The Defense Modeling and Simulation Reference Architecture – a Collaborative Process

Dr. Katherine L. Morse
JHU/APL
Laurel, MD
Katherine.Morse@jhuapl.edu

Brian Miller
US Army CERDEC NVESD
Ft. Belvoir, VA
brian.s.miller116.civ@mail.mil

Michael Heaphy
OSD(AT&L)/DMSCO
Alexandria, VA
michael.a.heaphy.ctr@mail.mil

ABSTRACT

Over the past few decades, the Department of Defense (DoD) has invested millions of dollars into interoperability and reuse solutions for models and simulations. While some architectures and tools have been developed to address specific community needs, we do not yet have an overall common technical framework. The barriers range across the technical and social spectrum, from computing power and data compatibility, to funding and resistance to mandated architecture policy. Meanwhile, the DoD's evolving information technology (IT) infrastructure may soon provide the computing power, network, and storage necessary to make transition of modeling and simulation assets to service oriented architectures making composability both feasible and affordable. Maximizing the value of service based architectures while maintaining Joint and Coalition interoperability requires a coordinated effort, across the DoD and internationally. The Defense Modeling & Simulation Reference Architecture (DMSRA) will provide best practices and guidance to assist modeling and simulation (M&S) activities' use of Department of Defense (DoD) information technology (IT) and enterprise services, leveraging technologies such as cloud computing and service oriented architectures (SOA), through adoption of DoD M&S enterprise standards to facilitate sharing of model and simulation assets.

This paper provides insights to manage modular, open architectures for defense M&S with a future focus of delivering these capabilities through service oriented architectures. It discusses the challenges in applying DoD guidance for reference architectures for the level of abstraction necessary for the scope of a reference architecture for DoD M&S. It describes the process used for developing the document through collaboration with the DoD Components and Services, and international community (e.g. North Atlantic Treaty Organization (NATO) Modeling & Simulation Group (MSG)-136), initially within the Training domain and expanding to include Acquisition and Test & Evaluation (T&E).

ABOUT THE AUTHORS

Brian Miller is with the Modeling and Simulation Division at the US Army Night Vision and Electronic Sensors Directorate (NVESD), part of the Communications - Electronics Research, Development and Engineering Center. He has been with NVESD for 23 years much of it spent developing modeling and simulation technologies for imaging sensor systems. Mr. Miller recently spent 3 years on temporary assignment to the Defense Modeling and Simulation Coordination Office. He has participated in NATO Science and Technology Organization (STO) technical teams supporting the Systems Concepts and Integration (SCI) and Sensors and Electronics Technology (SET) panels as well as the NATO M&S Group (NMSG). Mr. Miller has a Master's degree in Mechanical Engineering from The Catholic University of America and a Bachelor of Science in Mechanical Engineering from Virginia Tech.

Dr. Katherine L. Morse is a member of the Principal Professional Staff at the Johns Hopkins University Applied Physics Laboratory where she researches and develops technologies for improving simulation engineering, implementation, and application. She received her B.S. in mathematics (1982), B.A. in Russian (1983), M.S. in computer science (1986) from the University of Arizona, and M.S. (1995) and Ph.D. (2000) in information & computer science from the University of California, Irvine. Dr. Morse has worked in the computer industry for over 30 years, more than 15 of them contributing to open international standards. She has performed research and development in the fields of modeling and simulation, narrative engagement, systems and software engineering, computer security, online instruction, voice recognition, and compilers. Dr. Morse has made significant contributions to nearly a dozen international standards, including leading the development of the Federation Engineering Agreements Template (FEAT) standard. She has served in multiple leadership positions in the Simulation Interoperability Standards Organization (SISO). She is a member of Phi Beta Kappa, Dobro Slovo, ACM, and a senior member of IEEE. Dr. Morse was the 2007 winner of the IEEE Hans Karlsson Award.

