Synthetic Training Environment Experiential Learning for Readiness (STEEL-R) Demonstration

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INTRODUCTION

The Synthetic Training Environment (STE) Experiential Learning for Readiness (STEEL-R) team will present an introduction and give a live demonstration of STEEL-R at GIFTSym 2022. The STEEL-R Team intends to provide a live, web-based demo version of this system to the public in 2022.

STEEL-R is a combination of existing and new software that captures and evaluates the experiential competence of individuals and teams (Goldberg et al., 2021). STEEL-R incorporates modified versions of the US Army Combat Capabilities Development Command (DEVCOM) Soldier Center's Generalized Intelligent Framework for Tutoring (GIFT), the Competency and Skills System (CaSS; an open-source Learning Record Store (LRS) provided by Yet Analytics), and several other existing components. It enhances and extends the Total Learning Architecture (TLA) (ADL Initiative, 2019) learning ecosystem and adds several new components, including an Experience Design Tool (XDT) and an Observer/Controller Trainer (O/CT) analytics dashboard.

The STEEL-R project was initiated in 2020 (Goldberg, 2020). Previous research funded by the US Army Research Laboratory (ARL) used the TLA Experience Application Programming Interface (xAPI) (ADL Initiative, 2017) to capture learner data. STEEL-R goes beyond these previous efforts by (a) gathering data from multiple and diverse sources with a focus on immersive experiences, (b) measuring performance in multiple echelons (ranging from individuals to squads) and at multiple levels of proficiency, (c) using an xAPI profile that enables full traceability of evidence, and (d) providing a dashboard that shows competency and performance trends (Robson et al., 2022). The STEEL-R program includes research inspired by previous educational research on experiential learning throughout the 20th century, and previous ARL research from direct experience, interoperable performance assessment, measuring performance at multiple echelons (specifically the individual, fire team, and squad) (Owens et al., 2020), and establishing a foundation for adaptation of the team experience and individual experience.

A key aspect of STEEL-R is the incorporation of competency-based experiential learning (CBEL) (Owens & Goldberg, 2022). Based mostly on Experiential Learning Theory (Kolb & Kolb, 2017), and other related learning theories, CBEL was developed for volatile, uncertain, complex, and ambiguous (VUCA) performance training applications such as those that frequently occur in military operations. CBEL is an active approach for building expertise based on andragogy, in which learners (actors) engage in training sessions based on their own unique performance needs, their assigned team, competency states and/or the inherent needs of their unit. Actors achieve competence through long-term mental-models developed over time as they accumulate experience performing targeted tasks under various conditions. This approach gradually builds experiential expertise (Owens & Goldberg, 2022) that builds the "sense-making" competence required by all warfighters in VUCA conditions. STEEL-R focuses on building competence with respect to team and individual tasks and their related affective, behavioral, and cognitive competencies within the "crawl" phase of US Army training (US Army TRADOC, 2021).

The STEEL-R demonstration that will be shown at GIFTSym is the culmination of two-years of research that involved multiple parallel tracks. Underlying this work is a competency-based approach to measuring and orchestrating experiential learning. Originally intended to demonstrate a competency-based data-collection and modeling strategy for the US Army's Synthetic Training Environment (STE) program, STEEL-R now includes experience design. The conceptual high-level architecture in Figure 1 shows how STEEL-R fits within the larger STE and Army Training Information System (ATIS) domains. To manage its initial scope, the STEEL-R project has focused on the training environment for a new version of the existing US Army Games-for-Training synthetic environment (US Army PEO-STRI, 2005).

