Can we talk? Semantic Interoperability and the Synthetic Training Environment

Paula J. Durlach
U. S. Army Research, Development and Engineering Command
Orlando, FL
Paula.J.Durlach.civ@mail.mil

ABSTRACT

Future cloud-based, service-oriented training environments, such as the Army's planned Synthetic Training Environment (STE), are expected to consume authoritative data sources for terrain and simulation models, and to stimulate and consume data from mission command systems. This paper describes the envisioned capabilities of the STE in general, and the training management tools in particular. STE is anticipated to be supported by training management tools that will use unit training records and plans to help automatically or semi-automatically tailor STE training exercises to the unit's current training needs. At issue is how these adaptive training management services will exchange data with other STE components. The paper argues that semantic interoperability will be required. A review of existing and developing data exchange standards in the modeling and simulation domain and in the adaptive training technology domain suggests they are unlikely to support the semantic interoperability required. It is suggested that the National Information Exchange Model (NIEM) may represent a possible method of providing that level of interoperability. NIEM, which is federally governed, allows communities of interest to establish a common vocabulary and to use it to create standardized machine-readable information exchange packages. These data packages use World Wide Web Consortium (W3C) Extensible Markup Language (XML) schema or NEIM-Unified Modeling Language. In 2013 the Chief Information Officer for the Department of Defense (DoD) issued the "NIEM first" memorandum, which directed that the DoD shall consider NIEM first for their data exchange standards. A MilOps community of interest has used NIEM successfully to exchange information with coalition partners. Of additional relevance, work in the geospatial community has demonstrated the combined use of NIEM, intelligence community security specifications, Open Geospatial Consortium web services and Geography Markup Language-aware clients to support information exchange among authorized users. The paper recommends that STE proponents consider reuse of and building upon prior NIEM work to support the semantic interoperability required among the models, simulations, authoritative data sources, and training management systems that will make up the STE.

ABOUT THE AUTHOR

Paula J. Durlach has conducted and managed adaptive training research, as well as other projects, at U. S. Army and OSD organizations for more than ten years. She is currently working at Simulation and Training Technology Center, U. S. Army Research, Development and Engineering Command. She holds a Ph. D. from Yale University in Experimental Psychology.

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INTRODUCTION

As the Army, other services, and other government agencies move toward an integrated, information-sharing environment, the ability for cloud-based data exchange could allow many services and applications to leverage the same data for different purposes. Future technology-based training environments, such as the Army's planned Synthetic Training Environment (STE), are expected to operate within this context, relying not only on authoritative data sources for terrain and simulation models, but also data about unit mission essential tasks (METs), unit training records, and unit personnel data. The STE aims to support visualization of and immersion into the warfighting environment at multiple scales. STE training management tools are expected to retrieve or automatically generate training scenarios appropriate for a unit's training objectives. These adaptive training services are expected to use information about training needs and current skill levels to identify or adapt training scenarios appropriately (e.g. single threat vs. multiple threats or day vs. night). The ability to retrieve appropriate pre-scripted scenarios or to automatically or semi-automatically generate them will be essential to support one of STE's goals--training at the point of need, as opposed to the current model of training at fixed facilities supported by simulator operators and maintainers.

It is hard to imagine fulfilling the STE vision without semantic interoperability. Semantic interoperability is the ability for different digital services to exchange data with unambiguous, shared meaning. According to Ford, et al. (2015), sharing data across different communities (e.g., modeling and simulation, training management, and human resources), requires a way to cope with information exchange needs even when those specific needs are not known in advance, like future operational environments and METs. Their proposed solution is to create standards, methods and tools to align the terminologies of those different communities in order to support translation of data among them. In other words, to achieve semantic interoperability. The purpose of this paper is to describe how adaptive training management tools will need to interoperate with the models, simulations, and other services and data sources that will be the STE, and to suggest consideration of the National Information Exchange Model (NIEM) to support such interoperability. NIEM, which is federally governed and DoD-recommended, was designed to support semantic interoperability for data exchange across diverse organizations.

