Live Virtual Constructive (LVC) Architecture Interoperability Assessment

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ABSTRACT: *Substantive interoperability between Live, Virtual and Constructive (LVC) assets has long been a "Holy Grail" for the Modeling & Simulation (M&S) community. Currently, however, the M&S community utilizes different standards that are not natively interoperable and in some cases competing in nature. In most cases, the current level of interoperability is attained through the use of numerous gateway applications, embedded middleware solutions, or approaches such as Federation Object Model (FOM) agreements. These solutions to technical interoperability, however, are sometimes prone to violating latency thresholds, significantly increase complexity, mistranslate data, and require large workarounds. The resources required to develop interoperable solutions has prompted the M&S user community to identify an explicit gap in the area referred to as Simulation Interoperability, particularly where interoperability between Live, Virtual and Constructive assets is desired.*

In response, a US DoD M&S Steering Committee (SC) sponsored and funded study was established with the objective of developing an LVC Architecture Way Ahead (LVCWA). The study team is exploring and assessing a number of alternatives supporting simulation interoperability (at the technical level), business models, and the evolution process of standards management across the Department of Defense. This paper describes a plan for moving toward improved LVC interoperability based on the author's findings and recommendations assimilated from the study activities to date.

1. INTRODUCTION

The DoD overall, as well as a number of non DoD communities enabled by Modeling and Simulation (M&S) recognize the importance of Live Virtual Constructive (LVC) interoperability in accomplishing their objectives. For instance, LVC capability and integration development is called out in the October 1995 DoD M&S Master Plan [1], and is a key requirement in the DoD Training Transformation Implementation Plan [2]. LVC Interoperability is a key attribute of the Joint Mission Environment Test Capability (JMETC) program within the Test and Evaluation (T&E) community.

However, these communities, and their subsets, are currently utilizing several different interoperability standards. The current level of interoperability is achieved through a proliferation of gateways that bridge architectures and protocols. The gateways are typically proprietary, and add complexity, latency and the risk of data mistranslation, notwithstanding the extra resource burden that accompanies the use of multiple gateways integrated into a federation.

The High Level Architecture (HLA) is most often used in the M&S community for integrating virtual and constructive assets, while the Common Training Instrumentation Architecture (CTIA) and the Test and Training Enabling Architecture (TENA) are widely used to support interoperability among live and instrumented range assets. Distributed Interactive Simulation (DIS) is also widely used in the M&S community, but is typically bridged into the HLA environment using DIS-HLA gateways. The Aggregate Level Simulation Protocol (ALSP) is employed to provide interoperability between constructive simulations. Finally, a level of semantic interoperability is achieved through the use of numerous gateways to translate datasets among DIS, HLA, TENA, CTIA, ALSP, and other protocols/architectures.

2. BACKGROUND

Modeling and Simulation (M&S) has made significant progress in enabling M&S users to link critical resources through distributed architectures, and some characterize this advance as the “M&S Success Story” of the last twenty years. Building on early successes such as SIMNET [3], different user communities have, over time, evolved protocols tailored for the unique requirements of their community. ALSP (Aggregate Level Simulation Protocol), for example, dating back to the early 1990s, built on the SIMNET concept of distributed training, but focused on faster than real time simulations and aggregated entity levels to provide for a theatre-level experience for battle-staff training [4]. Roughly in tandem, SIMNET was evolving into the DIS (Distributed Interactive Simulation) standard, [5] Institute of Electrical and Electronic Engineers, Inc. (IEEE) 1278, to provide for technical interoperability for more types of distributed resources, above and beyond just homogenous simulators considered in SIMNET.

Building on and integrating some of the unique capabilities of DIS and ALSP into a single architecture, HLA (the High Level Architecture) was developed [6]. Central to the development of HLA was the notion of designing architecture versus simply communications protocols, as well as the broadened focus of M&S user and exercise requirements. Specifically, whereas the DIS and ALSP communications protocols had emerged from requirements from the Training community, HLA designers recognized that the Acquisition and Analysis communities each had their own unique requirements for simulation applications [7]. Thus, HLA was really the first distributed M&S interoperability paradigm designed from the ground up to support the collective requirements of three unique communities.

Placing a greater emphasis on run-time performance, TENA (Test and Training Enabling Architecture) was developed as a high-performance, low-latency communications infrastructure [8], largely used to integrate live assets at test range events and provide detailed performance data on the system(s) being tested. Similarly, with concerns related to performance in very large exercises, the Army’s CTIA (Common Training Instrumentation Architecture) was developed to link assets on an Army training range, typically a very large number of assets requiring a relatively narrow bounded set of data to support an after action review (AAR).

While highly capable in meeting the unique requirements for which they were designed, these paradigms and architectures are not inherently technically interoperable. One approach to interoperability is to convert simulation assets from one paradigm to another, but this can be costly [9] and comes at a risk. Other approaches include adopting a single, agreed upon protocol, but enforcement of this approach would require major policy changes[1]. Technical interoperability can also, however, be

[1] While interoperability paradigms newer than DIS or ALSP exist, survey by Bailey and Mihalecz (2005) reveals that of surveyed sites (i.e., NCARNG, BSTF, DMOC, NSC, 7ATC, PACOM, KBSC, SOCOM, 505ECS) only 25% use HLA, 25% use DIS, 0% use TENA, and 38% use ALSP.

achieved through a number of methods including: the use of gateways and bridges [10] which themselves may not be interoperable, ”reference” FOMS such as the Real-time Platform Reference Federation Object Model (RPR-FOM) [11], or embedded middleware solutions [12]. These solutions to technical interoperability, however, can be prone to violating latency thresholds, significantly increase complexity, mistranslate data, and can require large workarounds resulting from differences in protocols. Yet, even with these potential pitfalls, some practitioners [13] believe the benefits offered by a mixed-architecture approach (e.g., increased number of available federates, rapid integration and lower costs) outweigh these workarounds and their associated risks.