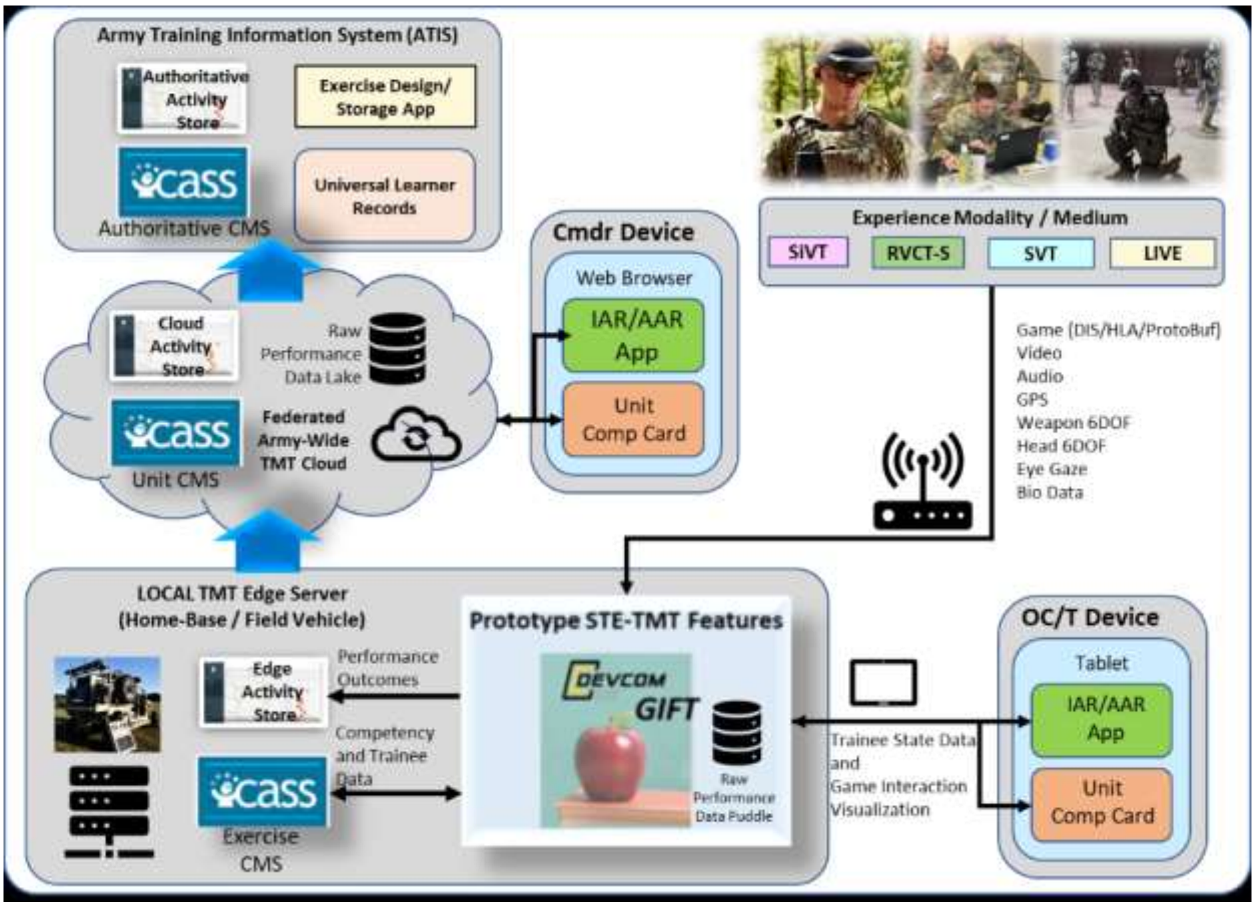

Figure 1. Functional Diagram of STEEL-R in a Future Army STE-based Training Architecture

The STEEL-R project engaged in regular working sessions with an active US Army regiment to develop a GIFT-based after-action and analysis review (A3R) dashboard referred to as Game Master (see Figure 2). Game Master is used for controlling the execution of the synthetic exercise and displaying and analyzing the individual and team task execution outcomes. It uses existing GIFT capabilities and new features that are being added to GIFT. To test the capability of real-time task data collection and processing, a Unity-based synthetic training application for a fixed Army battle drill exercise was created. This work was conducted with the STE Cross-Functional Team. It focused on building interfacing protocols and scripting capabilities that were not tied to the US Army's Virtual Battlespace (VBS) product so that a more agnostic application interface could be developed. With this initial prototype, multiple engineering experiments were conducted representing actual Soldier touchpoints to establish a baseline real-time assessment capability. This work will continue in partnership with a future US Army training facility as part of the STEEL-R capability validation and verification process.

