ITEA Journal 2010; 31: 355–364

Live, Virtual, Constructive, Architecture Roadmap Implementation and Net-Centric Environment Implications

Gary W. Allen, Ph.D.
Joint Training Integration and Evaluation Center, Orlando, Florida
Robert Lutz
Johns Hopkins University/Applied Physics Laboratory, Laurel, Maryland
Robert Richbourg, Ph.D.
Institute for Defense Analysis, Alexandria, Virginia

In 2008 the DOD Modeling and Simulation Coordination Office (M&SCO) published the Live, Virtual, Constructive, Architecture Roadmap (LVCAR) study. LVCAR focused on four important dimensions of simulation interoperability: technical architecture, business models, the standards evolution, and management processes. A key product from the LVCAR study was nineteen recommendations for future efforts. The purpose of this article is to describe how those recommendations are being implemented under the M&SCO High Level Task SC2. The article includes a description of each task area, how the task is being addressed, and current results. The article also describes efforts to look at potential advanced technologies like service oriented architectures (SOA) and their application to the DOD modeling and simulation (M&S) environment.

Key words: Modeling; simulation; live, virtual, constructive, architectures; gateways; bridges; net-centric environment; roadmap; object models; IEEE; DSEEP; ANDEM; SOA.

Current simulation event engineers have a range of architectural capabilities open to them. They can select a "minimalist" intercommunication architecture, providing little more than a communications service, or they can utilize a more complex architecture featuring multiple advanced services such as time and data management. They can also choose to rely on multiple architectures, as occasionally necessitated by the mix of simulation systems that will be combined in the event. However, mixing architectures is not easily achieved: bridges must be installed, gateways developed, and data exchange models (i.e., object models) rationalized and composed. The additional effort required to employ mixed architectures is "over and above" that necessary to join the simulations systems, which use a common architecture, and is frequently viewed as a baseless requirement that would be unnecessary except for the multiple architectures involved. As a result, the Office of the Secretary of Defense (OSD) Modeling and Simulation (M&S) Steering Committee commissioned a study to examine various aspects of M&S development and make recommendations that could improve architecture interoperability.

The Live, Virtual, Constructive, Architecture Roadmap (LVCAR) study began in April 2007. The M&S Steering Committee recognized that M&S capability had greatly advanced, routinely enabling the linkage of critical resources through distributed architectures. In part, the success was predicated on an iterative and evolutionary development of the intercommunication architectures, including progressive capabilities enhancements supporting more varied application of the technologies across expanding user domains. While the architectures displayed impressive capability to meet needs as designed, they were not implemented with a focus on ensuring architectural compatibility. Thus, each requirement to connect systems using different architectures within a single simulation event was accompanied by substantial design and engineering effort to achieve cross-architecture interoperability. Given this environment, the LVCAR study was chartered to "… methodically and objectively develop a recommended roadmap (way forward) regarding LVC interoperability across three broad areas of

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Live, Virtual, Constructive, Architecture Roadmap Implementation and Net-Centric Environment Implications**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Joint Training Integration and Evaluation Center,Orlando,FL,32820**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**10**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

concern: notional definition of the desired future architecture standard, the desired business model(s), and the manner in which standards should be evolved and compliance evaluated." (Henninger et al. 2008)

Study emphasis was placed on analysis of the technical options that could achieve or make transparent architecture interoperability. The analyses were influenced by several characteristics of the operating environment. A fundamental observation was that the user communities expressed little, if any, complaint that architectural capabilities were lacking; the multi-architecture state not only provided a high level of support across a diverse user community but also allowed a degree of user choice in selecting the architecture that best balanced cost and capability within the context of a specific application. Moreover, connecting the different architectures together was a tractable problem with which the community had developed a base of expertise and resources, albeit nonoptimal. The study also concluded that the cost of switching applications to use of different architectures was high, often prohibitive at the level where costs would be borne. Thus, any unfunded mandate directing users to change architectures would likely be ignored. Further, no existing business or management tools could enforce such mandates. In this context, the study concluded that fundamental change either to the number of available architectures or to the architectures themselves was not warranted or desirable. Finally, the implementation of a new, "improved replacement" architecture would only introduce yet another architecture requiring integration, effectively degrading interoperability.

Based on these characterizations of the problem, the study recommendations emphasized a two-front philosophy. First, near-term actions were necessary to ease the problem of architecture integration. Integration should be made transparent, so that users would interact with a seamless "architecture of architectures." Second, a longer-term goal emphasized an evolutionary process of Common Training Instrumentation Architecture (CTIA), High-Level Architecture (HLA), and Test-Training Enabling Architecture (TENA) architectural convergence. Individual actions supporting both strategies are now ongoing.

The current LVCAR Implementation (LVCAR-I) program is the follow-on effort, concentrating on five tasks designed to address specific recommendations identified in the original LVCAR report. These five tasks include LVC Common Capabilities, LVC Architecture Convergence, Common Gateways and Bridges, Joint Composable Object Model (JCOM) Development, and Managing the LVC Environment.