The resources needed to develop these interoperable solutions coupled with the frequency these efforts are required has prompted the M&S user communities, represented by the DoD Modeling and Simulation (M&S) Integrated Product Team (IPT) and Steering Committee (SC), to identify an implied or explicit gap[2] in the area referred to as Simulation Interoperability. These applications span all forms of live, virtual, and constructive (LVC) M&S-supported events which, as scoped by the funded study, may be composed of all or any subset of LVC capabilities (i.e., L, V, C, LV, LC, VC, LVC).

The purpose of the DoD M&S SC Live Virtual Constructive Way Ahead (LVCWA) study is to thoroughly investigate the issues related to Live, Virtual and Constructive interoperability and to recommend a way ahead to increase interoperability across several areas: notional definition of the desired future architecture standard, the desired business model(s), and methods in which standards should be evolved and compliance evaluated. The study is responsible to provide:

- A rationale for recommendations, citing the findings on which they are based
- An assessment of how any LVC architecture policy change might be perceived in the user communities, with a recommendation on optimal ways to communicate the new direction
- Recommended next steps (e.g., prototyping new architecture(s), merging of architecture(s) and protocols, timelines, new standard(s), etc.)

[2] Other efforts identifying similar need to review interoperability standards include DoD reports on Composability for M&S (Davis and Anderson, 2003) and M&S Leadership Summit Recommendations (Andrew and Waite, 2007).

3. LVC ISSUES

Distributed M&S and/or LVC Federations[3] have been produced, refined, studied and debated for many years. However, there has never been a comprehensive knowledge network for federation architecture and design established so that experts in the field could share and compare notes on how to best address interoperability challenges and issues. Live, Virtual and Constructive interoperability issues are much broader than simply issues between HLA and TENA. Even though these are the two most widely employed architectures for Live, Virtual and Constructive integration, the other protocols must be considered due to the significant communities and applications dependent upon them. The following sections address specifics of the architectures, but the issues described are relevant to the broader LVC community.

Despite their lack of native interoperability with each other, all of the interoperability architectures share a number of characteristics, which are outlined below.

3.1 Basics of Data Transfer/Object Models

All the interoperability architectures have mechanisms for describing state. In modern terms, they all require object models for technical or semantic interoperability. A TENA meta-model describes the elements used to construct a TENA Logical Range Object Model (LROM) [14]. Similarly, the HLA Object Model Template (OMT) describes the elements of an HLA Object Model [15]. A TENA LROM represents an interface “contract” for a given logical range, while an HLA Federation Object Model (FOM) represents a data ”contract” for a given HLA Federation. TENA Object Models, in general, offer a richer schema, supporting increased Object Oriented (OO) representations. The support includes composition, which is not currently supported by the HLA OMT. Thus, while TENA and HLA require an object model, their object model representations are significantly different in structure and application.

As previously mentioned, the object model formalism present in HLA and TENA first arose in ALSP to promote interoperability. The concept exists in DIS in the form of protocol data unit (PDU) definitions, a static object model.

CTIA is based on the concept of various interface definitions, which distinguishes it from HLA and TENA. CTIA is comprised of four components:

- Primary Objects
    - Objects with Identity, State and Persistence
    - e.g. Entity, Organization

- Events
  - Instantaneous occurrence of something of interest
  - Logged in the exercise database to support AAR, playback, reports, etc.
  - E.g. EntityTrackingEvent, OrganizationStateChangedEvent
- Interface Objects
  - Specify an interface that must be implemented
  - E.g. PlugAndPlayComponent, Managed Process, AlertPublisher
- Data Objects
  - Attributes of other objects and parameters to APIs
  - E.g. Filter, CommandResult, SituationAwarenessRegionData

3.2 Organizational Oversight/Standards Processes

The TENA Architecture Management Team (AMT), a government oversight organization, provides policy and guidance for TENA implementation. In a similar fashion, the HLA Architecture Management Group (AMG) provides recommendations for HLA implementation within the DoD. Actual HLA oversight is provided through governing standards organizations, IEEE and the Simulation Interoperability Standards Organization (SISO). Oversight of these architectures provides two distinct and opposite business model constructs to consider. In the early days of HLA, the HLA AMG played a more active role in HLA standards definition, but as the HLA has transitioned to an open international IEEE standard [15,16,17,18], the AMG's primary responsibility has been to ensure that the HLA continues to meet the needs of the DoD M&S community. AMG members represent M&S users across the DoD and play an active role in the IEEE process. Similarly, the TENA AMT plays a very active role in the evolution of the TENA standard. The AMT meets approximately every three months and is represented by the major stakeholders of TENA, who collectively discuss design decisions, issues and concerns identification, investigation, and resolution impacting the TENA user community. The TENA community is mostly represented by US interest whilst HLA has an international representation.

