEngine, which was derived from O*Net, which was derived from the work of Dr. Michael Brown from SkillsNet. SkillsEngine has developed technology to detect what are called discrete work activities (DWAs) which can be written in the form [Action Verb] [Object Modifier] [Direct Object] [Statement Modifier], e.g. Identify (verb) Maintenance (modifier) Problems (Object) in Aircraft (modifier), see for example [35].

statements that define a fact, principle, or belief is true or false, or require a learner to identify the correct statement among multiple choices. Explanatory knowledge checks[4] ask learners "How?" and "Why?" questions that are associated with deeper learning than simply memorization. In the rideshare driver example, asking "*True* or *False*: Inebriated passengers are dangerous." is assessment through recall. Asking "Why are inebriated passengers dangerous?" is assessment through an explanation.

Skills cannot be assessed by a recall assessment and should not be assessed by explanation. Instead, they should be demonstrated through their application in a controlled environment or from evidence captured within an operational environment. Spencer and Spencer [13] discuss skill competencies manifesting as the ability of an individual to complete a physical or mental task. Competency frameworks to measure skill often includes knowledge competencies.

Abilities are rarely assessed as part of a course or curriculum. Abilities transcend the application of knowledge and skills across a range of varying tasks. Abilities may include physical characteristics, traits, behaviors, or capabilities that an individual possesses that enhance their performance of a job duty or task. Abilities may change over time.

2.4.1 Indicators

An indicator is an observable behavior that provides positive evidence of competency. Proficiency levels of a competency are derived through evidence resulting in a prediction of future performance. A rideshare driver may obey every traffic law during a driving test but still lack technical knowledge on the "Move Over" and "Slow Down" laws, which mandates drivers to move over to a nonadjacent lane or to slow down when approaching the rear of a vehicle providing roadside assistance. Real-world competency frameworks often list indicators rather than actual assessments or provide rubrics that list performance levels and indicators for each level.

Behaviors need to be well-defined in the work environment. At a high-level, concepts like trustworthiness, confidence, judgment, and morality are difficult to quantify and need to be abstracted into the evidentiary data feeds that can be generated from a trusted system. An example is tracking the work of a technician and noting their production rate when deployed in a hostile environment.

2.5 Relationship to DACUM

DACUM's process is well known and widely used since it defines a curriculum that trains learners to do a specific job like being a rideshare driver. It is supported by community colleges, other sponsoring organizations [15], training centers [16], and certification programs [17]. The CFD process incorporates many principles used by DACUM and other task-analysis processes.

The output of DACUM includes the decomposition of a job into a set of duties. Typically, these duties are included on a resume and are paid for, each of which comprises a set of tasks broken down into steps. DACUM tasks correspond closely to skills that are expressed using the same [Action verb] + [object] statement. DACUM steps often reveal indicators that are too fine-grained

[4] If an explanation can assess knowledge, then it can be turned into a skill statement of the form "Explain why" or "Explain how."

to be considered skills in a competency framework. The DACUM process closely aligns job duties to top-level competencies and TLOs. In a course, these often correspond to sub-units such as modules, chapters, or lessons.

Figure 4 depicts how DACUM objects, such as duties and steps relate to CFD objects, such as competencies and KSAOs, how CFD objects relate to ISD objects, such as TLOs and ELOs, and how they assess various objects.

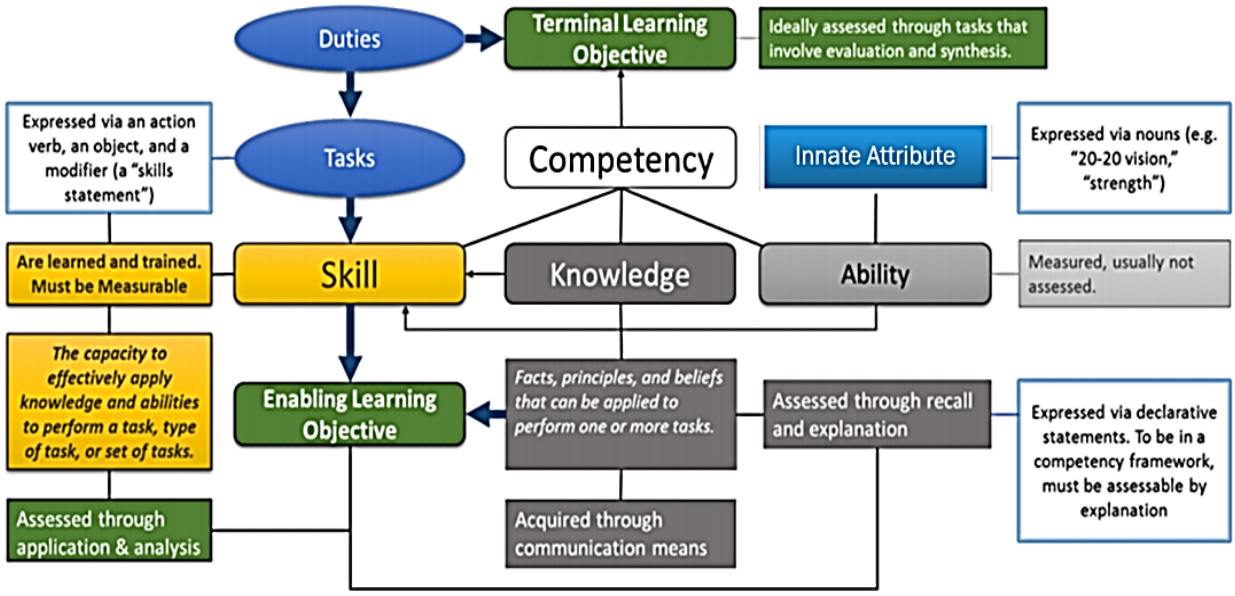

Figure 4. Relationship between DACUM, Learning Objectives, Competencies, and KSAOs. *Through the DACUM process, a job is decomposed into a set of duties. Duties are decomposed into tasks, steps, and the KSAOs required to perform them. From these, competencies are defined, and a competency framework is developed. Workplace performance indicators are aligned to the competency framework along with ELOs, TLOs, assessments, and other evidence.*