LVCAR-I project overview

The project's aim is to explore organizational and structural (e.g., use of standards) options to better (a) manage LVC architecture interoperability; (b) create reference models to focus data and service reuse efforts; (c) reduce LVC architecture divergence and tool proliferation; and (d) explore emerging technology issues related to future LVC architecture performance and requirements. The planning, development, and execution of LVC events are universally recognized to be expensive by any measure. Also, the M&S community lacks the agility to support unforeseen events without great difficulty. Given this situation, the objective of LVCAR-I is to reduce overhead and thus improve the ability to construct and conduct timely LVC events. Described another way, the goal for LVCAR-I is to get M&S support inside the military operations decision cycle.

The project leads have taken a holistic approach to organization and definition of an acquisition strategy. Fundamentally, LVCAR-I is designed to work in an environment where there are many different factors and incentives that influence decisions, including willingness to change and the adoption of technical solutions. Understanding these factors and their effects are as important to the success of the project as the technology advances themselves. As a result, the LVCAR-I team distilled the 19 recommendations found in the LVCAR study to the grouping of core, affiliated, and supporting efforts as described in *Table 1*.

Core task organization and grouping

Beginning in Fiscal Year 2009 (FY09), a team led by the Johns Hopkins University/Applied Physics Laboratory (JHU/APL) initiated efforts to implement the LVC Architecture Roadmap. The overall organization of the effort is shown in *Figure 1*.

This particular organization was designed to reflect the blended, two-front strategy defined in the Roadmap. "LVC Common Capabilities" and "Common Gateways and Bridges" focus on improvements in the processes, tools, and supporting resources used to develop LVC environments in the near-to-mid term. "LVC Architecture Convergence" focuses on mid-to-long–term actions to prevent further divergence (and facilitate convergence) among the major simulation architectures in wide use across the Department of Defense (DoD) today. In addition, the "Managing the LVC Environment" task is designed to identify existing business models and management structures for each of the major simulation architectures, assess the relative strengths and weaknesses of each, and

Table 1. Overview of live, virtual, constructive, architecture roadmap—implementation efforts.

	Core task	Affiliated task	Supporting task
Standards development	Systems engineering process Federation agreement templates Reusable development tools Asset reuse mechanisms		
Software development	Common gateways and bridges Architecture convergence	Joint composable object model	
Studies	Management—product transition strategy	Management organizations and processes	SOA concepts LVC futures
Outreach	Core task workshops	Management workshops	M&S forums/presentations Working group presentations Web-based information

SOA, service-oriented architecture; LVC, live, virtual, constructive; M&S, modeling and simulation.

recommend some potential realignments to improve efficiency and reduce maintenance costs in the future.

The following sections describe the rationale and objectives associated with these three main technical areas of LVCAR-I tasking, and delineates the specific activities being performed within each area.

Core task: LVC common capabilities. During LVCAR development, it was recognized that the absence of supporting products was creating an unnecessarily heavy burden on developers of multi-architecture LVC simulation environments. This increased the technical and cost risks inherent to the LVC development process and adversely affected LVC interoperability. LVCAR workshops were held with users and developers of multi-architecture environments to assist in the identification of necessary products and to estimate the return on investment associated with implementing these products. Based on the assessment of workshop feedback, four categories of products were identified as having the highest value to the LVC community, as summarized below.

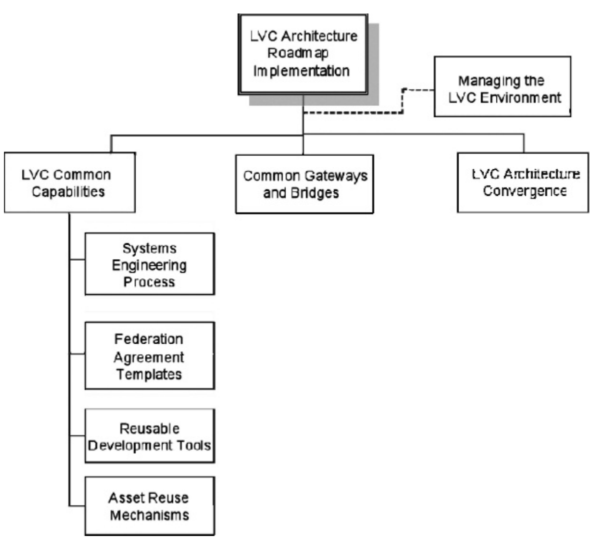

Figure 1. Organization for live, virtual, constructive, architecture roadmap implementation.

Systems engineering process. When user communities of different simulation architectures must develop a unified multi-architecture distributed simulation environment, the different development processes native to each user community can create barriers to effective collaboration. For multi-architecture LVC development to be successful, the communities aligned with the different simulation architectures need to work together toward common goals; differences in the practices and procedures inherent to these communities can lead to misunderstandings, misinterpretations, and general confusion among team members. The key product identified to address this problem was a common systems engineering process for the development and execution of multi-architecture simulation environments.