As mentioned previously, DIS is governed by an IEEE standard, IEEE 1278. The organization and processes created by the M&S community to develop and govern the standards morphed into the IEEE standardization organization that supported HLA. This organization is known as SISO[3].

In 1993, ALSP transitioned to a multi-Service program, as defined in the ALSP Management Plan[4]. The original philosophy of community-based development is still demonstrated in the Interface Working Group (IWG) which meets three times per year. The IWG pulls from the collection of developers, proponents, and users to work together to meet user requirements by producing an improved Confederation each year.

CTIA is an Army program managed by PEO STRI, and governed by five groups[5]:

- Systems Engineering and Integration Team
- Architecture Working Group
- User Working Group
- Integrated Development Environment (IDE) Working Group
- Risk Management Working Group

3.3 Set of Core Rules/Foundational Assumptions

All the interoperability architectures define rules which facilitate interoperability within their respective domains. HLA rules are specified in an IEEE Document [16]. HLA rules outline the responsibilities of HLA federates and HLA federations to facilitate a consistent implementation of the architecture. DIS has a set of foundational assumptions/rules that govern and shape its use defined in the IEEE standard.

TENA's technical architecture view [19] specifies rules for using TENA and affiliated standards that assist applications in achieving TENA's technical requirements and broader DoD goals. TENA rules specify three levels of compliance that applications may attain.

ALSP has a set of formal rules governing information exchange. In addition, a community of practice has evolved that effectively defines conventions and best practices shared among developers and users.

CTIA also has a set of processes, rules, standards that support Live Training Transformation (LT2). These are defined by the various management groups mentioned in paragraph 3.2 above. CTIA defines five levels of compliance, with components at higher levels

[3] http://www.sisostds.org/
[4] http://alsp.ie.org/alsp/
[5] https://ssl.peostri.army.mil/CTIAPortal/PublicBriefings

of compliance possessing greater levels of reusability within the architecture.

3.4 Use of Middleware

A common misconception of CTIA, HLA and TENA involves implementation. TENA, CTIA and HLA are all architectures, and not implementations. However, their use requires an implementation of the respective architecture. TENA Middleware is the implementation of the communication and delivery infrastructure of the TENA architecture. It is roughly analogous to the Runtime Infrastructure (RTI) of HLA. Both the HLA RTI and TENA Middleware offer an Application Programmers Interface (API) through which applications address the infrastructure software.

Although TENA and HLA are similar in some aspects, their native incompatibility is a major inhibitor to seamless LVC interoperability.

ALSP consists of three components: 1) the ALSP Infrastructure Software (AIS) providing distributed runtime simulation support and management; 2) a reusable ALSP Interface consisting of a set of generic data exchange message protocols (i.e., formal rules for information exchange) to enable interaction among objects represented in different simulations; 3) participating simulations adapted for use with ALSP. As such, the ALSP community of practice has a set of shared middleware for creating compliant applications.

CTIA provides a set of common software service components to developers. The layer diagram in Figure 1 illustrates the services provided[6].

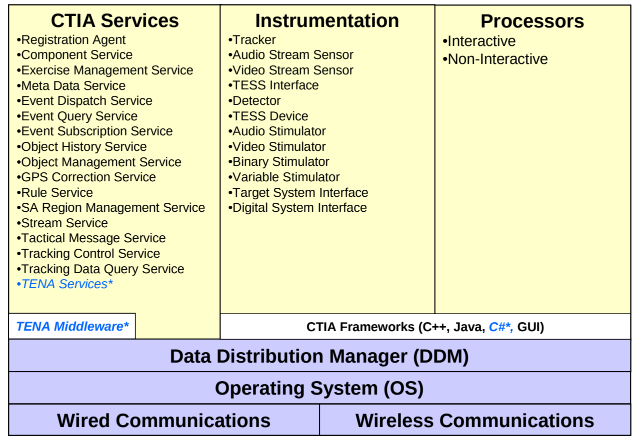

Figure 1 - CTIA Layer Diagram

4. INTEROPERABILITY INHIBITORS

There are several key inhibitors to Live Virtual Constructive interoperability that require investigation.

4.1 Lack of understanding of the interoperability issues between Live Virtual Constructive

If seamless LVC interoperability is the desired end state, the differences between Live, Virtual and Constructive environments must be thoroughly investigated and documented. As an example, domain specific strategies such as dead reckoning (commonly used in virtual and constructive domains to reduce data transmission) will need to be addressed for the live domain. Understanding interoperability issues will allow the requirements of the various domains to be more readily addressed.

4.2 Differences in Intended Use

The various architectures were developed for different domains and uses based on “their” communities requirements. Zimmerman and Rumford [20] point out that TENA and HLA were developed with complementary objectives. HLA was intended to provide interoperability among, and reuse of, virtual and constructive assets (M&S), while TENA and CTIA were intended to provide interoperability among and reuse of test and range resources. TENA is becoming widely used to integrate live range assets into test, training and experimentation environments. DIS grew out of the virtual training community and ALSP from the constructive training community, each with interfaces to live elements. Each was developed to meet the particular needs of its community.