2.6 Running the CFD Process

While DACUM requires in-person sessions over 2 or more days, the CFD process uses online web-conferencing tools to collaborate. Documents, spreadsheets, and presentations are all web-based or implemented using other collaborative office software. Meetings take place using common web conferencing tools that promote interactive online collaboration. Key features required to support the CFD process include hand-raising, polling, and video so participants can see each other. The ability to see facial expressions proves useful in the consensus-building processes and helps maintain engagement. Real-time, collaborative tools also reduce the time and costs required to develop frameworks. The CaSS solution includes tools for storing, editing, displaying, and sharing competency frameworks in electronic formats. In its current state, CaSS supports the functionality needed for Eduworks facilitators to run CFD processes and to capture the results.

CaSS is currently being modified to better support the CFD process by non-Eduworks personnel. This is being accomplished in collaboration with AETC. Upon completion of the CaSS CFD Authoring tool, the AETC is expected to have the ability to operate independently from Eduworks

to develop their own competency frameworks to support Air Force Specialty Codes (AFSC). The collaborative online workspace and many of the other tools are commercially available and commonly available across the DoD.

3 AIR EDUCATION TRAINING COMMAND (AETC) PROCESS

As part of this report, Eduworks conducted two interviews with AETC to understand and analyze the processes used by AETC to generate competency frameworks. ADL Initiative and Eduworks staff conducted interviews with AETC personnel from the Institutional Competencies Branch. The AETC process shares similarities with the CFD process as both are independently based on DACUM. AETCs process is effective and therefore results in valid competency frameworks that can be used by ISDs to develop training materials and assess Airmen. This report identifies the key differences between the Eduworks and AETC process.

3.1 Definition of a Competency

AETC defines competency as *an observable, measurable pattern of behaviors, knowledge, skills, abilities, and other characteristics needed to perform successfully on the job.* The definition shares a similarity to the definition in the CFD process. There is a need to conduct further research to determine how differences in authoring approaches affect the interoperability of competency frameworks.

Figure 5. AETC Model

When developing a competency framework, AETC distinguishes between two types of competencies: *foundational and occupational.* Foundational competencies refer to the core competencies required of all Airmen, uniformed or civilian, regardless of grade or position. Occupational competencies deal with Air Force Specialty Code (AFSC) positions. For example, Airmen within an aviation-maintenance group share the same foundational competencies but possess different occupational competencies based on the specific duties they perform.

In CaSS, there are two ways to deal with this distinction. One is to define separate competency frameworks and cross-link them through relationships. The other is to define a single competency framework where each competency in the same framework is labeled as foundational or occupational. Separate competency frameworks provide a more flexible approach because specific AFSC competency frameworks can reference the same foundational competencies.

3.2 Modeling Levels

AETC assigns four performance levels to competencies: *basic, intermediate, advanced, and expert.* True performance levels are a measurement of the same competency in which the individual performs differently, such as being more accurate or faster, but the KSAOs remain the same. Attainment levels are competency levels that require different KSAOs and different levels of performance.

Example: A master carpenter does everything a novice carpenter does but with more proficiency and accuracy. A master carpenter also possesses additional skills and knowledge. Although they share some competencies, a master and novice carpenter are two different top-level

competencies. The shared supporting competencies themselves have performance levels with the master requiring higher performance than the novice on shared sub-competencies.

Attainment levels are different competencies that share a common set of KSAOs and a common label. This is true for AETC, where levels have different observable behaviors and apply to different contexts, such as workplace tasks versus management decisions. They might be better modeled as related competencies by adding *expert* or *advanced* to their job titles.

CaSS supports performance and attainment levels. A CaSS framework defines various performance levels assigned to competencies. The act of associating assessments with levels allows CaSS to store necessary data to publish rubrics for assessing the level at which competency is held. Attainment levels are modelled as distinct, related competencies with the same name but with different levels in their titles and overlapping supporting competencies. During the CFD process, it is best to avoid defining levels as it requires explaining the differences between performance and attainment, which is not always easy for practitioners to understand.

3.3 The AETC Development Process

The AETC process uses surveys, observations, focus groups, and other methods to gather input. They naturally include instructors, administrators, and in some cases, consultants or other experts whose perspectives could introduce an explicit bias towards measuring competencies in terms of learning activities rather than the KSAOs needed to perform a job. In contrast, the CFD process entirely focuses on practitioners and uses facilitation sessions to gather data. In running this process, the goal is to avoid instructors, administrators, and other non-practitioner perspectives and to ensure the resulting frameworks is the result of a consensus process.

3.4 Conflation with Credentials

The best way to de-conflict competencies and credentials is to decompose credentials into their associated competency frameworks. AETC's occupational-competency frameworks are tied to AFSCs. The respective career-field managers must approve all frameworks for each AFSC. Without exercising proper care, this may conflate the competencies required for a job within the Air Force with the credentials required, which are not the same thing. The AETC approach involves cross-coordination between departments to reduce the chance of having duplicate competencies created within the same career field.