Rather than develop a whole new process, this task leverages an emerging Institute of Electrical and Electronic Engineers (IEEE) process standard (IEEE 1730) as a framework onto which multi-architecture issues and solutions can be overlaid. This framework, the Distributed Simulation Engineering and Execution Process (DSEEP), tailors best practices in the systems and software engineering communities to the domain of distributed simulation. The DSEEP defines the sequence of activities to develop and execute distributed simulation environments in an architecturally neutral manner *(Figure 2)*. Using this framework, the key technical issues associated with multi-architecture development are aligned with the activities within the process, and user guidance is provided on how to address each issue based on existing community practices.

Upon completion of the Systems Engineering Process task, IEEE standardization is expected to commence. Given the close ties to the DSEEP, the

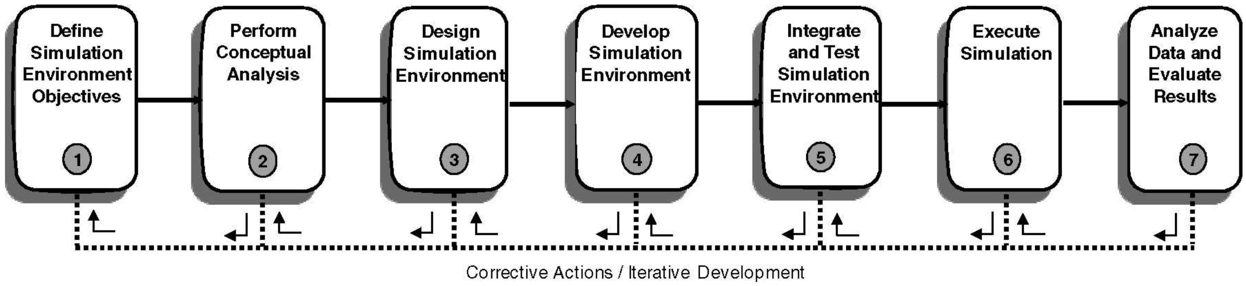

Figure 2. Distributed simulation engineering and execution process top-level process flow.

Systems Engineering Process is expected to become the first officially recognized DSEEP overlay (i.e., IEEE 1730.1). Other supporting overlays are expected in the near future (e.g., verification, validation and accreditation, test and evaluation) to provide additional LVC community support.

Federation agreement templates. Many agreements must be established for an LVC simulation environment to function properly. Examples include reference frames, shared databases, entity enumerations, and supporting tools such as loggers and viewers. In multi-architecture LVC environments, there is an even broader list of agreements that must be negotiated, including execution management mechanisms, gateways, and supporting middleware. Unfortunately, there is no cross-architecture standard for the content or format of federation agreements; these agreements are usually local conventions or are completely ad hoc. This implies that multi-architecture LVC initiatives must continuously recreate the types of information or products requiring cross-architecture agreements, increasing development time, and introducing the possibility of missed agreements. The lack of a standard template for federation agreements also adversely affects the reusability of the agreements between programs.

The purpose of the Federation Agreements Template task is to develop an architecture-independent template for establishing federation agreements, along with potential architecture-specific extensions. The content and format of the emerging template is based on examples of federation agreements documents developed to support programs across the DoD and represents a reconciliation of the varying interests of the different architecture communities. The template is expressed in an Extensible Markup Language (XML) schema, enabling machine-readable interchange of federation agreement data. In the future, a tool will be developed that implements the schema and provides some degree of automation for all users of this product.

Reusable development tools. Every step in the process of distributed simulation development includes many opportunities for automation. These include utilities such as requirements development tools, scenario development tools, conceptual and object modeling tools, testing tools, and after action review tools. While these tools satisfy most functional needs, a wide range of business models are used across the tool spectrum, including government off the shelf, commercial off the shelf, and proprietary solutions *(Figure 3)*. This is a significant impediment to sharing of tools, especially for multi-architecture development. The varying formats used by these tools to store and exchange data are yet another impediment to reuse of tools across architectural boundaries.

The purpose of this task is to examine the various business model options associated with efficient sharing of tool resources for LVC simulation applications, identify the most beneficial approach, and implement that approach in a phased, controlled fashion driven by the areas of greatest need. The main product of this activity is an identified set of LVC development tools that are reusable across different architectures along with supporting business models for tool distribution and maintenance. The other product of this activity is a set of architecture-independent formats for data storage and exchange across architectures.

Asset reuse mechanisms. There are currently several repositories and registries in use across the DoD. The main clearinghouse for M&S information is the Modeling and Simulation Information Analysis Center (MSIAC). The Services' Modeling and Simulation Resource Repository is accessible through the MSIAC, thus allowing a wide range of search capabilities relevant to developing or employing M&S applications. However, estimates of utilization indicate that there are relatively few users, and the level of M&S asset reuse appears to be much lower than desired.