ADAPTIVE TRAINING IN THE SYNTHETIC TRAINING ENVIRONMENT

U. S. Army Directive 2017-24 designated the STE as one of eight modernization priorities. The intention of the STE is to merge current live, virtual, constructive, and gaming environments into a single simulation-based training environment. According to the Synthetic Training White Paper (U. S. Army Combined Arms Center, 2017), artificial intelligence organic to the STE will be used for adaptive training in order to increase the rate of skill and task acquisition. Moreover, "big data" techniques will be used to improve training effectiveness, using performance data aggregated across multiple exercise events and units. In the near term (next three years), STE prototyping will focus on unifying terrain databases (One World Terrain), and low overhead, reconfigurable, and transportable semi-immersive training capabilities to support combined arms training at the point of need for Company and below. In the midterm (2022-2025), besides expanding training capabilities to higher echelons, the STE program plans to incorporate cloud-based intuitive training management tools that can automatically retrieve and/or adapt unit-relevant scenario-based training exercises. In the far term (beyond 2025), the intentions are to integrate both live training, intelligent tutoring methods, and training effectiveness analysis capabilities.

In the context of the STE, adaptive training refers to the ability to provide training scenarios tailored to learners' needs, knowledge, and skills, as well as other factors, such as available time to train. In particular, the midterm goal to automatically retrieve and/or transform unit-relevant scenario-based training exercises implies selecting the right level of challenge as well as the right training objectives. In the education literature, this has been dubbed mastery learning (Bloom, 1984) and more recently competency-based learning (Glowa & Goodell, 2016). It's analogy in the training literature is deliberate practice (Ericsson, Krampe, & Tesch-Romer, 1993). Mastery learning requires that students demonstrate their ability to apply knowledge in relatively simple situations first, with complexity increasing only once proficiency has been demonstrated at each prior level. Students cycle through exercises on their particular weaknesses at each level (with feedback), possibly receiving additional support, until mastery is achieved. Mastery learning has been shown to lead to positive effects for a number of variables including higher achievement and better retention (Barsuk, 2009; Kulik, Kulik, & Bangert-Drowns, 1990; Wayne, 2006). Implementation of mastery learning requires several instructional design decisions. What constitutes mastery (e.g., all critical performance steps rated a "Go")? What is the assumed prerequisite knowledge? In the pre-mastery stages of learning, how will content be varied during deliberate practice, and how will extra support be provided to learners when needed? What factors need to be considered to provide increasing complexity or difficulty as mastery increases?

In an attempt to make assessment of training readiness more objective, the U. S. Army has recently revamped its training guidance for collective tasks, in a manner that answers some of these questions, conveniently providing a framework that adaptive training methods in STE could adopt (HQDA G/3/5/7, 2017). Each collective task has an associated Training and Evaluation Outline (T&EO), providing subtasks, conditions, and standards, as well as required prerequisite skills. The T&EO also specifies increasing levels of task complexity, and thus provides a guide to training progression. This is illustrated schematically in Figure 1, with a hypothetical unit requiring three exercises before demonstrating readiness to go from complexity level one to complexity level two, two exercises before going to level three, and three exercises at level three before meeting the fully trained criteria. One factor specified to increase scenario complexity is whether the exercise is conducted during the day or at night. Another is the number of PMESII-PT variables (Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, Time) that are included as important factors in the scenarios. An issue for the STE will be how to automate or semi-automate the process of determining the appropriate level of complexity, and creating multiple scenarios at each level of complexity. An intelligent training management service will need to be able to identify the elements to be included in a scenario, based on a unit's training objectives, current level of mastery, and other information, such as scenarios already attempted, unit-relevant terrain and other geological features, expected time to complete, and so on. It will then actually have to find and retrieve a matching scenario from a repository, or actually create a scenario, perhaps by altering an existing one. In order to be able to do this, the training management services will have to be able to understand the features of stored scenarios and/or how to ask the training simulation software to include certain models and trigger events in the training scenario. This will require semantic interoperability between the training management software and the training simulation software.

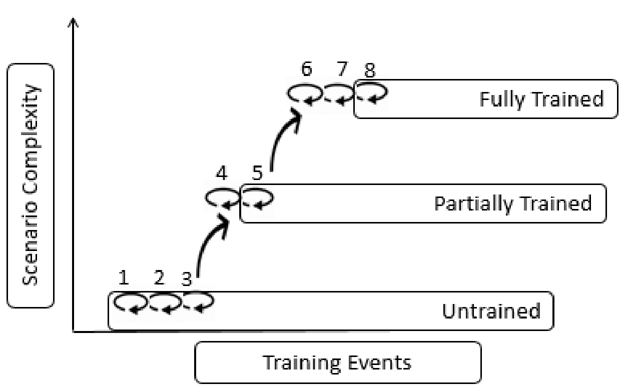

Figure 1. Illustration of how deliberate practice at increasing levels of scenario complexity can achieve mastery.