[6] CTIA Architecture Details, Version 1.4, August 15, 2005. https://ssl.peostri.army.mil/CTIAPortal/PublicBriefings

4.3 Incompatibilities in Data Transfer/Object Modeling

Data transfer/object modeling has consistently been an obstacle to interoperability and composability, even within a single architecture.

The DIS protocol attempted to solve the interoperability problem by developing a single data model to be used by all DIS participants. However, the approach failed to offer the flexibility needed to represent complex, changing and diverse systems. HLA shifted to the other end of the spectrum by specifying a format for recording the object model, but left the definition and content of the object model open. This approach offered greater flexibility, but introduced interoperability challenges due to the diverse nature of object model template development across the M&S community. The complexity of integrating an HLA Federation increases significantly when participating simulations have different HLA Object Models. Within the HLA Community, some effort has been made to develop standard “Reference” FOMs, such as the Realtime Platform Reference (RPR) FOM.

TENA specifies its object model format in the TENA Meta-Model [14], and also specifies a suite of “Standard Object Models”, from which users compose more complex object models. The Standard Object Model subsets approach appears to offer a more flexible tradeoff between flexibility and standardization. Even though the TENA object model approach appears to be a “best practice”, this has not yet been substantiated by the LVCWA study team.

As discussed earlier, CTIA and ALSP also have unique object modeling approaches. Furthermore, DIS has a fixed object model in the form of Protocol Data Units (PDUs). As a result it can be postulated that all object modeling approaches are unique to specific architectures or protocols, and remain an impediment to interoperability. Thus, it can be concluded, that to reach a seamless LVC architecture, common and standard object modeling referential is required to ensure interoperability.

4.4 Lack of Composability

Composability is defined within the DoD M&S Master Plan [1] as “the ability to rapidly select and assemble components to construct meaningful simulation systems to satisfy specific user requirements”. Such composability is intended to “enable effective integration, interoperability, and reuse.” However, composability across the M&S community has not adequately been achieved. For instance, the lack of composability support offered by HLA object modeling has made assembling HLA FOMs from piece parts much more difficult. This deficiency inhibits the ability to achieve interoperability between the HLA and TENA [10, 11, 21].

A FOM serves as the binding contract which allows systems and simulators to exchange meaningful information. If difficulty or delay occurs in producing a FOM, interoperability for the systems and simulators may be compromised.

Component composability is a key focus of CTIA. As stated previously, the architecture compliance levels are organized by (degree of) ability for reuse and composability. At a minimum, all components must implement a CTIA:PlugAndPlayComponent interface.

It is recognized that a single object modeling methodology, focused on achieving composability, must be considered in the LVCWA study.

4.5 Systems Engineering Process

Early experiences (successes and struggles) with HLA led to the development of a well defined systems engineering process for building and executing HLA Federations. The resulting HLA Federation Development and Execution Process (FEDEP) [18] represents a system engineering process adapted to the development of HLA Federations. Object Modeling is a critical component of several steps of the FEDEP, however the community failed to recognize the importance of capturing “knowledge” from developers to facilitate lessons learned orchestration in a timely manner. The LVCWA study is working to capture this information in formulating recommendations.

The FEDEP does not preclude live participation, and in fact, alludes to the use of live assets in an HLA Federation. TENA has a similar system engineering process outlined in the TENA Architecture Reference Document [19]. In addition, the JMETC program has adopted the TENA Systems Engineering Process renamed the “JMETC Integration and Customer Support Process”. A single systems engineering approach is desirable and would be a significant enabler for LVC interoperability. The upcoming IEEE FEDEP review process will offer an excellent opportunity to align the systems engineering processes across the various architectures.

The DIS community developed best practices that serve their needs. The ALSP community formalized processes, such as the All Actor Integration and Confederation Test cycle to enable ALSP integration.

CTIA formalized a set of Domain and Product Line Engineering Processes[7], which is a bounded group of capabilities defined to facilitate communication, analysis, and engineering in pursuit of a product line. There are three types of domains considered:

- Closely related groups of ***end user systems***
- Commonly used functions ***across multiple systems***
- Widely applicable ***groupings of underlying services***

4.6 Business Process Attributes

The architectures/protocols adopted different business strategies for governance and implementation. The DIS and HLA communities have embraced an international standards approach with emphasis on a commercial off the shelf (COTS) implementation strategy.

ALSP, CTIA, and TENA have adopted a Government off the shelf (GOTS) solution, which emphasizes development and control by a US Government agency and open access to "their" community of interest. Advantages and disadvantages of each approach require detailed investigation. The LVCWA study team recognizes that the business model for governance and implementation of a new LVC architecture is a sensitive subject that requires sound research with documented findings and substantiated recommendations. At this point the LVCWA study team recognizes that perhaps a hybrid business model that emphasizes a GOTS architecture framework with COTS plug and play modules may be the most efficient solution. Even though the "hybrid framework model" appears to be a "best practice", this has not yet been substantiated by the LVCWA study team.

4.7 Middleware / Infrastructure Incompatibility

ALSP, CTIA, HLA, and TENA implementations all provide a communications infrastructure layer with a well-defined user API. In addition, they provide a set of services designed to distribute data between producers and consumers, based on a publish/subscribe paradigm. Although they provide similar message delivery services, they differ in their intended uses. If the middleware implementations are merged in the future, functionality specific to the different M&S domains will need to be addressed.