In a competency-based learning paradigm, credentials are defined by the competencies they represent. This is the approach taken by the Credential Engine® [18] [19], which incorporates CaSS as an embedded competency-management system. Credentials are defined using the *Credential Transparency Description Language (CTDL)*. The CTDL is used to reference unique competencies. If frameworks are too closely tied to credentials, the resulting frameworks may represent credentials rather than actual KSAOs and may replace training objectives with credentialing objectives. The concept is antithetical to the underlying principles of CBL where competencies, rather than proxies for competencies like credentials, are the underlying currency.

3.5 Tying Training to Competencies

Despite how competencies are created, they have limited value if they cannot be referenced by the systems that need them. Systems like CaSS assign persistent and unique identifiers to competencies, exposing them through Uniform Resource Locators (URL) and Application Programming Interfaces (API) that facilitate the lifecycle management of competency frameworks including authoring, updating, versioning, and maintaining competency frameworks. This approach enables any training-development system to reference and link activities to competencies through search interfaces and drop-down menus. Moreover, when learners interact with these activities, they use the Experience API (xAPI) to transmit statements about learner performance that reference the same competencies.

3.6 Cost and Maintenance

Organizations typically focus on the initial development of competency frameworks and identify that as a primary barrier. To maximize the return on investment, the total cost of ownership needs to be considered and aligned with ongoing modernization efforts and acquisition strategies. To reduce maintenance costs, competency frameworks should be centrally managed and stored in electronic formats that can be easily updated and distributed to other DoD systems in real time as needed, such as Human Resources, LMS, and Intelligent Tutor.

As AETC continues to develop frameworks across a range of specialties, AETCs definitions and implementations of competency frameworks may evolve. AETC connects the approval of its competency frameworks to AFSCs. This implies that new interpretations of the legacy credential models depend on the approval of existing AETC subject-matter experts (SMEs) with a responsibility to assure the quality of all training for certification and its role within an AFSC at a specific rank. Updating and maintaining these competency frameworks will require a flexible system with user-friendly authoring tools. AETCs' current practices make scalability, interoperability, and responsiveness major hurdles for them. The next section discusses the recommended process and features to support AETCs' transformation to CBL.

4 AUTHORING TOOLS AND AETC INTEGRATION

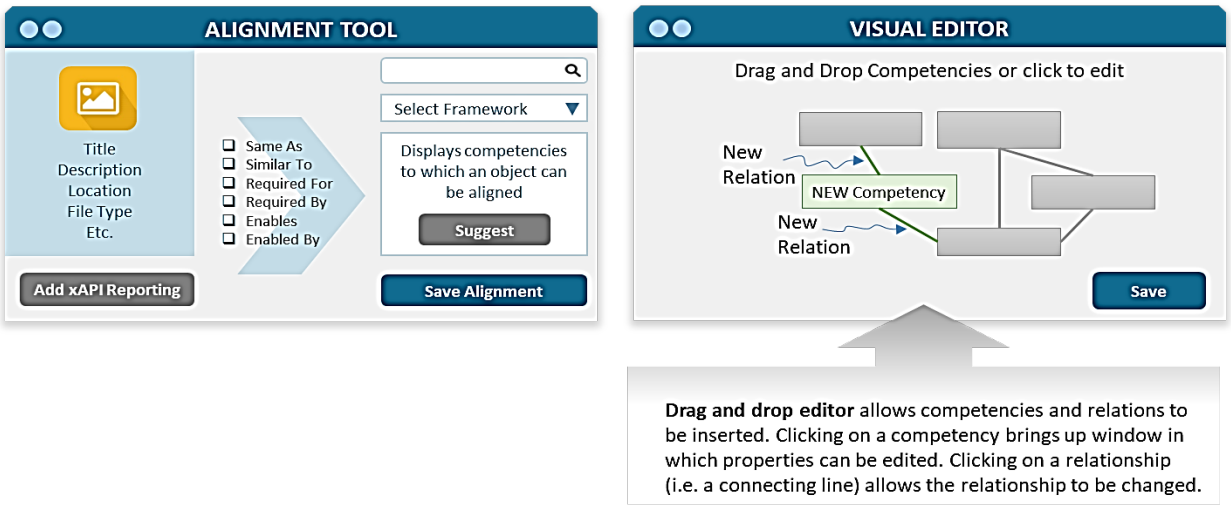

Figure 6. Notional Screenshots of an Improved CaSS Authoring Tool. *CaSS Authoring Tools are being modified to support the AETC workflow for building functional and occupational competencies.*

Figure 6 depicts multiple interfaces and descriptions of what a mature authoring capability might look like that supports AETC and CFD processes for creating new competencies and new competency frameworks.

Current CaSS tools for creating and editing competency frameworks do not require coding or scripting skills. However, they were designed for users with familiarity on how frameworks are defined, stored, and managed in CaSS. Eduworks staff uses the tools to create frameworks developed using other CFD tools like spreadsheets and to touch up frameworks imported or generated from external sources, such as O*Net, OpenSALT, CASE, or Product Lifecycle Maintenance Data. These tools are not user-friendly and lack simplicity and integration capabilities with other systems and tools. **Table 1** below includes a list of recommended features that should be developed into the CaSS Authoring Tools project to support AETC goals and objectives.

Template inclusion is a critical component for creating frameworks that meet quality standards and capture the necessary complexities of frameworks created by different practitioners at different times. CaSS currently supports displaying competency frameworks as lists and visualizations. Updating these interfaces will require user testing to validate their improvement over the current CaSS capability, which ADL previously leveraged in its experimentation [20].