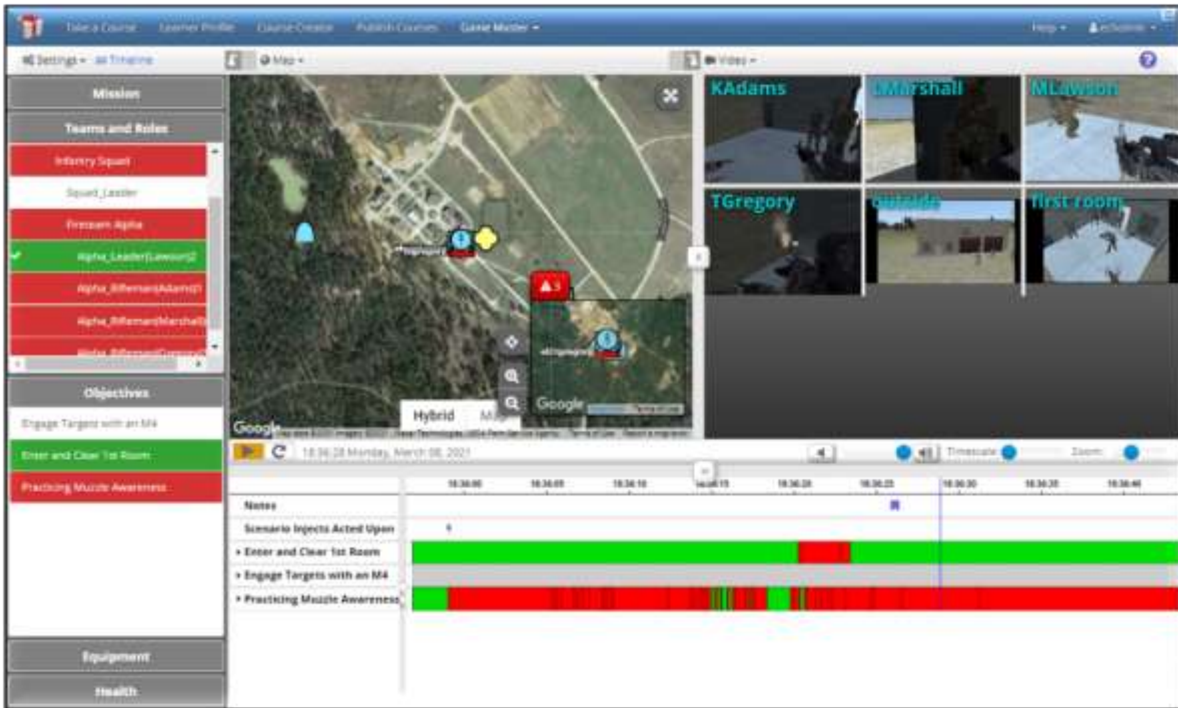

Figure 2. Game Master Dashboard

The STEEL-R based exercise demonstrated for GIFTSym is associated with a US Army Infantry Battle Drill, set within a variable experiential context. The required team and individual team-role tasks and measures are pre-selected and designed to be part of the Plan and Prepare phases of the CBEL process, which is discussed next.

The Plan, Prepare, Execute, and Assessment Process

US Army Doctrine Publication 5-0 describes the Plan, Prepare, Execute, and Assess (PPEA) process as a "...workflow focused on enhancing and improving mission command by more fully incorporating the official doctrinal approach towards training and assessment of its Soldiers within a given Operational Environment (OE)" (US Army TRADOC, 2019). STEEL-R is architected to support a learning environment within a realistic OE, where training is actively conducted to build warfighting situational experiences through synthetic and live stimulus and feedback. The GIFTSym demo will demonstrate how STEEL-R is used within this PPEA process.

Each phase of the PPEA workflow revolves around the decision-making needs of the unit's commander and the ability to train the unit's individual Soldier and combat team tasks to support success on the battlefield. In STEEL-R, data about each Soldier is sampled during real-time assessment and used to produce incremental and summary overviews of trainee readiness under varying task conditions.

Plan and Prepare Elements of STEEL-R

CBEL training planning is a multivariate design and development activity. Depending on the need and source of the training requirement, a different set of experiential source data is selected through automatic indexing and filtering. This process produces a series of exercise design decision-support recommendations that target the specific competencies, tasks, and experiences of a unit team or unit Soldier (a "learning-actor"). STEEL-R is currently focused on training for platoons and below echelons (tactical small-units), a domain of Army training planning that is not well supported today. Currently, the US Army uses multiple tools within the Army Training Network to help Commanders produce training plans and strategies, but at the tactical small-unit level such tools and strategies do not exist. It is a goal of STEEL-R to provide these capabilities in a manner that will be available in the future STE-Training Management Tool (TMT).

Within STEEL-R, the concept of operations for training planning incorporates tools that provide training leader /manager decision-support in the exercise design process. The first tool is a competence dashboard or leaderboard shown in Figure 3 that also can provide feedback to a team or individual. This tool provides training leaders / managers with a means to view, compare, and select the competencies that need to be trained. Information from the dashboard and other inputs from a unit's commander will be combined with an experience index (XI). An XI maps and filters design variables that are used to configure experiential training events.