The purpose of this task is to examine existing DoD repository and registry capabilities for M&S reuse. This includes sponsored reuse initiatives such as M&S catalogs and metadata discovery specifications. The product of this task is a plan of actions and activities to

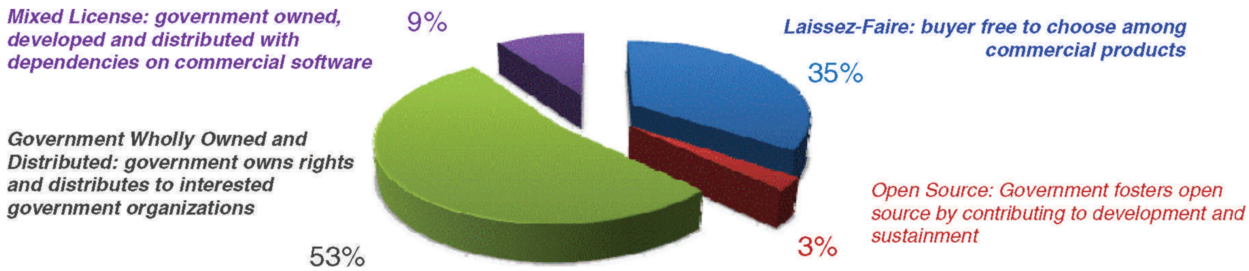

Figure 3. Live, virtual, constructive development tool business models.

better support the reuse of LVC assets across the Department. This plan not only identifies basic infrastructure improvements but also provides recommendations on supporting processes and business incentives based on an analysis of the causes behind programs "building new" rather than reusing existing capabilities.

Core task: common gateways and bridges. The second major category of LVCAR-I core tasks examines common gateways and bridges. These are essential elements that link disparate LVC assets and translate across multiple protocols in multi-architecture environments. However, there are several persistent problems that result in barriers to cross-architecture interoperability. Many of these issues stem from the lack of standard mechanisms supporting gateway capability discovery, configuration, and employment. Thus, many project managers find it much easier to simply build their own gateways, specifically tailored to their specific application, rather than attempt to reuse existing gateway assets. This has resulted in a large number of program-specific gateways that are not reusable outside of their design context. This is grossly inefficient from a corporate perspective, as not only does the government pay over and over again to build the same basic gateway capabilities, but it also pays for the maintenance of a large number of redundant gateways.

The purpose of this task is to develop supporting products that improve efficiency and effectiveness related to gateway use. The task involved an early outreach activity to characterize existing gateways according to a defined set of features. This provided an early glimpse of the requirements that could be met through existing gateways. While this identified a small number of capability gaps, it also brought out the high degree of redundancy among current gateways. Next, a strategy was developed to discourage new gateway development while making existing gateways more accessible and easier to use. The fundamental, enabling tasks that collectively define this strategy can be summarized as follows:

- A common *Gateways Description Language*, which allows for the description of gateway capabilities in a machine-readable form. This allows gateway users to discover needed capabilities via automated means rather than manual searches of gateway documentation.
- A set of *Gateway Performance Benchmarks*, which provides a common way of assessing the relative ability of competing gateways to provide needed capabilities.
- A common *Gateway Configuration Model*, which provides a standard means of initializing, tailoring, and configuring gateways.

Efforts to begin all three of these products have been initiated. Tools to implement these specifications are expected to be developed in the FY12 timeframe.

Core task: LVC architecture convergence. There is a general consensus within the LVC community that some degree of convergence among the major simulation architectures would be beneficial. Adjudication of architectural differences, even if it can only be achieved for some service categories and only between certain architectures, would reduce efforts to implement potentially ad hoc cross-architecture solutions during LVC developments and generally improve LVC interoperability. However, there are many barriers to achieving architecture convergence. While there are certainly technical challenges, the business model and management challenges are even more formidable. The full range of these challenges must be addressed for any viable architecture convergence strategy to succeed.

The purpose of this task is to examine the issues and risks related to architecture convergence and to develop an evolutionary strategy to achieve convergence. The task required an analysis of existing simulation architectures to identify candidates for convergence, followed by an assessment of the implementations of the various architecture services to determine exactly how and where to target convergence activities. Finally, convergence options were identified and evaluated