Table 1. CaSS Authoring Tools AETC Requirements. *The following features and capabilities are required to support the AETC workflow used to develop functional and occupational competency frameworks.*

Feature	Remarks	Status
Framework Editor	ADL expects AETC to define templates for competency frameworks. A template will define the different types, levels, relationships, concepts, schemes, and controlled vocabularies, which are available to all framework competencies. The templates will allow users to simplify the framework definition process and will support both the CFD and AETC process. ADL anticipates templates will include methods to link frameworks to AFSCs, AETCs authoring tools, and other systems.	The current editor allows users to edit properties but does not support framework templates.
Competency Editor	Each framework template will define and limit the number of properties given to a competency. The envisioned user interface (UI) sorts these into three categories: • Basic and commonly edited fields, • Useful but often optional rather than essential fields, and • Additional and remaining fields. They will display the templates on different screens. Developers plan to create an authoring tool that will intelligently pre-populate them.	CaSS profiles will define available properties. The current editor shows all fields and assumes the user knows what they are and how to use them.
Alignment Tools	*Alignment* refers to several processes, including tagging training resources with the competencies they teach, require, or assess and cross-walking competency frameworks. The envisioned CaSS alignment tools will have simple UIs and a *Suggest* button, which will recommend alignments by applying methods ranging from a simple phrase matching to a sophisticated natural language processing (NLP). A critical use case is associating formal training activities and informal learning with competencies.	CaSS has a visual tool for cross-walking two frameworks. Although the UI works well, the tool is not intuitive and does not bring the many alignment possibilities under one umbrella.

Feature	Remarks	Status
Integrations	In a TLA environment, all components should be integrated through services that enable competencies defined in CaSS to be easily referenced in authoring tools, training delivery systems, such as LMS or simulator, by xAPI statements, in analytics tools and career management systems. Whether they achieve a full level of integration and interoperability, the competency frameworks shall propagate to the tools used to develop and deliver training content. At first, custom integrations may support this functionality. However, additional guidance from ADL and AETC is necessary to determine what standards-based approaches will be durable and stable.	CaSS integrates with other systems through its APIs and industry-standard APIs for functions like user management. In implementations, CaSS uses the APIs provided by the host environment.

5 APPENDIX

5.1 Directed Acyclic Graphs as the Expression of Digital Competencies [1]

The Institute of Electrical and Electronics Engineering (IEEE) Learning Technology Standards Committee (LTSC) defined a Data Model for Reusable Competency Definitions (RCD) under their IEEE 1484.20.1-2007 Reusable Competency Definition (RCD) Standard [21]. The RCD workgroup is currently updating the standard based on inputs from a community that includes academia, industry, and Federal Government participants. The workgroup also informs the mathematical underpinnings of the TLA CBL standards by providing a format for describing (defining) competencies and associating them with other competencies within the context of an overarching competency framework. The IEEE defines an RCD as any aspect of competence, such as knowledge, skill, attitude, ability, or learning objective.

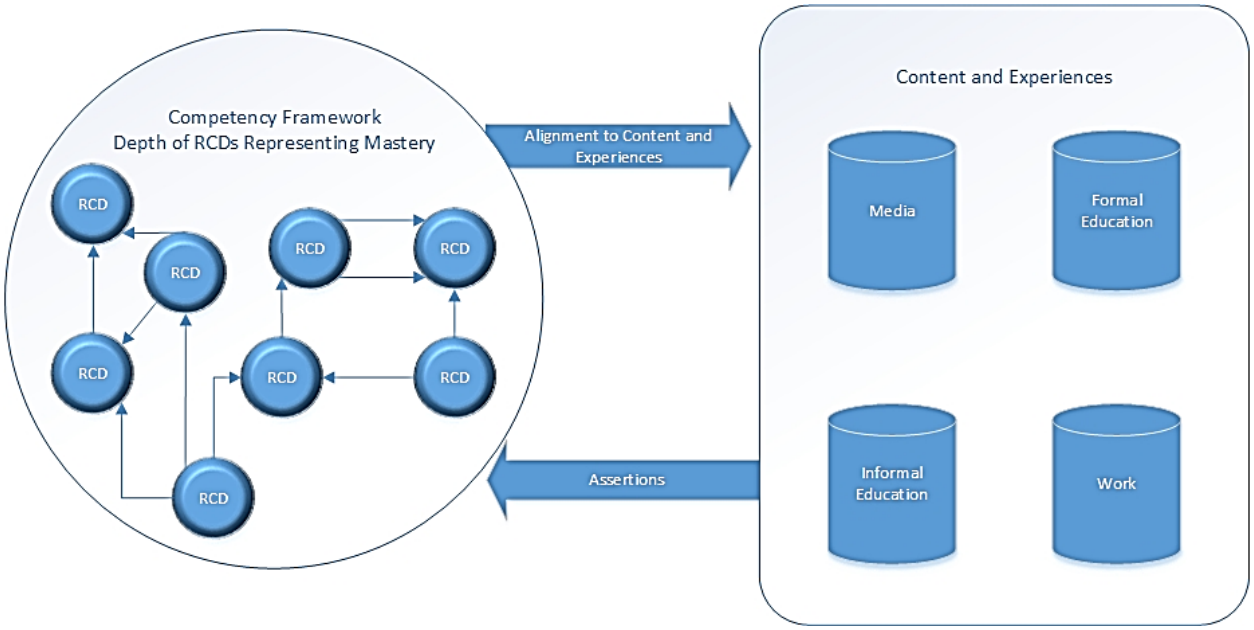

Figure 7. IEEE 1484.20.1 Reusable Competency Definitions. *CFD competency frameworks are defined using the RCD specification. Each competency has numerous bi-directional relationships to other competencies or competency frameworks. ELOs and TLOs are mapped to one or more RCDs across numerous competency frameworks.*

RCDs provide the foundation for a competency framework that aligns formal and informal learning activities, instructional content, and work experience. Using this standard as a guide, existing courses and learning activities can preserve the ELO and TLO structures that are already in place. Each RCD has a unique identifier which allows CFD participants to map the ELOs and TLOs to one or more RCDs across numerous different frameworks. As shown in ***Figure 7***, the nodes within a competency framework have many bi-directional relationships. This perspective reveals that competency is not strictly hierarchal, and a single job may align with multiple top-level competencies. Experience shows that many frameworks are structured in hierarchy and time. Time represents two variables within CBL:

- The linear progression of how traditional education is scheduled, and
- The rate that competency degrades in an individual.