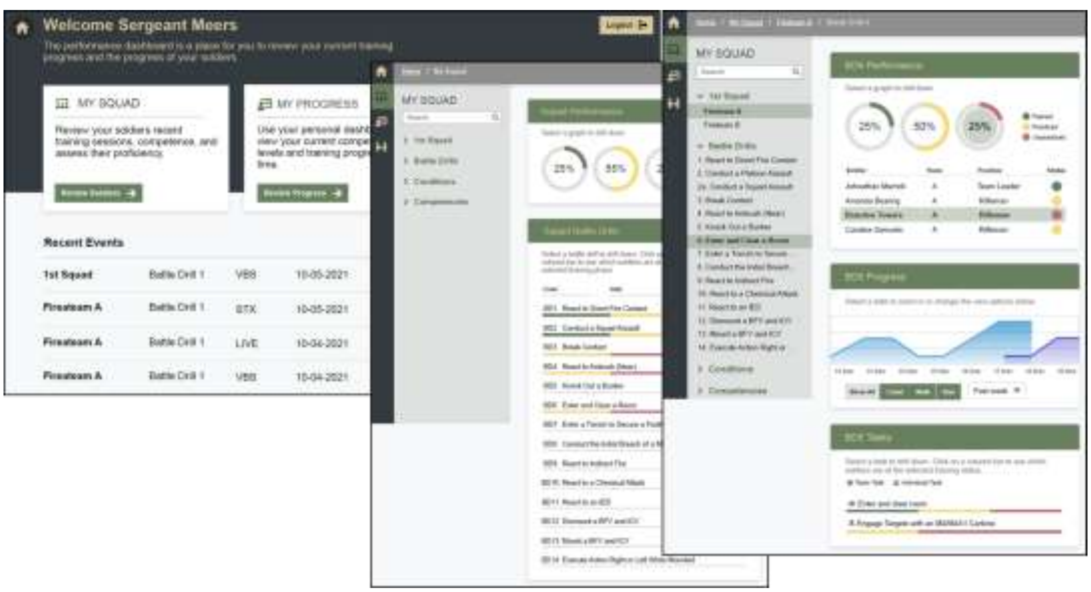

Figure 3. Competence Dashboard

Other elements that help define the experience decision-making process are the mission order and its subordinate fragmentary orders that cue experience-events at the task execution level. Each mission is expected to represent operating orders used in previous live exercises or real-world events. The mission defines the environment, force, and other plot contexts such as the enemy, terrain and weather, available troops or support resources, time to perform, and civil variables (known as a METT-TC format). Once the experience context is specified, the unit echelon, team(s) and/or role(s) to be trained on a target competency or task are determined. These decisions further filter down to the specific sub-competencies and tasks that can be measured within the selected mission, which is where the actual experience design process can begin.

Experience Design Tool (XDT)

As noted earlier, the STEEL-R project was expanded to include a research thread focused on developing the experiences that enable data to be collected and specify Soldiers will conduct CBEL to build competence in warfighting tasks. This is done in STEEL-R through the XDT. The XDT expands upon concepts developed in a previous US Army project called Squad Overmatch (Johnston et al., 2017). This project produced a variable stress-condition based series of classroom, synthetic, and live "lane-based" events intended to build levels of teamwork, advanced situation awareness, and combat resilience. XDT uses a similar approach in that its function is to create experiential exercises consisting of multiple mission-oriented conditional variables (including difficulty and stress) and including one to many serial or actor-triggered episodic competency/task performance prompts, referred to as Experience Events (or xEvents). xEvents can be conceived of as "competency test-questions;" they measure a target actors' ability to perform a specific targeted task / competency at specified conditions of difficulty (e.g., volatility, uncertainty, complexity, or ambiguity) and stress (cognitive load, physical load, environmental load, etc.).

What makes the XDT different from a traditional exercise design tool is that in addition to creating the selected scenario plot (i.e., the mission), it is configured to help design the various xEvents along with their associated measures and criteria. XDT also supports selecting the source data required to serve as evidence of a task's formative and summative measured outcome. As will be discussed more during the GIFT discussion, as learning-actors encounter and perform against xEvents in the synthetic environment, they produce objective performance data that is reported by sensors and/or the training environment itself. XDT also helps the designer not only test if the appropriate data is produced but test if the target task/competency is optimally being measured, and then defining an appropriately defined criteria for each resulting performance level, as it fits within an xEvent's conditions.

The XDT (using GIFT capabilities) will also design strategies that either provide actor interventions (e.g., feedback) or exercise adaptations (e.g., different artificial intelligent actor behaviors) to further develop the learning actor's experience and task-competence. It is the long-term exposure to these kinds of dynamic conditions and interactions, over many of these experiential opportunities, that enables a learning-actor to develop the ability to automatically respond to similar combat events while later performing in a live training or real-world environment. The result of these experiences, and later feedback of their performance, are what stimulates subsequent reflection by the actor (or their leaders), which further stimulates long-term experiential learning and expertise beyond what can be learned in a didactic learning environment. This process is also what allows the learning-actor to develop ideas for constructing new performance strategies to help them improve their outcomes in future dynamic xEvents focused on the same task/competency. An xEvent will usually follow a design structure similar to that shown in Figure 4 below.