The simplest case is to assume that all possible training scenarios have been pre-scripted and are stored in a repository that a recommendation engine could search. The user would enter the relevant features of a scenario on which they want the unit train, such as unit type, tasks, complexity level, terrain type, etc. The recommendation engine would then search for stored scenarios with matching metadata and/or embedded information. The question is how to ensure that the recommendation engine coming from the training community and the scenarios in the repository, coming from the modeling and simulation community, speak the same language.

More sophisticated training management implementations could remove the human searcher partially or entirely from the loop. Training management tools could be intelligent enough to evolve a training plan, keeping it tailored to unit needs as new training results and personnel data (like turnover) are rolled in over time. The needed training scenarios could be recommended from a repository, or might be assembled just-in-time, and allow a unit training developer to refine and approve the final product. Such newly created scenarios could be added to the repository for others to find and use. As training results are collected over time, data analytics and machine learning techniques can be used to evaluate training effectiveness (if training outcomes are collected and aggregated), and to make predictions about training time, such as how many repetitions a unit would be expected to need on a specific learning objective at a specific difficulty level. Using machine learning, training results can also be fed back into the recommendation service and scenario composition algorithms to improve both. A schematic layout of at least some of the components that would need to interoperate to support this is depicted in Figure 2.

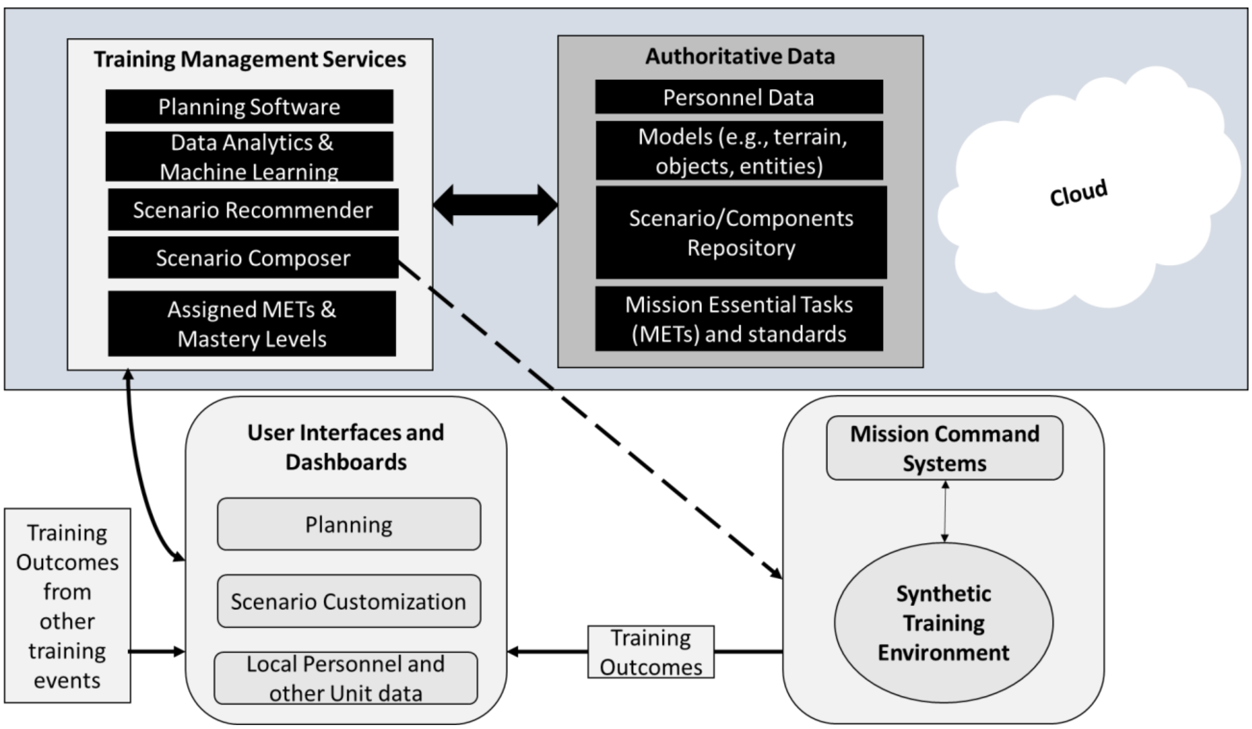

Figure 2. Notional schematic of the components or services requiring interoperability for the STE. Arrows indicate data exchange. User Interfaces and Dashboards refer tools used by unit personnel to plan training and view/enter training outcomes (analogous to currently existing Army Training Network).