Mathematically, the RCD must behave as a Directed Acyclic Graph (DAG). In graph theory, a DAG structure comprises nodes connected with edges. Each node in the graph corresponds to a competency object, and the edges define the relationship between them. These relationships are directed in that they have a direction. For example, A→B is not the same as B→A. Acyclic suggests relationships are non-circular. When an individual navigates from node to node by following the edges, he or she never encounters the same node twice.

A competency framework provides a mechanism to measure individual and team mastery of the KSAOs required to successfully perform in the work environment. Assertions can be collected from a variety of systems that drive updates to predicted proficiency levels for an RCD based on trusted evidence. From this perspective, assertions provide evidence about an individual and team proficiency from all types of systems including those beyond the traditional training and education environment. Within the TLA, each LRP is described using metadata derived from the Learning Resource Metadata Initiative (LRMI). The LRMI specification utilizes an alignment object to map different activities to each RCD. As CaSS receives assertions, it uses the metadata to differentiate between the different learning experiences and activities that are asserting proficiency.

The concept of using performance data from operational systems to predict competency is relatively new. Traditional educational pipelines are designed to fulfill a credential, which includes many different competencies. However, competencies are independent of time and may be completed in sections based on individual experiences. Individuals with different experiences will become proficient in different RCDs. The challenge is in understanding the context of an RCD in the performance of a job, such as how an individual applies this competency to their job or how different environmental factors play a role in overall performance outcomes.

Alignment between evidence and competencies often requires weighting to quantify the different assertions being made. A person who lacks competency in basic concepts will struggle with more complex tasks. Different learning activities infer different levels of competence at different times within the continuum of learning. Thus, the weighting becomes a multivariate equation that involves the contextual weighting between related competencies, the weighting and currency of evidence, and the weighting of assertions that increase or decrease over time based on the context of the evidence. As a result, this may allow competencies with multiple weights to reflect its context in a job or task.

5.2 CaSS Overview

CaSS was developed to support CBL-related initiatives across the DoD, the Federal Government, industry, and academia. CaSS is basically comprised of a Software Development Kit (SDK) for CBL that aims to save users time and money in the development and management of competencies and competency frameworks. The CaSS framework repository enables competencies to be defined, organized into structured frameworks associated with a job, task, subject, or knowledge domain and shared in conformance with industry standards. CaSS allows all stakeholders to view, comprehend, and interpret competencies.

5.2.1 Properties of Competencies

The underlying RCD data model makes all elements in Schema.org [20], and CaSS-specific elements available. Developers select a subset of the elements and then create meaningful properties to map them to the underlying schema.

Table 2. Competency Metadata Elements. *The following metadata elements are part of a TLA profile for defining competencies in CaSS and illustrate the metadata type that can be associated with competencies.*

Element Name	Description	Purpose and Applications
Name	Short name or title of the competency.	This is what the user will see when they search for a competency. It should be descriptive.
Description	Text description that defines the competency.	A good competency description explains what it is and how it applies. Descriptions are short and require significant tacit knowledge to interpret. There are additional elements intended to narrow the context and meaning of competencies to enable portability and readability of competencies.
Scope	The scope to which a competency applies and the conditions under how to perform or assess them.	Derived from models like Mager's three-part objective definition. It is used to define and narrow the context of competency. For example, a competency like "communicates effectively" can be scoped to communication skills when speaking with coworkers rather than applying any time and any place.
Type	The competency type selected from a local taxonomy, which is specified at the framework level.	The element type allows each organization to create its own taxonomy and labels for such objects. In education, competencies are often called standards, like the Common Core Standards. However, ISD competencies come from task analyses in the ISD world.
Education Level	The education level to which this competency applies.	This is a Dublin Core Metadata Initiative (DCMI) term. See http://www.dublincore.org/specifications/dublin-core/dcmi-terms/#terms-educationLevel.
Language	The primary language used in or by this competency.	Language defines the language that the competency is written, using ISO standard language designations.
ListID	An alphanumeric string found in the source framework showing the relative position of a competency in an ordered list of competencies such as "A," "B," or "a," "b," or "I," "II," or "1", "2".	This element records the numbering; it also enables hierarchies and sub-competency structures from a source framework to preserve the framework after importing it into CaSS. For example, a framework associated with a Mission Essential Competency (MEC) might have a numbered list of skills and sub-skills.