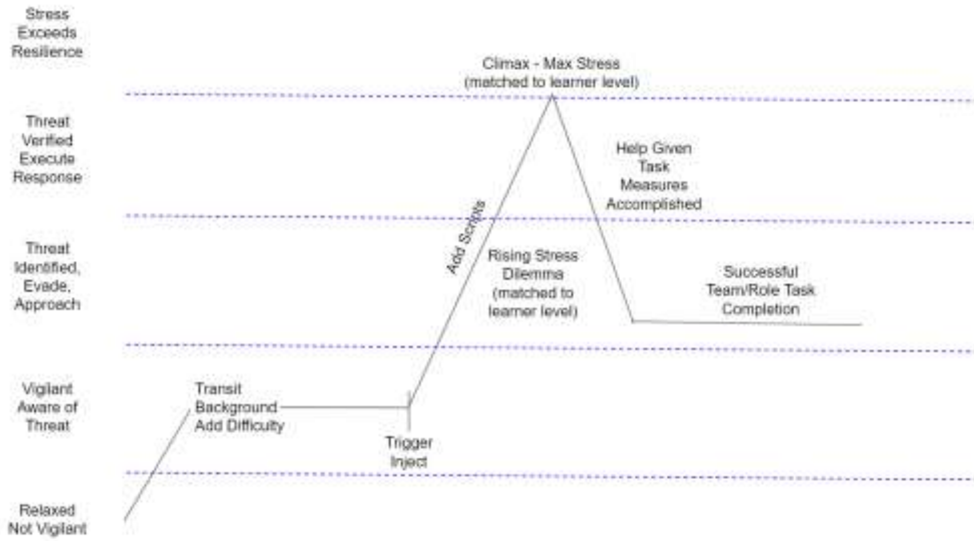

Figure 4. General Experience Event Design Structure

The results of the XDT based design process are saved, stored, and shared within what is referred to as an experiential training support package (XTSP). An XTSP is a semantically normalized structure that can exist in the cloud or saved off as a JavaScript Object Notation (JSON) artifact. Key is that the xTSP is a machine-readable format that helps Soldiers rapidly and automatically set up complex training environments, data collection devices, as well as automate much of the re-designed real-time assessment capability provided by the GIFT architecture. In this way, the XTSP essentially provides GIFT much of the initial parameters used in its Domain Knowledge File (DKF) for its task-based assessments and strategies for a given synthetic or live training application. This includes the domain mission, the mission-based actor organization, and the competency related tasks, concepts (measures) and automated or manually data-informed measurement criteria. The XTSP also provides GIFT with the training experience difficulty and stress points used by GIFT to calculate an xEvent's overall difficulty or stress level that is reported with the assessment result via the xAPI statements GIFT produces.

The prepare phase of the PPEA process is used just before a designed XTSP is to be executed. During this stage, the actual learning-actors (teams or individuals) are selected and assigned to pre-defined mission defined teams and their respective roles. In addition, the preparation phase is when each learning-actor is assigned to a specific training environment device so the training application can report to GIFT what synthetic performance belongs to which actor. Preparation is also when the exercise mission is provided and discussed so the learning-actors understand the context, restrictions and/or support resources they must perform with. In addition, during the prepare phase, it will provide the designated training leader the option to modify or add additional parameters to the XTSP based on specific attributes of a given actor's learner-profile that may not have been designed for originally in the XTSP. Once these activities are completed, the execution phase can begin.

xAPI Profiles and DATASIM

xAPI is the primary method within the STEEL-R architecture to transfer the data describing assessments between systems. The xAPI Profiles (ADL Initiative, 2017) specification, a companion to xAPI itself, is a specification for describing the statements and patterns of xAPI data. This allows an author to describe the concepts, statement templates, and expected flow of statements in an xAPI dataset produced by a system or collection of systems.