[7] Domain/Product Line Engineering Processes, August 15, 2005, https://ssl.peostri.army.mil/CTIAPortal/PublicBriefings

5. STUDY

5.1 Open and Collaborative Governance Structure

Figure 2 depicts the USJFCOM chaired working group (WG) comprised of a balanced set of representatives from the user communities with hands-on expertise, approved by the Oversight Group. Service, Agency, Industry, Academia & Coalition representative experts will support USJFCOM and the working group. The study support team(s) will be led by JFCOM selected lead(s), who will determine the study support and expert team composition, subject to the concurrence of the Oversight Group. Generally, the study support team can expect guidance, input and feedback from the working group members, whereas the working group can expect execution plans, subsequent findings, and draft deliverables from the project support team. The work products of the expert or project support team will be reviewed and commented on by the working group as a whole before being released for external review and subsequent submission to the Oversight Group. The unique combination of process and management along with participation from the Services, Agencies, Industry, etc. will ensure that the evaluation process is balanced and transparent. Finally, an independent Red Team will directly support the Oversight Group in review of findings and recommendations to ensure total objectivity.

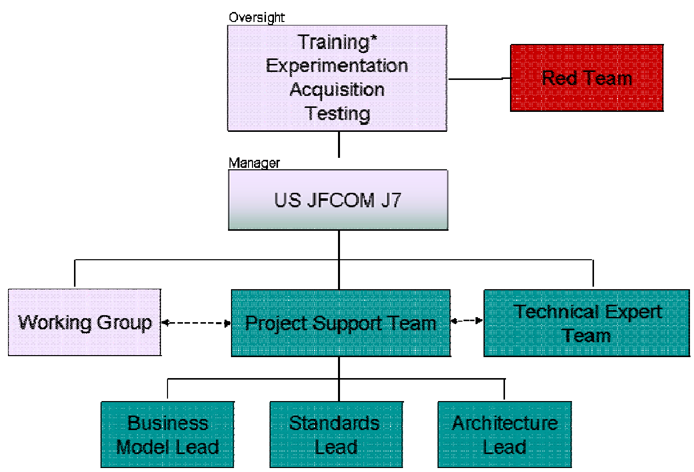

Figure 2 - LVC Project Organization Chart

5.2 Transparency in Processes

Figure 3 depicts a generalized version of the vetting process by task. To ensure balance and transparency, there are numerous opportunities to provide feedback and capture "new ideas". Tasks will be formed, largely

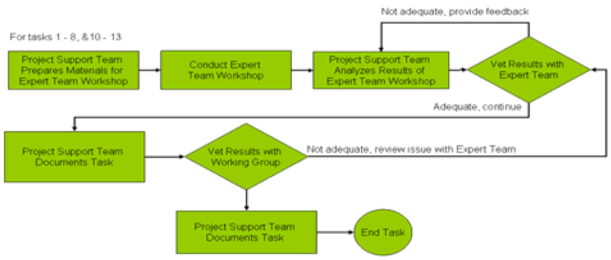

Figure 3 - Task Vetting Process

through a modified Delphi Process[8], with the Expert Team serving as the creative body in that process. When pertinent, the results of tasks are vetted with the Expert Team prior to presentation to the WG. If there is an unresolvable conflict at the WG level, the issue is reconsidered by the Expert Team. If the Expert Team and the WG do not concur, final guidance will be the responsibility of project management and project oversight, given input from the WG, the Expert Team, and the Project Support Team. All of these mechanisms are available to promote collaboration and transparency. However, consensus is an aspiration, not a requirement, for project success.

Outreach opportunities (e.g., I/ITSEC, DMSC, SISO, AMSC, NDIA, NTSA etc.) will be used to socialize the LVCAR. These mechanisms, much like the WG, will be used to share latest results and invite feedback from interested colleagues.

5.3 Stakeholders

M&S is a knowledge enabler and is in use worldwide by government agencies (e.g., DoD, DHS, NASA, NATO, etc.) industry, academia and coalition partners for a variety of purposes. Recent Congressional support has catapulted the appreciation for the technology to highest levels of government[9]. Thus, stakeholders can rapidly expand beyond the military applications reviewed earlier. Presently, however, we assess the following to be examples of stakeholders and activities which will rely on and benefit from this project's deliverables, how the results may impact them, and how they will be involved.

5.4 Project Plan Execution

The original project plan for the LVCWA provided a complete step-by-step process for examining pertinent issues and providing substantive recommendations to resolve attendant problems in a 24 month effort. However, the DoD M&S SC funded the first part of a two-part effort, at a reduced amount, to be completed in 15 months with an initial allocation for the first (9) nine tasks in nine (9) months with a requirement for an interim report. Even though there are resource constraints imposed on this project, it is the desire of the project team to achieve the major goals indicated in the original project plan while not exceeding the available time, personnel, or funding that has been made available for this effort. The project plan described below identifies the original 13 tasks to be executed in order to address desired future architecture, the desired business model(s), and methods in which standards should be evolved and compliance evaluated. Execution details are provided for the first nine (9) tasks with an outline being provided for the remaining (4) tasks.