CodedNotation	An alphanumeric notation or ID code as defined by the promulgating body to identify this competency.	This element enables the ID scheme from a source framework to be preserved when the framework imports into CaSS. In CaSS, all competencies receive unique IDs, which can be referenced from URLs. This element maps CaSS IDs to the original framework's IDs.
Derived From	The URI competency from where this competency begins.	It enables the user to link back to the source competency. CaSS allows competency frameworks in CaSS or from external sources to be copied, with no changes allowed, or cloned, after which they can be edited and used in other frameworks. This element retains an all-important link back to the authoritative source of the competency in question.
Identifier	An alternative URI by which this competency framework or competency is identified. This comes from the Identifier property of https://schema.org/Thing.	It is a flexible field that can define alternative identifiers. For example, if an organization like AETC had an authoring tool to store competencies, the element could associate a competency in a CaSS framework with the same competency as it appears in the authoring tool.
Keywords	Word or phrases that help define the meaning or context of a competency.	Keywords aid search, discovery, and interpretation.
Concept Terms	Selected terms from controlled vocabularies that describe the context and application of the competency.	This is used to define the context in which they should interpret a competency, like a department or job classification to which it applies. This element comes from controlled vocabularies, which the organization that maintains the frameworks may define. In CaSS, these lists are machine-readable and represented as Simple Knowledge Organization System (SKOS) concept schemes, which allow applications to interpret and reason with them. It also allows changes in them to automatically populate throughout all applications that reference them.
Skill Embodied	Cognitive, affective, and psychomotor skills directly or indirectly embodied in this competency.	This is used to establish traceability between the learning science and psychological perspectives related to a competency and its expression within a framework.
Level	A performance level associated with a competency.	The performance level comes from a list of levels defined for a framework. The description of the level shows measurable criteria for assessing performance. **NOTE:** Performance levels are not the same as attainment levels. As an example, consider the skill of juggling three balls in a cascade pattern. Performance levels might address the number of throws accomplished before dropping and the uniformity of the height of the balls. For the higher-level competency, juggles three balls levels, such as a beginner, intermediate, advanced, and professional are attainment levels because a professional juggler not only performs each trick better but also knows more and different tricks. In CaSS, two attainment levels of the same competency are modeled as two different but related competencies.
Weight	A numerical value that indicates the importance of competency within a framework.	Used to indicate whether competency is "required" or "desired."

5.3 Machine-Readable Competencies as Linked Data

A primary function of the CaSS framework repository is to allow organizations and training systems to access and share competency frameworks programmatically. To accomplish this, CaSS exposes competencies and competency frameworks as machine-readable linked open data (LOD) [21] [22] [23] in JSON-LD format that can be accessed through URLs and manipulated through CaSS Create, Retrieve, Update, and Delete (CRUD) Web Services or through code libraries. This enables training and talent management systems to reference and apply the same competencies and to allow system users to create shared understandings of the meaning of learning objectives, learning records, and the KSAOs possessed by trainees. This shareability is a prerequisite to use technology to support any competency-based training, education, and talent management.

5.4 Support for Industry Standards

In alignment with the ADL Initiative's mission, the CaSS project supports existing standards for representing competency frameworks and lacks interest in becoming another standard. CaSS can import and export competencies and frameworks in a variety of formats. This enables CaSS instances to import, export, or link to data in repositories, such as OpenSALT [24] and the Achievement Standards Network. Interoperability is crucial when sharing data across organizational and cultural boundaries. CaSS supports full import and export functionality for the format used by the Achievement Standards Network (ASN) [25] [26] the variant used by the Credential Transparency Description Language (CTDL-ASN) [27], and the IMS Global Competency and Academic Standards Exchange (CASE) specification [24]. CaSS also supports import from Medbiquitous [28]. Additionally, CaSS can import frameworks from spreadsheets that have columns corresponding to the internal CaSS data model or ASN-CTDL fields. These standards have been mapped to and correlated with the U.S. Department of Education's Common Educational Data Standards [29] and standards supported by the Postsecondary Education Standards Council (PESC) in work supported by the CaSS project, and that is now going through an IEEE standards process [5] which, when complete, will be used to broaden standards in CaSS.

5.5 Ingest 3rd party Competency Frameworks through an API

Other products like OpenSALT and many organizations, such as O*Net [30]; NIST, for cybersecurity education [31]; members of the Competency-based Education Network (C-BEN) [32]; and industry consortia like the National Institute for Metalworking Skills [33], also maintain competency frameworks. CaSS can ingest these, and other non-standard frameworks through the CaSS API. Once in CaSS, the frameworks can be mirrored (where the authoritative data is elsewhere), or they can re-publish them, so the authoritative copy resides in CaSS.

CaSS's capability to ingest competency frameworks through APIs provides the infrastructure for a public-facing or DoD-facing repository of competency frameworks. Within the Credential Engine, which uses CaSS, CaSS maintains 240 small frameworks, and the CaSS test servers have ingested 1,400+ frameworks ranging in size from small to 19,000 competencies. Cass's web services consume frameworks in ASN, CTDL-ASN, and IMS CASE formats.

5.6 Competency Frameworks as Networks

Most competency frameworks are associated with a specific job, task, or occupation. These are conceived as hierarchical frameworks or *flat lists* that do not recognize the potential of multiple competencies to depend on some underlying foundational competency. A hierarchical representation also limits the ability to create complex relationships between a single competency to competencies within other frameworks. Most standards referenced above, including the ASN variants, allow Simple Knowledge Organization System (SKOS) [34] relationships among competencies.

CaSS tools allow a user to define relationships between competency objects like RCD, such as "*is the same as*," "*is similar to*," and "*is related to*," from ASN frameworks, or "broadens" and "narrows," which generically applies to most other hierarchies. As a result, competency frameworks in CaSS are represented as a network rather than simple hierarchies. Single frameworks are almost always instantiated as Directed Acyclic Graphs, regarding the broadens and narrows relationships, or other user-defined hierarchical relationships. When frameworks are linked to each other, more complex structures can arise.

5.7 Uploading Competency Frameworks to CaSS

After completing a CFD process, a digital version of the competency framework is created using the CaSS Editor. In CaSS version 0.4, this can be accessed by selecting the "CaSS Editor" option after logging into CaSS. **Figure 8** shows the CaSS Editor Home page, which is the primary interface for accessing CaSS features used in the creation and maintenance of competency frameworks.