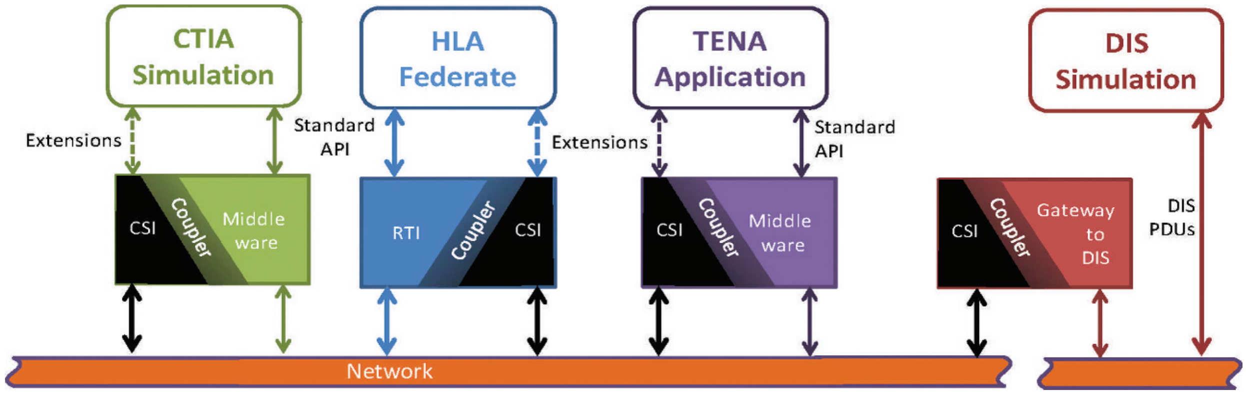

Figure 4. Common simulation infrastructure concept.

from the technical, business, and management perspectives. Recommendations on subsequent convergence activities are made as part of this assessment.

A key aspect of the convergence task is to categorize simulation architecture services into those that are architecture specific (i.e., do not need to be interoperable between architectures for multi-architecture events to operate properly) and those that are "functionally similar" across the architectures. The functionally similar services are candidates for becoming "converged" services, which must be aligned for the architectures to work together without loss of functionality. Three alternatives for implementing the converged services have been considered:

- Establish a wire standard defining how all simulation architectures communicate data;
- Establish a static application programmer's interface and implementation of the converged services; and
- Build a shared implementation of the converged services, referred to as the Common Simulation Infrastructure (CSI).

Figure 4 illustrates how the CSI concept would work. All architecture-specific communication would take place via the same middleware services that the simulations currently use. However, the middleware would communicate through the CSI for all "converged functionality" communication with other simulations. The CSI would automate the alignment across the converged services so that effective and direct interaction among simulations employing interfaces from different architectures is possible. Note that gateways are still required to integrate Distributed Interactive Simulation (DIS) simulations into multi-architecture LVC environments, due to the difficulty of achieving meaningful convergence between DIS and other architectures.

Follow-on efforts in the architecture convergence area are expected to focus initially on socialization of convergence options with affected communities, and potentially some early experimentation with a CSI prototype. Discussion of business model and management concerns will be part of this socialization process to ensure community support before progressing down any particular convergence path.

Affiliated task: the Joint Composable Object Model (JCOM) program

The JCOM effort is being jointly sponsored by the Joint Forces Command and the Modeling and Simulation Coordination Office. The effort will result in a repository of commonly used components of object models, an Architecture Neutral Data Exchange Model (ANDEM) format to represent those components, and a set of tools to facilitate the assembly of those components. The JCOM effort relies on an information-based approach in that much of the disparate information necessary to create an object model is both represented in the system and linked to related information. That is, run-time data exchange between simulation systems occurs to support a specific purpose (e.g., training for chemical, biological, radiological, nuclear, and high-yield explosives operations; acquisition related to Joint close air support; planning for time sensitive targets missions). Several mission areas have been decomposed and represented in the JCOM repository, including links to related components of object models. Users can exploit these linkages by identifying components that support specific mission areas or by finding the degree of mission support offered by a specific object model. JCOM is the only utility that exploits these types of relationships between mission areas and object model components and thus offers a unique capability supporting widely ranging users including acquisition executives, trainers, experimenters, and event designers. JCOM also provides unique capabilities for event engineers who make the related simulation event a reality.

Typically, event engineers start their work by adapting solutions to similar problems. In the JCOM context, event engineers start with the object models from a set of previously completed simulation events that collectively solve the problem at hand. The problem then becomes one of composing a new object model from the existing set of object models. This is a familiar problem usually solved at a "FOMorama," a meeting of engineers well versed in the contents of each object model. Collectively, they are able to compose the different models into a single object model that meets the needs of all systems. This task is a laborious manual analysis completed by a group of very experienced engineers. JCOM addresses this part of the problem by automatically comparing data exchange models (including cross-architecture comparisons of models from HLA, TENA, CTIA, or DIS) to identify both similarities and differences. This permits the engineers to focus their attention on only those parts of the object models that JCOM could not automatically equate, greatly reducing the time and effort to prepare a composition that supports the needs of all systems.

Supporting task: M&S service-oriented architecture concept pilot—educate, inform, and present.

Educate and inform. Service-Oriented Architecture (SOA) technology holds great promise for addressing many of the technical challenges documented in the Live Virtual Constructive Architecture Roadmap Study. Where existing architectures use different protocols and interfaces, SOA offers services that enable composability of systems via a layer of abstraction. Where current M&S data repositories, such as terrain databases, are duplicative, SOA offers the possibility of services that promote reusability. The philosophy of SOA is constructed on the guiding principles of "reuse, granularity, modularity, composability, componentization, and interoperability" (IBM 2004).