Incorporating intelligent tutoring methods into STE training would add even more complexity. Intelligent tutoring methods involve a collection of automated instructional techniques intended to emulate the capabilities of a human tutor. At this point in time, there is no standard definition of an intelligent tutor. They are almost all created by research groups (not companies), with each research group taking a relatively unique approach in developing the tutor behaviors and the learner experience (e. g., Corbett, Koedinger, & Hadley, 2001; Nye, Graesser, & Hu, 2014). While different intelligent tutors instruct in different ways, one thing they all do is monitor and assess learner performance automatically, and act on those data to make real-time interventions, like providing hints, feedback, and activity selection. Most address solving problems in well-defined domains (e.g., algebra). Only a few have been created for scenario-based training, and these have all been for individual, not team, training (e.g., Wong, Kirschenbaum, & Peters, 2010). Considerable research and experimentation needs to be conducted before intelligent tutoring techniques can be applied to collective training (Johnston, Sottilare, Sinatra, & Burke, 2018; Sottilare, Graesser, Hu, & Sinatra, 2018). The complexity and dynamic nature of team behavior and the central role of communication and coordination make automated performance assessment during collective "free play" training scenarios challenging (Stacy & Freeman, 2016). Automated agents will need to monitor scenario events, interpret what they mean, and make decisions about whether to alter the scenario's course. The challenge is how to use artificial intelligence to turn low level simulation data into measures that can be used to assess performance on METs. Stacy and Freeman (2016) propose methods using what they call Training Objective Packages, which are designed to represent essential training constructs (e.g., training objectives, scenario conditions, and performance measures); however, use of the proposed methods is still theoretical, and their application to team/collective training has still to be conceptualized. In the near to midterm, at least, intelligent tutoring for teams may take the shape of a human-agent teams sharing the burden of interpreting, intervening, and coaching (e.g., see Pharmer & Milham, 2016).

CURRENT STANDARDS IN SIMULATION FOR MILITARY TRAINING

The Simulation Interoperability Standards Organization (SISO) lists 18 approved standards, and 15 existing product development groups. Could these approved or developing standards support the interoperability of STE training management tools and STE simulation software and models? One potentially useful product is SISO-STD-007-2008 Standard for Military Scenario Definition Language (MSDL), which was designed to standardize the specification of scenario initialization. MSDL has the capability to provide metadata describing the purpose of the scenario as well as other potentially useful characteristics upon which to search in a scenario repository (the msdl:MilitaryScenario/ScenarioID Element); however, these elements are optional and it is not clear from the documentation that any standard vocabulary is used for these descriptions. In particular, it is not clear they are stated in terms of training objectives and difficulty level, which from a mastery perspective, is an important search factor for finding the right training scenario (Stacy & Freeman, 2016). Other factors that training managers will likely want to search on are represented in other MSDL elements (e.g., Environment); but, again it is not clear that any standard vocabulary is used. With respect to environmental features, the Open Geospatial Consortium (OGC) is currently working to harmonize source geospatial database specifications; but it is not clear that their feature definitions will be translated into scenario metadata, or run-time messages. According to Saeedi, et al. (2017), synthetic environments tend to store ingested geospatial source data with their own proprietary formats and semantics. Thus OGC standardization efforts might have little impact on how the STE's simulation software represents the data internally. Designers of that software need to recognize the need to interoperate with training management tools (in addition to the already established need to interoperate with command and control (C2) systems and live training sensors).