For STEEL-R, an xAPI Profile has been written for GIFT, whereby the xAPI data emitted follows these rules (Blake-Plock et al., 2021):

- As a domain session is requested, data is cached for use in the creation of the xAPI statements
- As a domain session starts, an xAPI statement is generated which identifies the user and the course selected
- As a knowledge session is created, one or more xAPI statements indicate that either a session host created and started a session or that upon creating the session lobby, other users joined the lobby and then the host started the session
- As an updated request passed through a knowledge session, the team position of the session member provides information for use in the creation of xAPI statements
- The knowledge session begins for the team and statements are emitted
- The learner state is derived from the relevant GIFT components regarding: cognitive state, affective state, and performance state; user interaction within the course causes an update to these attributes
- As formative assessment is completed, a request is made to publish the lesson score, and summative results are recorded as xAPI statements
- The session is closed if an xAPI statement is emitted indicating that the user has exited the course

Following the recommended data flow of the TLA, xAPI data emitted from GIFT is validated and captured by a Noisy LRS — the Edge Activity Store in Figure 1 above. This xAPI data then is filtered through LRSPipe, an open-source middleware that provides the ability to govern the business logic of the data flow through the TLA by means of an xAPI Profile (https://github.com/yetanalytics/xapipe). This filtered data, governed by the master xAPI Profile is then forwarded and made available to an LRS in the transactional layer — the Cloud Activity Store as described above. The data collected through this process of filtering is used by CaSS as immutable evidence in the assertion of competencies.

One of the uses of the Data and Training Analytics Simulated Input Modeler (DATASIM) in the context of the STEEL-R project is to quickly model changes to xAPI datasets and to evaluate the design of the xAPI Profiles used by the system. Because xAPI Profile modifications can be performed and resulting data can be simulated very quickly using DATASIM, we have been able to rapidly evaluate the effects of hypothetical changes to GIFT xAPI data on CaSS assertions without performing code changes on source systems beforehand. This is because DATASIM generates synthetic statements that reflect those changes and sends it to CaSS in much the same way GIFT produces statements from active training sessions with learners.

DATASIM is also used to test components of the system in isolation and evaluate system stability at scale. DATASIM is capable of generating tens of thousands of xAPI statements per second, which can result in datasets that can be used to evaluate system performance at or above realistic maximum production scale conditions.

Execute and Assess Elements of STEEL-R

In STEEL-R's process, each action by each participant is captured and stored for further analysis. This allows the OC/T to discern adjustments that must be made and how their plans must be modified in real time or in an after action review (AAR).

To facilitate this, commanders are provided with easily digested real-time assessments of individual and team performance and competencies. Assessment results enhance the commander decision making and help commanders and the staff keep pace with constantly changing situations.

GIFT

In the STEEL-R solution, GIFT (Sottilare et al., 2012) is used to produce evidence of training experiences in the form of xAPI statements and session logs generated from the learning experiences that are being executed.

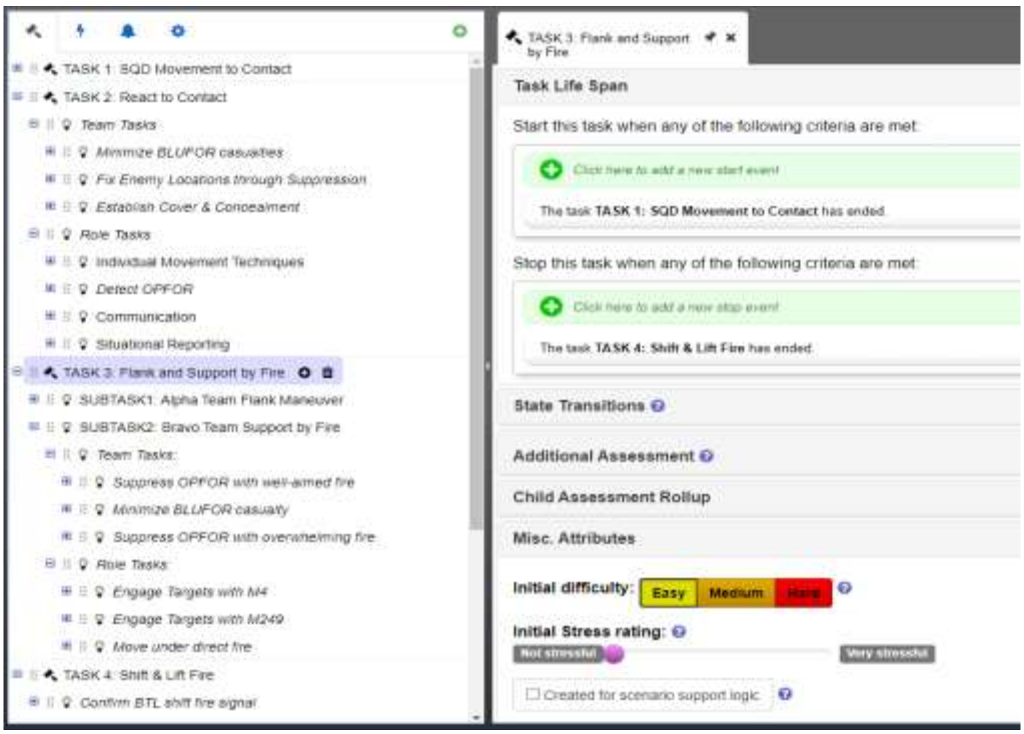

Figure 5. Screenshot of the GIFT DKF authoring tool with the React to Contact related tasks and concepts.