5.4.1 Technical Architecture

The task required to assess future technical architecture interoperability way ahead will involve thorough review of literature, requirements documents, identifying deficiencies and addressing the issue of potential convergence. There have been many papers authored surmising potential solutions. The common theme is that there needs to be object model harmony to reach true composability. A paper written on functional interoperability assessment at John Hopkins University Applied Physics Laboratory concluded a need for "object model unification" through an enhanced framework to facilitate unification of the HLA and TENA infrastructure.[11] Cutts, Gustavson, and Ashe concluded that "Base Object Model (BOM) as a unifying approach to object modeling" could provide an effective approach to converging Object Models across the various architectures.[10] Finally, it

[8] The Delphi technique was developed in the 1950s by Rand Corporation as a tool to estimate the probable effects of an atomic bomb attack on the United States. In general, the Delphi provides a practical approach to the collection of currently unavailable data that cannot be efficiently generated by more traditional, precise analytical methods. The traditional Delphi method is characterized by three distinguishing features: anonymity for all respondents, iteration with controlled feedback, and statistically interpretable group response

[9] "This technology importance has been addressed directly with President Bush and it is anticipated that M&S will be recognized as an official technology for the Nation" (I/ITSEC 2006 Program, page 28).

has been suggested that perhaps common object model components (using Base Object Models) could provide a basis for a composite Joint Federated Object Model (JFOM) that will support a set of object model components "extensions" unique to the particular needs of each federation.[22] Many of the "convergence" concepts articulated in the above mentioned papers have been postulated based on a convergence theory first proposed in 2004 and shown in figure 4 [23].

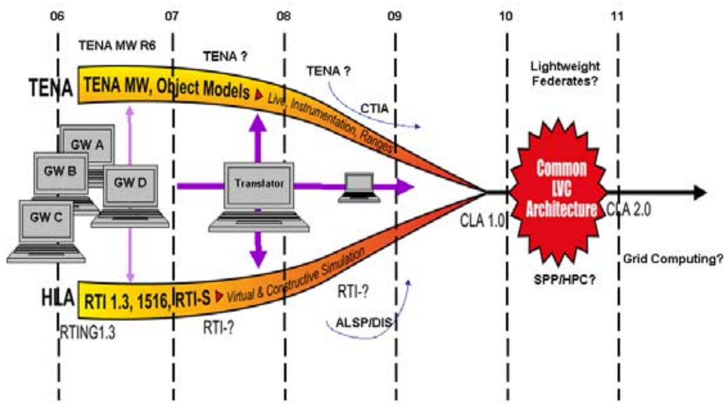

Figure 4 – Common LVC Architecture

It is evident that the M&S community is actively searching for approaches to become more efficient in the way they do business by focusing on how to make the composability theory a reality. This project will attempt to outline a way ahead toward a true composable architecture by accomplishing the following tasks (based on resource constraints):

Task 1. Literature Review – this will be a continual process. The LVCWA team has already collected a large amount of relevant literature and is collecting more documentation through survey and RFI processes. It is assumed that this set of documents will meet the research needs of the group, but collection of more documentation will be conducted as required.

Task 2. Use Case Identification – Related uses cases, developed as part of the Joint Data Alternatives (JDA) project, have already been developed. JDA use cases are being examined to ensure that each functional area is included and reuse to the maximum extent possible is planned. However, it is recognized that additional use cases may need to be developed and assistance is being solicited from the WG, subject experts and DoD M&S IPT.

Task 3. Functional Requirements Definition – Personal knowledge and experience of the project support team, expert team, WG, the survey responses, the RFI responses, and the literature review will provide a sufficient basis to identify the functional requirements, prioritize them, and map them to use cases. If there are gaps, additional literature review and interview processes will be conducted.

Task 4. Capabilities Specification - Personal knowledge and experience of the project support team, expert team, WG, the survey responses, the RFI responses, and the literature review will provide a sufficient basis to identify the capabilities and limitations of competing architectural models.

Task 5. Capabilities Mapped Against User Requirements – Based on the results of 3 and 4 above the project team will compare the capabilities list to the requirements and compare the limitations list to the requirements; then document capabilities and limitations mapped to requirements.

Task 6. Comparative Analysis of Middleware Functionality – Based on resource constraints, this task will involve review of literature of prior comparative assessments and conducting focused experiments with existing architectures, (minimal federation instantiations) to ensure that the protocols can be used, gain a better understanding of how each protocol functions, and to assess the relative level of difficulty in instantiating a federation using the protocol. Existing gateways will be used to connect the different federations. Finally, interviews will be conducted with others who have implemented more complex federations (including the requisite middleware) so that the project team can benefit from their experiences, both good and bad. These activities will be shared with the expert team and provided to the working group members so that a greater appreciation for the various architectures is assimilated prior to making the recommendations for the interim report.

Task 7. Comparative analysis of the business models – This task will not be addressed by the architecture study team group.

Task 8. Comparative analysis of the standards management and evolution process –
This task will not be addressed by the architecture study team group.

Task 9. Mid-project report – This report will be the culminating effort of the architecture working group at the end of the 9-month period, which will be reviewed by the expert team and provided to the working group.

Task 10. Perform a Systems Engineering Analysis of Alternative means to achieving LVC architecture interoperability.

Task 11. Create a Draft Recommended Way Ahead.