Both MSDL and another SISO standard, Coalition Battle Management Language (C-BML), are now managed by the SISO Product Development and Product Support Groups for Command and Control Systems-Simulation Systems Interoperation (C2SIM). The primary rationale for initiating a common C2SIM family of products was to harmonize the message representations for scenario initialization and for simulation-to-command and control (C2) systems and/or among different C2 systems (purpose of C-BML). According to Sigopogu, Grupton, & Schade (2016), however, C2SIM will additionally need a formal ontological semantic structure if it is going to achieve semantic interoperability. Without this it is not clear how easily C2SIM will be able to interoperate with intelligent training management services, or future artificially intelligent algorithms expected to manage intelligent automated forces.

Another SISO Product Development Group (recently formed) is Human Performance Markup Language (HPML). Ingesting standard run-time simulation data streams such as Distributed Interactive Simulation (DIS) and High Level Architecture (HLA), HPML is a potential means to use the same assessment scheme across different simulation environments. HPML could theoretically send data to intelligent training management systems, if they both used a standard vocabulary for training objectives; but, developing a standard vocabulary for training objectives is not in the scope of the product development group.

There are standard data dictionaries for military terminology. For example, there are the DOD Dictionary of Military and Associated Terms (http://www.jcs.mil/Doctrine/DOD-Terminology/) and the Defense Technical Information Thesaurus (http://dtic.mil/dtic/services/dtic_thesaurus/thesaurus.html). The Joint C3 Information Exchange Data Model (JC3IED) also provides formal definitions for thousands of concepts from the C2 domain. The NATO Multilateral Interoperability Programme (MIP) Information Model (MIM) adopts the JC3IED terms, and expresses them as a formal ontology (Sigopogu, Grupton, & Schade, 2016). It represents the C2 domain by a set of hierarchical classes with formal naming and defining of concepts, properties, and their relationships to one another. Singaopogu, Grupton, & Schade (2016) suggested that the MIP-MIM could be exploited by C2SIM; but, that it might require extensions.

CURRENT STANDARDS IN LEARNING TECHNOLOGY

According to Robson and Barr (2018), until recently, the driver for standards use in the area of learning technology was content portability and the content and learning management supply chain upon which the eLearning industry relies. Other standards were certainly developed, but they were never widely adopted. However, several factors have recently led to a resurgence in interest in learning technology standards, with the big driver being “learning portability”—the market demand to share learning data and qualifications accumulated across multiple learning and/or career experiences, even across a lifetime. This has been driven by several technological innovations and societal conditions: eCommerce, cloud computing, mobile devices, social networking, artificial intelligence, big data, machine learning, competency-based learning, and the internet of things. In essence, these multiple factors have led to a market desire for learning records to be portable across education, training, human resources, institutions of higher education, job placement systems, and so on. This portability requires standardized data exchange services. There are several organizations working on developing learning technology standards, such as IEEE Learning Standards Committee, Postsecondary Electronic Standards Council, IMS Global Consortium, the Learning Resource Metadata Initiative, Access 4 Learning Community, the Ed-Fi Alliance, the Education Data Exchange Network, and the Common Education Data Standards project (CEDS). Given the multitude of efforts, some like CEDS, provide tools to align (or map) one standard to another.

At the same time as these technological and societal changes have been impacting eLearning, there has been increasing interest to make online learning experiences more adaptive and personalized. This interest spans traditional education, workforce development, and military training. For the latter this has been based at least in part by acknowledgement that adaptive training can be more effective than one-size-fits all, and might help compensate for reductions in manpower, heterogeneous training audiences, rapidly changing technologies and operational environments, and limited time to train (e.g., NAWCTSD, 2017; Pharmer & Milham, 2016; TRADOC, 2017). The resurgence in the development of learning technology standards is good for adaptive training services and applications. Adaptive training applications, such as intelligent tutors, traditionally have been stand-alone, single-domain systems. Learning portability would allow these applications to use student data from other sources besides their own, enhancing the ability to implement mastery learning. It is also possible that the emergence of new standards for exchanging learning data may lead to modular services whereby different modules, algorithms, and/or agents responsible for different aspects of adaptive training may be “plug-and-play.” That would enable the STE to integrate best-of breed modules, instead of having to lock-in to one vendor for all training management tools. For example, different modules for expert performance models, student modeling algorithms, pedagogical decision making, and scenario generation may work in concert, even though coming from different vendors. The current learning technology standards space should be monitored for potential application by DoD Enterprise training systems.