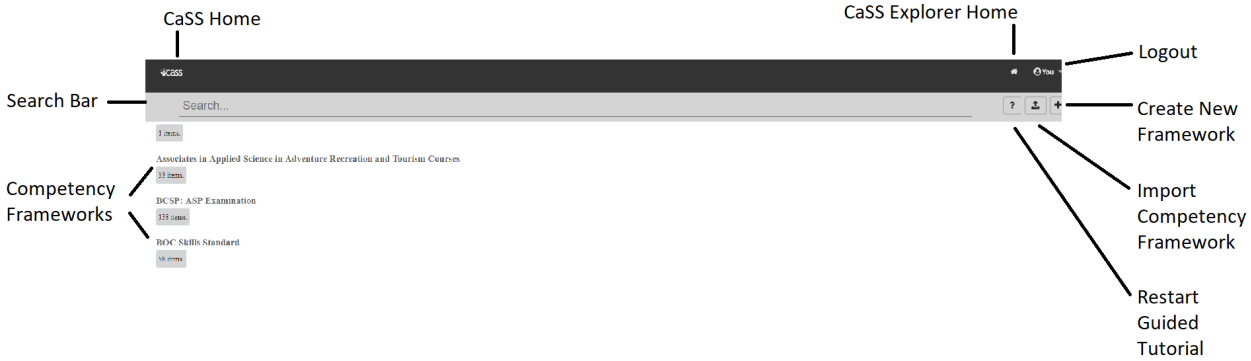

Figure 8. CaSS Editor Tool Bar. *CaSS editing tools allow users to search competency frameworks in the CaSS Framework repository, to import existing frameworks across a variety of tools and formats, or to create frameworks manually.*

5.8 Creating a New Framework in CaSS

There are several options to create new frameworks in CaSS. Users can import frameworks from almost any existing framework representation using existing standard formats (RCD, CASE, O*Net, ASN). Specific variants such as Medbiquitous XML, Achievement Standards Network RDF+JSON, and CTDL-ASN formatted JSON-LD can also be imported but require the additional step of being exported into a spreadsheet using Comma Separated Values (CSVs) which can then be imported into CaSS. This extensibility allows competency frameworks to be developed using virtually any commercially available tools that a CFD participant has access to.

Click ***Create New Framework*** to create a new framework (See ***Figure 9***). This opens the manual editing toolbar where framework properties and each competency may be entered. This capability is essential even as new semi-automated authoring capabilities are being integrated into CaSS. Many competency frameworks only contain tens of competencies, so the process of manually editing and updating the framework is straightforward when using current CaSS tools.

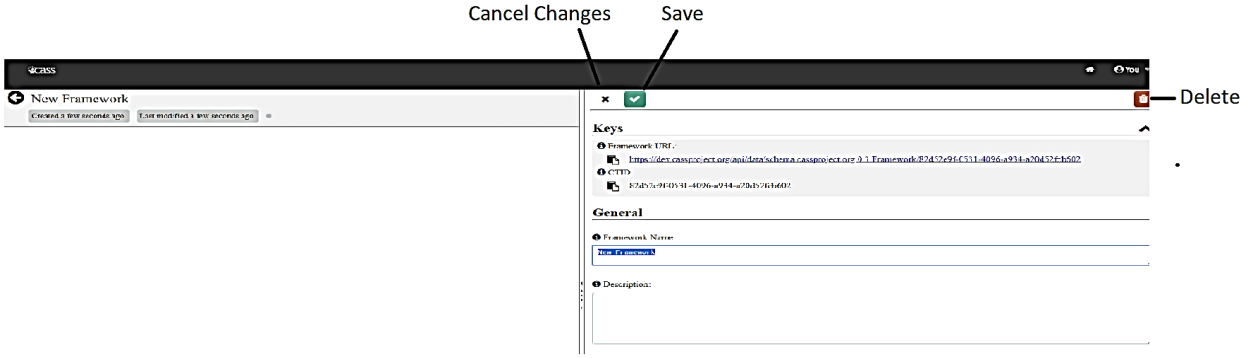

Figure 9. CaSS Editor – Create New Framework. *The Create New Framework toolbar allows the user to manually define the competency framework competency by competency. This capability is also used to edit, update, and maintain existing competency frameworks*

5.8.1 Creating a New Framework

Click ***Create New Framework*** to create a new competency framework. The framework's URL and CTID keys will display on the screen. It is best to name and describe the competency framework. Click ***Cancel Changes*** to cancel any changes made on the new competency framework screen. Press ***Delete*** to delete the new competency framework being created. Always click ***Save*** to save the competency framework. Also, click ***Save*** before adding competencies to the framework.

5.8.2 Adding Competencies

After the user saves the competency framework, it can be edited. After creating the initial competency framework, it will have no associated competencies. These need to be defined and added to the framework. This can occur by creating an entirely new competency (**Figure 10)** or by importing an existing competency. When possible, a user should strive to leverage an existing competency object to maximize reuse; however, given the nature of competencies, each framework will utilize the competencies differently in how they roll up into mastery.