Task 12. Develop a Plan to Socialize the Way Ahead and Solicit Feedback

Task 13. Produce a Final Report

5.4.2 Business Model

The business model analysis for LVC way ahead is equally, if not more important than the analysis of technical interoperability. In fact, technical interoperability, while usually the focus of many interoperability discussions, may not be the key inhibitor or impediment to realization of LVC interoperability. One might argue that even if technical interoperability can be achieved, unless business interoperability is attained, the Department still might not have a functional solution. Regardless of technical interoperability, LVC stakeholders may not choose to participate if it is not within their business interests. Alternately, if business concepts and models have not been accommodated for and facilitated in the overall architecture, then the necessary transactional elements may be unaccounted for and the overall business incentive constrained. Therefore, the architecture and business concepts are intertwined, and for the sake of discussion each may be individually contemplated. However, in the end, they need to be integrated and complimentary. For business purposes, interoperability can be explained as the ability of disparate, independently-developed systems to communicate with each other and thus work together toward a common business goal. Or for LVC users, products or service providers it is the ability to provide services to and accept services from other users, products or service providers , and to use and exchange the services to enable them to operate effectively together within the context of the parties collective business goals.

Based on the clear pattern of business success entailing both government and industry desire to "control" their destiny, it is imperative that the LVC business model accommodate all parties. Thus, a potential solution may involve an architecture framework that has a core, which is government owned and maintained, whilst tools (e.g. loggers, monitors, configuration management) and plug ins for unique situations (e.g. faster than real-time, high-fidelity physics models, multi-level security) can be competed to industry to foster continuous innovation. This project will outline a way ahead toward a true compatible business model to accommodate both industry and DoD desire to actively "control" their destiny by accomplishing the following tasks:

Task 1. Literature Review – From the perspective of the business model effort, the literature review and survey has three main topics: a characterization of the current business environment surrounding LVC activities; a brief overview of the economics surrounding LVC technology and its use; and an overview of business models in general. From a level-of-effort point of view, the overview of the current business LVC environment and the business model overview receive the most attention.

The characterization of the current LVC business environment will identify and document the stakeholders – who are the parties impacted by any decisions regarding the future of LVC technology. To the extent possible, the scope of impact will be addressed. This will be an assessment as to the breadth and depth of change a stakeholder would have to absorb. This assessment can provide an analytic backdrop for subsequent analysis in Task 7. An identification of the major LVC products and services being delivered will also be produced. The intent is to understand the nature of the current system of transactions that take place between various stakeholders. This information provides a baseline to begin the discussion on business models. The next step will capture the prevailing business models employed to deliver the existing products and services. Any real or perceived insufficiencies in business models will be documented. A brief characterization and quantification of LVC economics will be attempted. Ideally, the following information will be collected:

- The magnitude of the total dollar value of goods and services associated with LVC interoperability
- The number of government organizations involved with LVC interoperability
- The number of industry organizations involved with LVC interoperability
- The number of academic organizations involved with LVC interoperability

The purpose is to understand the size of the "ecosystem" that revolves around LVC-related economic activities. A poorly understood aspect of technology businesses and market niches is the cost of producing and maintaining a technology, and its complexity, relative to the size of the community that uses it. In subsequent phases of the analysis, comparing the LVC marketplace to other structural analogs (e.g. interoperability in healthcare IT, interoperability in enterprise information systems, etc.) will be critical in discussing the merits of various business models. Having some understanding of the size of the LVC marketplace becomes essential.

Task 2. Use Case identification – In this section the concept of operations (CONOPS) of business models for LVC product and services will be described to capture and describe the analytic construct for this aspect of the study. In addition, this task will capture, to the extent possible, actual business data for two of the technical use cases. The overall goal is to frame the business model analysis structure to be employed throughout the remainder of the study.

Task 3. Requirements Definition - The primary focus on this task is to understand any constraints or impacts of the technical approach or requirements on the business model. For instance, an open standards-based set of technical requirements supports one set of possible business models. Alternatively, a set of technical requirements that supports a proprietary approach enables another set of business models. To the extent possible, an understanding of what constraints exist on the business model as dictated by the requirements should exist. These constraints may be regulatory, legal, or practical in nature. The main focus, however, will be to outline what activities the business model must enable (the requirements of a business model):

- Development
- Unit and Integration Testing
- Operational Use

The sustainability of a business model is one of the key features of business model analysis. Understanding how the LVC technology base is created (who invests) and how the ecosystem perpetuates itself (or not) is at the heart of a business model study. Additionally, this task will postulate the themes around which the enterprise can unite (e.g. Total Ownership Cost). An illustration will be provided as to how the various business models facilitate or hinder the achievement of enterprise goals.

Task 4. Capabilities Description - The key feature of the business model analysis, from the perspective of capabilities, is to create an understanding of what needs to be accomplished by the business model for the LVC enterprise. As such, document:

- What must the business model do that is not currently being done
- Anecdotal evidence of problems
- Transactions are inhibited by the current business model(s)
- Multiple business models currently being simultaneously employed

As time permits, the study will identify instances of mixed business models in other domains with a similar structure (e.g. healthcare IT, CRM), and in general address the general question of the desirability of multiple business models, and business model interoperability. The real focus, however, will be to outline the "ecosystem", or set of relationships the business model must facilitate, the key functional components of the ecosystem, and illustrate how these components work together. The sustainability of a business model, and how the business model facilitates the achievement of enterprise goals must also be captured.