One relatively new specification that the DoD has endorsed is the Experience API (xAPI). The updated DoD Instruction 1322.26 Distributed Learning (DoD, 2017), recommends that DoD components will implement the xAPI and associated Learning Record Store (LRS) capabilities, as practical, to enhance learning data interoperability. One impetus for the development and subsequent DoD endorsement of xAPI was the inability to track learning using mobile devices by the more traditional DoD endorsed specification, the Shareable Content Object Reference Model (SCORM). Briefly, the xAPI is a specification that allows data from multiple learning applications (providers) to place data in an LRS (a data repository on a server). Data consumers (who might also be providers) can subscribe to and retrieve the data from the LRS for use and analysis. This allows the data to be used across different applications – data portability. Understanding the meaning of the statements in the LRS depends on the creation of a profile. A profile documents the vocabulary concepts, extensions, statement templates, and patterns that are required for xAPI to be implemented consistently for a specific use case. Without a profile there can be no semantic interoperability. It is up to Communities of Interest (e.g., serious games, open-badges) to establish profiles for specific use cases. The primary adopters of xAPI so far have been Learning Management Systems needing to ingest data records produced by mobile devices, although experimentation for other uses is ongoing, and the IEEE Learning Technology Standards Committee has recently formed a Technical Advisory Group on xAPI. The outputs of this advisory group should be monitored for potential application of the xAPI in the STE.

A POTENTIAL INTEROPERABILITY SOLUTION

The above discussion made the case that there is a need for interoperability across the modeling and simulation communities and the adaptive training communities for STE to function as envisioned. Within each community there is ongoing activity to establish intra-community interoperability; but, there appears to be little attention to achieving interoperability across communities, perhaps with the exception of HPML. This is not particularly surprising, since interoperability within a single community is hard enough, and there has not been a big demand signal thus far for across-community data exchange in these areas. In the context of coalition operations, however, there is a recognition that, among other things, future information exchange solutions must accommodate a diverse user community and quickly integrate unanticipated users. To accomplish this, the Joint Staff has been experimenting with the National Information Exchange Model (NIEM, https://www.niem.gov/) to exchange C2 information among coalition partners during Coalition Warrior Interoperability Exercises. Integration efforts have also been underway between NIEM and the NATO Core Data Framework (NCDF), and the MIP-MIM. NIEM is governed by a partnership of the U. S. Department of Justice, Department of Homeland Security (DHS), and Department of Health and Human Services. In 2013 the Chief Information Officer for the Department of Defense (DoD) issued the "NIEM first" memorandum, which directed that the DoD shall first consider NIEM for their data exchange standards. This was formalized in the 2014 DoD Instruction 8118.01, titled "Mission Partner Environment (MPE) Information Sharing Capability Implementation for the DoD" and reiterated in the Army Data Strategy (Office of the Army Chief Information Officer/G-6, 2016), which has the stated objectives of making data visible, accessible, understandable, trusted, and interoperable.

NIEM

NIEM is a community-driven approach to defining a "lingua franca" for the terminology used by diverse public and private organizations. It allows each organization to map its terminology to the NIEM ontology, thereby supporting semantic interoperability. It can be thought of as a dictionary of agreed-upon terms, definitions, relationships, and formats, independent of how information is stored in individual systems. So if you say automobile and I say car, it allows us to know we are really talking about the same thing. NIEM also provides repeatable, reusable processes and tools for information exchange and domain management. The tools aid in the creation of information exchange packages (IEPs), which use W3C XML schema or NIEM-Unified Modeling Language (UML). The IEP is usually coupled with additional documentation, such as sample XML instances, business rules, and other information. NIEM-UML can also help users manage NIEM domain data model content and create both a UML and XML schema representations.

To implement a NIEM data exchange, XML code is created that conforms to the IEP, both on the sender's end and the receiver's end. Other participants can join in the data exchange at any time by implementing the IEP. IEP creators are urged to consider including only data that make sense for their business case. New ontology elements are created only when participants believe it will make their exchanges easier to implement. Use of NIEM does not preclude use of other exchange schemas; it can be used in parallel with other schemas. With respect to bandwidth, NIEM can work in low-bandwidth environments, using Efficient XML Interchange (EXI) for compressed binary XML data (Renner, 2014).