However, SOA is not a panacea. In particular, using an SOA to provide the interfaces to an LVC distributed simulation, in and of itself, will not cause all fundamental problems to disappear. SOA use can provide the scaffolding to address these issues at the time of design and initial implementation, easing future burdens of functional and communication compatibility.

There have been studies and demonstrations that the SOA framework can support LVC multi-architectural distributed simulations. However, SOA has not been embraced by the M&S community or by LVC multi-architecture developers. There are both real and perceived up-front costs of employing a new technology to address compatibility issues that have traditionally been addressed with ad hoc gateways and bridges, one-of-a-kind database connectors, and other single-point design solutions. Therefore, the objective of this effort is to educate and inform the DoD M&S community of the benefits and barriers related to employing SOA technology.

SOA concept prototype. The DoD led the way in SOA-like architectures such as HLA, TENA, and CTIA—all of which built on the then-emerging Common Object Request Broker Architecture defined by the Object Management Group. These architectures were designed to integrate enclaves of individual systems and are not optimized to bridge enclaves across an enterprise. In contrast, industry has developed robust SOA-based software technologies and standards that clearly have the potential to provide for architecture interoperability to interconnect between stand-alone enclaves at the enterprise level and to serve as the primary infrastructure for common services, such as interfaces to battle command systems or models of the synthetic natural environment.

The concept of using the SOA-based software and standards in this mode, as shown in *Figure 5*, is not new and is being eyed with keen interest by many in the simulation industry. However, no extant program of record can afford to put their program at risk (especially in the current high ops tempo environment) on an unproven approach, no matter how promising. As an early step towards realizing the concept shown in *Figure 5* the "Present" portion of the M&S SOA Concept Pilot implements an integrated set of supporting simulation services and creates a prototype linking two disparate enclaves using real federations and real simulations along with a surrogate service *(Figure 6)*.

This effort will bridge the Joint Conflict and Tactical Simulation (JCATS) federate in the Army's Entity Resolution Federation (ERF) with the WARSIM Intelligence Model (WIM) federate in the WARSIM federation and a surrogate service to emulate the Order of Battle System (OBS) to initialize both federations.

The prototype will provide information to assess the ability of SOA to address the following LVC requirements:

- a common data interchange;
- enclave policy translation;
- use of a common service to replace equivalent application (federate) functionality; and
- run-time performance and scalability.

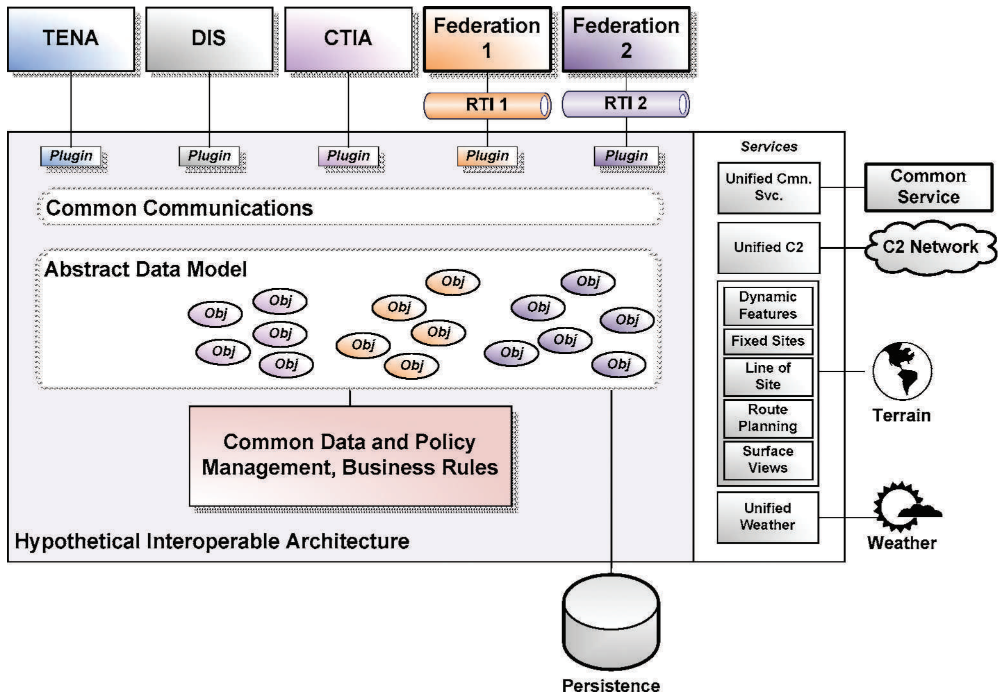

Figure 5. A hypothetical interoperable architecture linking legacy enclaves and common services.

Supporting task: beyond SOA—a look to the future for U.S. DoD M&S. The purpose of this task is to look at emerging technologies and processes that the DoD M&S community should consider in future development projects. This is not intended to be an exhaustive study but rather an overview with rationale that explains why each technology/process is significant.