GIFT accomplishes this by first aligning its assessment model to the experiences outlined in the xTSP via the DKF. The DKF shown in Figure 5 contains the tasks and concepts related to a React to Contact scenario. Notice that 'TASK 3: Flank and Support by Fire' is selected and that some of its attributes are shown, including when the task should start or end and the initial difficulty and initial stress ratings of the task. After the DKF is created, GIFT works with the integrated training application (e.g. Virtual Battlespace, SE Sandbox, RIDE) to assess the various actions of the learners under different tasks and conditions.

The OC/T can utilize GIFT's Game Master interface to monitor the ongoing assessments, override Artificial Intelligence (AI) assessments and provide observed assessments as needed during the training. As the training unfolds, GIFT frequently updates its representation of the individual and team learner state. These updates are delivered to a LRS via xAPI statements that conform to the GIFT xAPI profile. This profile follows TLA standards and best practices.

When the training scenario is completed, GIFT produces summative xAPI statements that contain the overall assessment. This is generated automatically using production rules. The OC/T can then use the Game Master Past Session interface to make final assessment decisions that can further augment existing xAPI statements and produce new xAPI statements. The Game Master can be used to conduct an AAR as well using a timeline to playback, synchronize numerous data streams, and customize the delivery of key events to the target audience. At the end of the training session, a robust, supervised, evidence-based data set exists that CaSS can then use for readiness and talent tracking.

CaSS

CaSS provides a key capability to STEEL-R by gathering evidence, authoring and storing competency frameworks, and generating assertions of competency based on the gathered evidence. These assertions are presented via dashboards or as data to other systems so observers or other trusted agents can judge the effect on an individual or team's proficiency. CaSS has been evolving since 2016 via the Advanced Distributed Learning Initiative (ADL Initiative, 2017), US Navy (Gafford et al., 2019), US Army (Goldberg et al., 2021), and US Air Force (US DoD ADL Initiative, 2020) investment, and is now a comprehensive, reusable, open-source system for incorporating competency-based learning in a training or education ecosystem (ADL, 2019).

In STEEL-R, CaSS stores competency frameworks that represent the knowledge, skills, abilities, and other attributes related to the training exercises that STEEL-R manages. CaSS receives GIFT-generated xAPI statements from an LRS and translates these into assertions about the competencies held or demonstrated by individuals and units. These are used to estimate competency states, which in turn are displayed in a dashboard during the Assess phase of a training event. The model used to estimate competency states takes factors such as repetition and skill decay into account and is being modified to require that competency be demonstrated under a variety of conditions that induce stress or add difficulty to a task. The goal is to provide a tool to STE that can be used to optimize the effectiveness and efficiency of training interventions that support squad development. All data produced by CaSS are available through APIs so that CaSS and STEEL-R can be used in a Multi-Open System Architecture.

The current STEEL-R dashboard, depicted in Figure 6, is built to expose the assertions identified in CaSS. The STEEL-R dashboard is built with the Vue javascript framework allowing for rapid and iterative development as requirements and designs evolve. The dashboard was designed with scalability and performance in mind to be able to handle large amounts of data flowing into it from CaSS, and also with extensibility such that it could be further modified to display additional data as it becomes available.