As illustrated in Figure 3, NIEM consists of core and domain-specific elements. The core includes common elements that domain-specific models build upon. For example, elements in the NIEM core include general concepts such as "person," "location," "item," "organization," and "activity." "Person" has about 200 subcomponents such as birth date, and sex. Domain communities of interest build upon the core and can reuse elements already created by other communities to establish a model for their own needs. The concept of inheritance is used throughout the NIEM data model to support extensibility. For example in the Emergency Management domain, "alarm" is a child of "activity" and therefore has all of the characteristics associated with "activity," as well as specific characteristics for "alarm," such as an alarm category code.

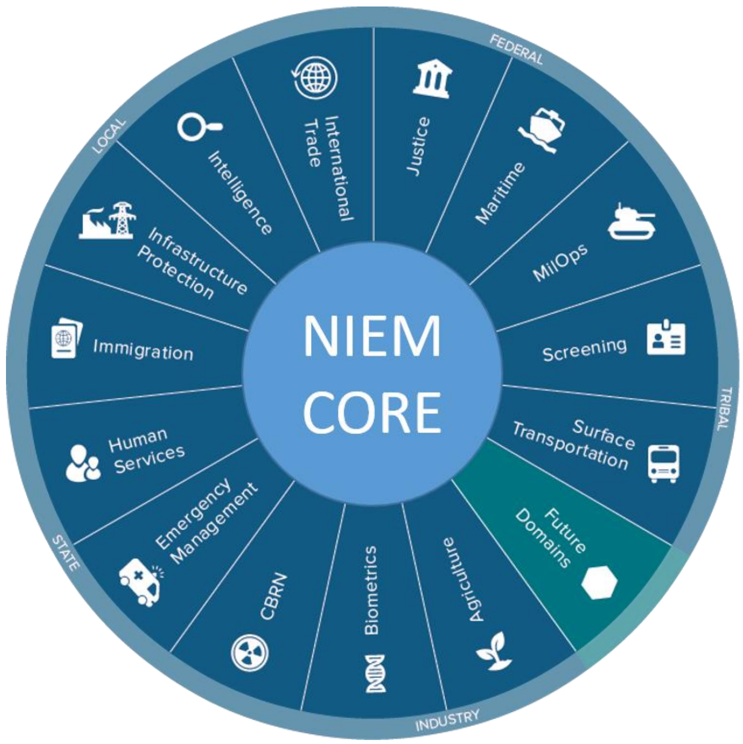

Figure 3. Illustration showing how specialized domains are built on top of NIEM core concepts, such as activity, person, and location, and organization.

Domain communities of interest are formally established, to officially manage and govern their portion of the NIEM Data Model. A MilOps Domain Configuration and Control Board was formally stood up in March 2014 and is stewarded by the Joint Staff. The semantic model is sectioned off into distribution permission levels (A: Public release, C: U.S. Government Agencies and their contractors, D: DoD and U. S. DoD contractors only, and Classified). The DoD is adopting NIEM initially to help support its net-centric data strategy (Renner, 2014). Besides MilOps, the DoD is involved with other communities of interest such as Maritime, Biometrics, and Cyber (Renner, 2014). An ongoing project is Geospatial for NIEM (Geo4NIEM), a collaboration of the NIEM Program Management Office, the OGC, DHS, and the Program Manager for the Information Sharing Environment (PM-ISE). The Geo4NIEM initiative provides guidance on leveraging NIEM content in map-based environments.

NIEM and its potential role in the STE

It is likely that existing NIEM domain models already contain at least some terminology that would aid in data exchange among the Army Training Information System (ATIS), adaptive training services, and simulation services. In order to implement mastery learning, adaptive training management tools will need to identify simulation scenario missions and tasks and to map these onto training objectives. Because NIEM domain models are extensible, current vocabulary can be increased in level of detail as needed, if current vocabulary does not cover the required topics. Other scenario aspects will also need to be identified in order to understand scenario complexity and whether it is at the appropriate level given past training experiences and outcomes. For example, does a scenario contain dynamic threats or only static threats? How many PMESII-PT variables are in play?