Since the DoD is a consumer, not a driver of the Information Technology (IT) market place, it must make best use of the commercial IT standards,

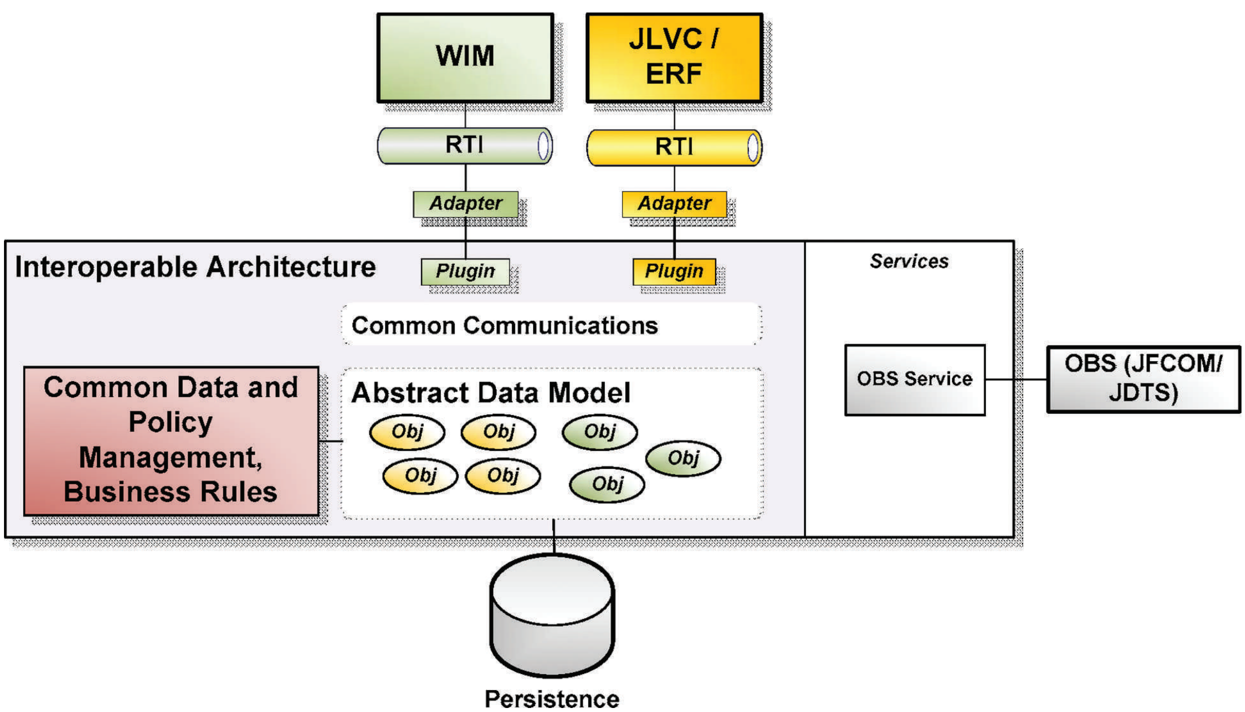

Figure 6. Proposed prototype for an interoperable architecture implementation between two disparate architectures.

practices, and technologies available to meet their needs. Given the long lead times that are typical for DoD project initiation (3–10 years), the Department must have a long view, informed by knowledge of coming capability, as a precondition to relying on best practices. A set of military operational scenarios covering the spectrum from high tempo kinetic operations to natural disaster relief are used to guide the identification and application of these future technologies. The technology areas under consideration are divided into two areas: (a) Development Components (technical areas including Mobile Computing and Augmented Reality, Ubiquitous Surveillance and Automated Reasoning, Event Model Driven Architectures, and Self-Healing and Self-Managing Systems), and (b) Use Components (considerations that affect adoption of technology including M&S Social Graphs, The Paradox of "Choice and Budge," Mashup Software, and fast, inexpensive, simple, and tiny (FIST), Cloud Encapsulation, and "Everything is a Game").

Supporting task: public outreach. Implied missions of the LVCAR-I project are to inform the M&S community of project activities and where possible get the community involved, and at the earliest opportunity provide access to the project's products. The project team examined the realm of possibilities to meet the various aspects of this mission and decided that it was best to take a three-pronged approach and engage the M&S community through (a) M&S forums, (b) working groups, and (c) electronic and print media.

The M&S forums include presentations at the National Defense Industrial Association (NDIA) Systems Engineering Conference, NDIA M&S Congress, Simulations Interoperability Standards Organization events, and National Training and Simulation Association's Interservice/Industry Training, Simulation and Education Conference (I/ITSEC). These opportunities have provided access to a variety of special use groups within the M&S community, and there are plans to continue using these opportunities as they arise.