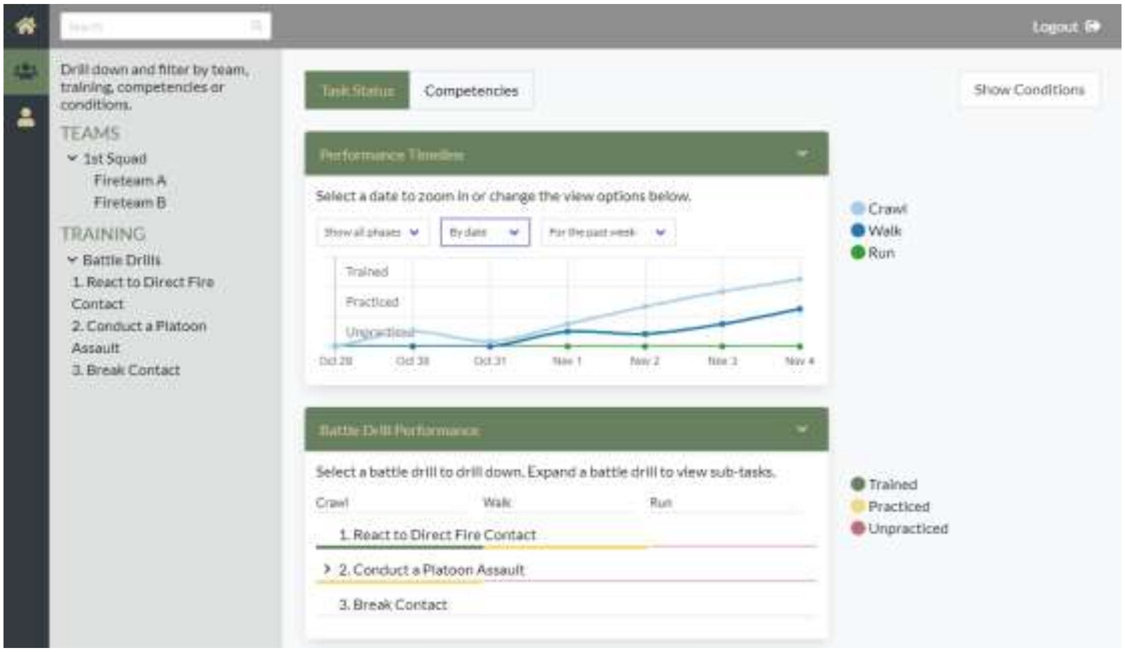

Figure 6. STEEL-R Dashboard

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

STEEL-R's capability to homogenize data from a range of sources and to estimate learning gains over time is intended to have a positive impact on experiential US Army training. In the third year of STEEL-R, the team will coordinate with US Army units to collect data from a range of synthetic and semi-synthetic training experiences. This data will be used to verify the STEEL-R architecture and models, and to mature dashboard interfaces.

During evaluation of the system and discussion with Subject Matter Experts (SMEs), it was identified that STEEL-R could be operated by a variety of training personnel, from the personnel engaging in the training themselves, to an OC/T, to a set of training staff as a part of a highly structured formal training event. STEEL-R's design follows PPEA, which aligns with the current Army model for training. However, STEEL-R is not limited to the PPEA paradigm and can be used as a standalone scenario design tool or a means to collect data and assess competency and readiness in conjunction with other STE training regimens.

To enable this flexibility, it is necessary for STEEL-R to support the rapid execution of pre-canned scenarios, to enable scenarios to be constructed as part of training event planning, and to enable scenarios to be rapidly developed over short periods of time between training days. To this end a library of reusable experiences in the form of xEvents are linked to scenarios that implement them. In addition, these xEvents are associated with measures and competencies that are used to elicit performance. While some of this linked data resides in CaSS, it is advantageous to store and serve experience and scenario data separately. This is done using the XI which has been expanded to include experiences at multiple levels of granularity together with conceptual, instantiated, and instrumented experiences. This evolution of the XI concept requires further research and development.

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Mike Hernandez *is the Director of Business Development at Eduworks and acts as a contributor on the STEEL-R Project. He brings over a decade of Defense experience and has been a contributor to the Total Learning Architecture (TLA) effort since 2016. Throughout his career, he has stewarded the technical and programmatic development of multiple projects related to competency-based learning, performance tracking, and data analytics for the US Navy, US Army, US Air Force, and OSD.*

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Shelly Blake-Plock *is CEO of Yet Analytics. Key projects include the implementation of an xAPI-enabled platform for the U.S. Air Force under a program sponsored by the Air Force Research Laboratory as well as the design and development of the Data and Training Analytics Simulated Input Modeler (DATASIM) for the Advanced Distributed Learning Initiative. Shelly is a Senior Member of the IEEE and is an officer of the Learning Technology Standards Committee (LTSC) where he chairs the P9274.4.2 Working Group on Cybersecurity for xAPI as well as the Technical Advisory Group on xAPI.*

Cliff Casey *is the CTO of Yet Analytics, Inc. He obtained a Degree in Computer Engineering from McGill University and has over 15 years of software engineering, system architecture, and technical leadership experience including hiring, training, and coordinating large software development teams, vendors, contractors, infrastructure teams and QA resources. His technical experience is primarily in architecting, building, and deploying enterprise-scale applications and data solutions, both on-premises and in the Cloud. As the technical leader of Yet Analytics he has overseen and contributed to the development of the Data and Training Analytics Simulated Input Modeler (DATASIM), the Data Analytics and Visualization Environment for xAPI (DAVE), and the Open Source SQL LRS and LRSPipe projects.*