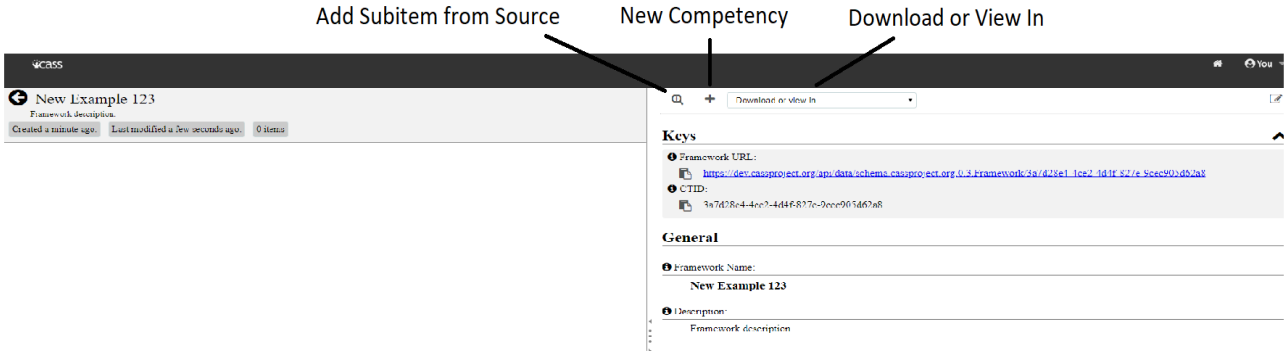

Figure 10. CaSS Editor- Adding Competencies to a Framework*. The CaSS Editor allows users to create a new competency. This can be manually created from scratch, or the competency may be imported from other competency frameworks.*

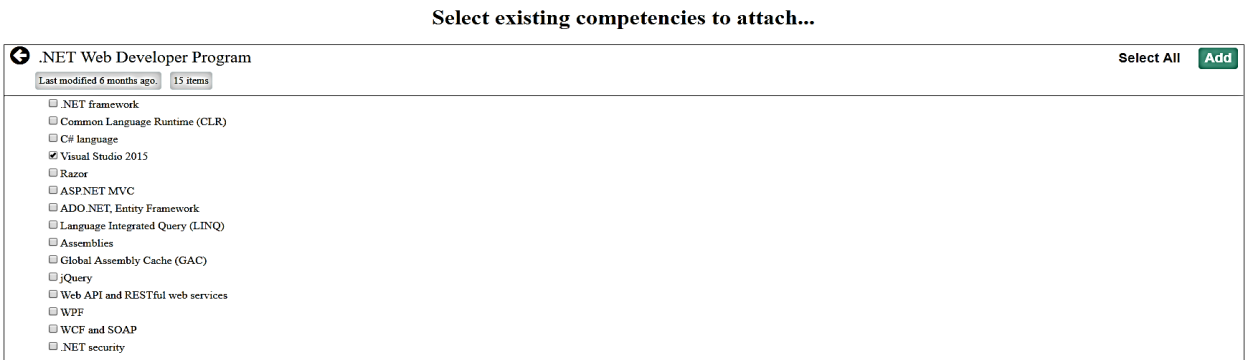

Figure 11. CaSS Editor - Using Existing Competencies to Describe a Related Competencies. *CaSS allows its users to search the framework repository to utilize competencies that have already been defined in an organization.*

To utilize previously developed competencies that support other frameworks, click ***Add Subitem* from *Source*** button to add competencies from other competency frameworks. As shown in **Figure 11**, the user selects the framework from which they wish to add competencies. From the *Select Existing Competencies to Attach* screen above, the user selects the competencies they wish to add to the framework. When adding competencies to the framework from another existing framework, users have two options after clicking ***Add*.**

Click ***Link*** to link the competency in the framework being created to the desired competency stored in the authoritative source. Any updates or changes made to competencies in the authoritative source will reflect in the new competency framework. Click ***Copy*** to allow the user to take a static copy of competency and add it to their framework. A copied competency does not automatically update when making changes to the authoritative source. Click the ***Download or View In*** button to download the competency framework currently being edited in a variety of standard formats, including ASN, Credential Engine, IMS Global CASE, and others.

5.8.3 Editing Competencies

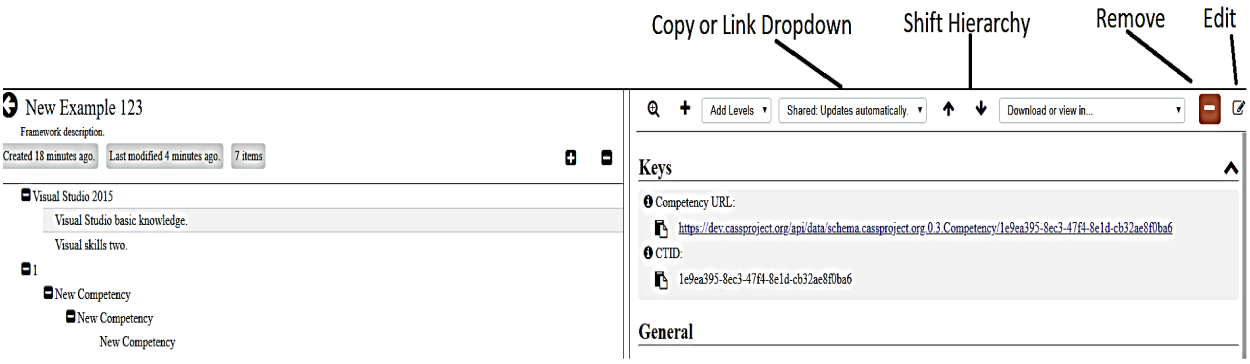

Figure 12. CaSS Editor - Editing Competencies. *The Edit button allows the user to make changes to a competency, including its name, description, and scope.*

After a user adds a competency to a framework, it can be edited by clicking ***Edit***. Click ***Remove*** to remove a competency from a competency framework. Change the hierarchy of competencies within a competency framework by dragging and dropping competencies into the correct order on the left side of the screen. Click ***Shift Hierarchy*** the hierarchy of competencies by clicking ***Shift Hierarchy***.

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