Because of the growing emphasis on LVC simulation constructs within the DoD, there are numerous programs and projects addressing training, analysis, testing, and acquisition requirements. Having related activities opens the possibility for these parallel programs to provide mutual support but also assumes the M&S community is cognizant of emerging developments. To improve community situational awareness, the program manager for LVCAR-I initiated an LVC Interservice Working Group (LVC-IWG) to provide a forum where the leaders of these various programs could share information about what is being undertaken and look for opportunities to leverage each other's work. In addition, the LVCAR-I project has sponsored numerous special interest workshops to solicit input to the various project subtasks.

Finally, this project is providing information through articles and a Web site. This article is an example of print media use, and through the sponsorship of Joint Forces Command HarmonieWeb there is a repository for publically released material from the LVCAR-I project (harmonieweb.org) under the work group "MSCO HLT SC2 LVCAR-I."

Next steps

The initial commitment of funds for the LVCAR-I project covered a 24-month period of performance. Since inception, a great deal of information has been gathered and analyzed. As with many efforts, we rapidly discovered the more we learned led to logical steps for future work that needs attention. Without losing sight that the goal is to improve LVC interoperability by providing practical tools and pragmatic approaches to the problem, the project will have follow-on efforts. Planning for FY11 and FY12 includes the use of test beds, design of software, initiation of standards, and continued sharing of lessons learned.

Conclusion

From the previous material, it is easy to see that the LVCAR-I is an ambitious project from both a technical and managerial standpoint. While having interoperability as the focus of the project provides a unifying goal and eases some management aspects, there are a number of ways to approach that problem set that add numerous levels of complexity. The functional area approach that underlies the project management is recognition that decisions and adoption of technical solutions are not based solely on logic or cost analysis. Understanding the other factors that relate to the adoption of technology will improve the use of the tools developed through LVCAR-I. In the end, interoperability and ultimately support to the warfighter will improve. ❑

Dr. Gary W. Allen has worked in various aspects of modeling and simulation for the past 30 years. During his career as a U.S. Army Officer, Dr. Allen was a member of the team that founded the Training Simulation Center for I Corps at Fort Lewis, Washington, in 1980. In 1989, he was selected to commence a doctoral program at the

University of Kansas in instructional technology, and after receiving his doctor of philosophy degree in 1989 he went on to be the director of the Simulation Training Branch at the U.S. Army Intelligence Center and School, Fort Huachuca, Arizona. In 1992, Dr. Allen was inducted into the Army Acquisition Corps and assigned as the project director for the TACSIM Intelligence Simulation and was part of the confederation that initiated the Aggregate Level Simulation Protocol (ALSP). After retirement from the Army, Dr. Allen joined federal service in 2002 as the U.S. Army liaison officer to the German Ministry of Defense for cooperative research and development. In 2009, he returned to the United States to fill the position as the Joint Training Integration and Evaluation Center's (JTIEC) project manager for the DoD Modeling and Simulation Coordination Office (M&SCO) High Level Task S-C-2 "Live, Virtual, Constructive, Architecture Roadmap Implementation" program. Dr. Allen is a member of the Phi Kappa Phi National Honor Society, a 1999 graduate of the Army War College, and an Acquisition Corps Level III Certified Project Manager. E-mail: gary.allen@us.army.mil

ROBERT LUTZ is a principal staff scientist at The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. He has over 29 years of experience in the design, implementation, and evaluation of M&S systems for military customers. Mr. Lutz served as both a study team and expert team member during development of the Live, Virtual, Constructive Architecture Roadmap (LVCAR) and is leading several technical tasks in the current LVCAR implementation phase. Mr. Lutz also serves as the U.S. Navy's Broad Area Maritime Surveillance (BAMS) Program M&S lead in the Airspace Integration (AI) area and leads several M&S standards activities within the Simulation Interoperability Standards Organization (SISO). He also serves as an Executive Committee (EXCOM) member within SISO and is a regular guest lecturer in The Johns Hopkins University Whiting School of Engineering. E-mail: Robert.Lutz@jhuapl.edu

DR. ROBERT RICHBOURG has been a member of the research staff at the Institute for Defense Analyses since joining the Institute of Defense Analysis Simulation Center in 1996. Prior to that, he was an active duty U.S. Army officer, serving the last 10 years of his career as the director of the Office of Artificial Intelligence Analysis and Evaluation and professor of computer science at the United States Military Academy, West Point. His simulation experience centers primarily on the area of environment representation. He has worked in the simulation areas of autonomous behaviors and architectures, and he led the recently completed architecture study for the LVCAR effort. E-mail: rrichbou@ida.org

References

Henninger, A., et al. September 2008. Live, Virtual, Constructive Architecture Roadmap (LVCAR) Final Report. Unpublished report available from the Modeling & Simulation Coordination Office.

IBM. 2004. http://www.ibm.com/developerworks/webservices/library/ws-improvesoa (accessed July 16, 2004).

Acknowledgments

The authors thank David Drake, Anita Zabek-Jones, Jon W. Labin, Katherine L. Morse, Randy Saunders, and John Schloman for their direct and indirect contributions to this article.