If the only thing STE training management tools needed to do were to search a repository of existing scenarios to find ones with the best matching metadata to unit training needs, NIEM might be an overly complicated solution. All that would be required would be agreed upon metadata tags. But for intelligent tutoring-like services, NIEM or something like NIEM is going to be needed. Interpretive artificially intelligent systems are going to have to process real-time performance data generated during scenario execution, relate the interpretation to the training objectives, and make decisions whether and/or how to trigger new scenario events, pause the scenario for feedback, or take other actions. Something akin to Stacy and Freeman's (2016) concept of training objective packages is going to be required. One feature of their concept is the idea of a Behavior Envelope—boundaries within which the scenario must stay in order for the intended training objectives to be exercised. For example, if the use of an unmanned aerial vehicle (UAV) plays a critical role in setting the conditions in the scenario, but it gets destroyed before then, the scenario will have strayed outside of the behavior envelope. Intelligent monitoring services could prevent this or intervene to provide the information the UAV would have provided in some other way, in order to return the scenario conditions back inside the envelope. Thus two-way data exchange will be necessary, with the simulation environment passing data to the intelligent training management tools, and the intelligent training management tools passing instructions back to the simulation software.

Automated scenario generation also could exploit the full power of NIEM. For automated scenario generation, the training management tools would first analyze the current unit training status and plans, including which personnel would be available and/or individually ready for the training exercise. They would then generate the training objectives, conditions, and trigger events for the scenario. These data would then be sent to a translator which would translate this information into simulation software and supporting documentation. NIEM could be used to exchange the required data from training records and plans to the training management tools and from the training management tools to the translator, without any of the components having to know anything about the internal working of the others. All they need is to agree on the NIEM-conformant information exchange specification. Additionally a human-in-the-loop may also participate in the exchange in order to refine the products produced by the artificial intelligence. In essence, this could be a real-time collaboration among human scenario authors and artificially intelligent authoring services.

CONCLUSION

Taylor, et al. (2015) argue that modeling and simulation are unique from other information technology when it comes to software-as-a-service implementation. This is because simulations implement conceptualizations and therefore require an additional level of alignment among the services to accurately interoperate. This cannot be accomplished merely by using interface protocols and information exchange standards, they assert; but, rather a conceptual representation (semantic interoperability) is required—explicit linkages to an ontology of what is being modeled and simulated. The premise of this paper is that integrating intelligent automated performance assessment, virtual humans, and during-execution adaptive training into simulation-based training certainly requires it. Existing standards in the simulation or learning technology domains do not provide the semantic interoperability required, and that NIEM should be explored as the potential vehicle.

Renner (2014) predicted that C2 programs will be among the early adopters of NIEM and that overtime, U. S. military message standards will converge on the NIEM approach. Singaopogu, Grupton, & Schade (2016) argued that the current standard for simulation interoperability for C2SIM needs an ontological basis; it would make sense for NIEM to serve as that basis if C2 programs are going to implement the domain terminology required. In addition, as adaptive training management tools are integrated into the STE, their being able to receive and understand C2 messages during run-time would go a long way to understanding what is going on in the scenario. They could also be sent other run-time simulation data, either directly using NIEM IEPs or perhaps indirectly through a chain of "pre-processing" steps including HPML and xAPI. What those pre-processing steps need to be is beyond the scope of this paper, other than to say that data interpretation would be facilitated if semantic information were associated with simulation entity data. In any case, having semantic interoperability among the various services that will be the STE should greatly facilitate the extent to which the simulation-based training infrastructure can become less dependent on fixed facilities, long scenario development lead times, and human role players. Proponents of the STE should monitor NIEM activities and consider experimentation involving the use of NIEM. The Navy is considering the use of NIEM for their Sailor 2025 program (NIEM MilOps Configuration Control Board Meeting Presentation, 2017). Sailor 2025 is about updating and integrating manpower, personnel, training, and education systems. STE proponents should monitor any experimentation the Navy might conduct in this area, and consider participation in development of domain knowledge aimed at use of personnel data for personalizing training.

A National Science Foundation report on research challenges in modeling and simulation (2016) stated that one of the unsolved issues in data sharing is culture. The success of the STE may depend on not only systems talking, but also disparate organizations collaborating to create a unified business model. Engineering for semantic interoperability depends on more than just a translation mechanism like NIEM. It depends on a mutual understanding of the larger context and employment of a carefully and deliberately designed System of Systems Architecture. Gallant and Gaughan (2011) address many interoperability challenges related to this, and stress the importance of an understanding how each of the cooperating layers, modules, and services contribute to the overall purpose of the integrated environment. A goal of the STE is to overcome many of the problems experienced by training systems federations; but these problems will persist if piece parts are designed in isolation.

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