Task 5: Capability vs. Requirements Mapping - As time permits, the business model will outline a scheme to represent business model capabilities against business model requirements. This assumes far fewer of each than exists for the LVC technical architecture, and in any event a simplified analysis with the most important features of each will be documented.

Task 6. Comparative analysis of middleware functionality – This task will not be addressed by the business model study team group.

Task 7. Comparative analysis of the business models – This task will aggregate the knowledge garnered in the tasks detailed above with the knowledge of the working group and expert team in order to: provide a greater appreciation of the breadth of business considerations; to identify and raise issues for further examination and to provide an overall context for the expert and work group teams to make further guidance and priority decisions.

Task 8. Comparative analysis of the standards management and evolution process - This task will not be addressed by the business model study team group.

Task 9. Mid-project report – This report will be the culminating effort of the business model project group at the end of the 9-month period, which will be reviewed by the expert team and provided to the working group.

5.4.3 Standards Development Process

Standardization is the use of common products, processes, procedures, and policies to facilitate attainment of business objectives[10]. Standardization has always been about ensuring interoperability. Numerous industrial initiatives in a variety of different economic sectors owe their success to a commitment of the stakeholders to join forces to agree on open specifications for interoperable systems. The standards process project group will focus on four main topics to include: (1) Identify potential standards organizations for LVC standardization. (2) Categorize the different standards development approaches for LVC systems. (3) Classify the types of LVC standards currently used by the community. And, (4) Identify certification and testing methodologies used for LVC standards. The LVC technical and business model interoperability implementation plan will depend on a cohesive and comprehensive standards process that accommodates DoD, industry and coalition requirements. Thus, the standards process project team may have the ultimate responsibility of determining the most effective way to implement LVC way ahead recommendations to accommodate DoD, industry and coalition requirements. This is a daunting task in that some within the DoD M&S community see no value added in working with international standard organizations. Thus, it is important that the LVCWA standards process project team key on complementary actions in accomplishing the following tasks:

Task 1. Literature Review - Compilation of prior work related to standards organizations, standards development, types of standards, and certification testing. The literature review will be a continual process rather than a single step taken to achieve an overall goal.

Task 2. Use Cases - The project team will examine use cases to ensure that each functional area is included and reuse them to the maximum extent possible.

Task 3. Functional Requirements Definition - Identify functional requirements for standards and their support of interoperability and map them to use cases in Task 2. Participants in the survey will also be asked to identify gaps in LVC interoperability. Many of those gaps will be in the form of missing functionality.

[10] http://www.ieee.org/portal/cms_docs/education/setf/glossary.html

Task 4. Capabilities Specification - Identify capabilities and limitations of current distributed LVC architectures within the context of use cases. Capabilities to evaluate include functionality, scalability, latency, computational demand, computational distribution options, network implications, information assurance, and quality of service issues. These capabilities will be assessed from a standards view, e.g., types of standards used, whether standards contributed to or impeded the architecture from achieving its goals, whether standards were used uniformly by participants or by a subset. The project will also identify real and perceived gaps in current LVC standards.

Task 5. Capabilities and Requirements Mapping - Support the architecture project team in mapping capabilities and requirements where standards are concerned.

Task 6. Comparative Analysis of Middleware - Support the architecture project team in identifying standards used to support the functionality being evaluated and identifying performance standards which can be used for evaluation.

Task 7. Comparative Analysis of Business Models - Support the business project team by defining certification, as well as identifying de facto and commercial standards used by the LVC community.

Task 8. Comparative Analysis of Standards Management and Evolution - This will include examples of success or failure of other IT and commercial standards management practices. The standards process team will identify standards management and evolution process models to be compared. Consideration will be given to non-LVC IT and commercial standards that might have applicability to LVC interoperability, such as:

- Internet Engineering Task Force (IETF). The IETF input is critical due to the impact of IPv6, multicast, and other network related issues, which transport LVC capability.
- DoD High Performance Computing Modernization Program (HPCMP). The HPCMP provides supercomputer services, high-speed network communications, and computational science expertise that can enable the LVC architecture. HPCMO input on a wide range of infrastructure and software developmental and Science & Technology (S&T) issues is important.
- World Wide Web Consortium (W3C). The impact of W3C on distributed computing is in

its infancy, so tracking and documenting this capability is critical.

- Object Management Group (OMG). Middleware technology inspired by OMG standards has dominated this field up to this point in history. The LVCWA team will track and confer with OMG to capture input in project documentation and ascertain applicability for future implementation.

Task 9. Mid-project report – This report will be the culminating effort of the standards process project group at the end of the 9-month period, which will be reviewed by the expert team and provided to the working group.

6.0 Conclusion

The Live-Virtual-Constructive Architecture Way Ahead project will provide a blueprint for LVC architecture issues for the next 5 - 7 years. Sponsored and funded by the Modeling and Simulation (M&S) IPT and SC, the study will explore and assess a number of alternatives supporting simulation interoperability (at the technical level), business models, and the evolution process of standards management across the Department. The goal is to define an efficient, effective path to maximize technical interoperability of M&S systems across the U.S. Department of Defense (DoD). The proposed path forward for the LVCWA project needs to be developed with cognizance of stakeholders' concerns, as well as resource and schedule constraints. Finally, the technical interoperability is almost secondary to the issues and challenges in ensuring business interoperability and standards process are clearly defined and sufficient to meet all stakeholder needs.

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