Michael Heaphy is a systems engineer with Booz Allen Hamilton providing support to the Defense Modeling and Simulation Coordination Office for the last four years, and currently serves as Lead Standards Analyst. He has worked with various DoD clients in the areas of: Modeling and Simulation (M&S) technology and policy, systems analysis and systems engineering, military training and the rapid fielding of technology. He has served in a variety of operational, training and leadership roles as a Navy Submarine Warfare Officer and in the Navy Reserve. He holds a Bachelor of Science in Systems Engineering from the US Naval Academy, and a Master of Engineering Management from Old Dominion University.

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Michael Heaphy
OSD(AT&L)/DMSCO
Alexandria, VA
michael.a.heaphy.ctr@mail.mil

INTRODUCTION

Over the past few decades, the Department of Defense (DoD) has invested millions of dollars into interoperability and reuse solutions for models and simulations. While some architectures and tools have been developed to address specific community needs, we do not yet have an overall common technical framework. The barriers range across the technical and social spectrum, from computing power and data compatibility, to funding and resistance to mandated architecture policy. Meanwhile, the DoD's evolving information technology (IT) infrastructure may soon provide the computing power, network, and storage necessary to make transition of modeling and simulation assets to service oriented architectures making composability both feasible and affordable. Maximizing the value of service based architectures while maintaining Joint and Coalition interoperability requires a coordinated effort, across the DoD and internationally.

The Defense Modeling & Simulation Reference Architecture (DMSRA) provides up-to-date best practices and guidance to assist M&S activities in:

- Leveraging DoD IT, enterprise services and technologies such as cloud computing and service oriented architectures (SOA)
- Developing simulations that take advantage of emerging technologies and enterprise services
- Adopting DoD M&S enterprise standards to facilitate sharing of model and simulation services

The DMSRA v1.0 is not a completely formed Common Technical Framework (CTF), but is a step forward. The DMSRA provides a unified vision, identifies key technologies and begins to outline those principles, rules and standards necessary for a CTF. While the focus of DMSRA v1.0 has been on SOA and cloud-based architectures, many of the principles, standards, and best practices may be applied in today's architectures.

BACKGROUND

Since the 1990s, the DoD Vision for M&S has included the tenets of interoperability and reuse, implemented through open systems architectures (DoD 5000.59-P, 1995). As technology and requirements have evolved, the tenets remain. The architectures of the 1990s are still heavily used in defense modeling and simulation today. However, technological advances in computing and network architectures are now available that bring a new set of capabilities and challenges to the pursuit of a CTF. By "CTF" we mean the minimum set of principles, rules, standards and guidelines that should be followed to maximize interoperability and reuse of models and simulations throughout the DoD, while allowing maximum latitude for innovative solutions within each program.

Accomplishments

Over the years, the M&S Steering Committee (M&S SC) and the Defense M&S Coordination Office (DMSCO) have invested at the "DoD enterprise" level in standards and common capabilities to support the billions of dollars invested across the DoD on development, operation, and maintenance of modeling and simulation assets. The ten years following the "'95 Master Plan" (DoD 5000.59-P) yielded interoperability solutions such as Distributed Interactive Simulation (DIS) (IEEE, 2012) and Aggregate Level Simulation Protocol (ALSP) (Weatherly, 1996); authoritative data representations to provide reusable data products, including Digital Terrain Elevation Data (DTED) (NGA), and Source for Environmental Data Representation and Interchange System (SEDRIS) (ISO, 2006); as well as best practices like the Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide (VV&A RPG) (2011). The past ten years have offered improvements to these initial investments and additional capabilities such as the High Level Architecture (HLA) (IEEE, 2010), the Live, Virtual, Constructive Architecture Roadmap (LVCAR) (Henninger, 2008), Environmental Data Cube Support System (EDCSS), and the

Defense M&S Catalog. These "enterprise" investments have sought to address the enduring challenges of M&S interoperability and reuse, and some are already leveraging cloud infrastructure to provide services, on-demand to their users (e.g. EDCSS). However, these successes are limited in number and the breadth of scope of implementation within the M&S community.

Technology Advances

Modeling and simulation is used throughout the DoD to enhance our warfighting capability through training, analysis, and decision support. IT is a key enabler of computer based modeling and simulation. Recent technology advancements have spurred a change in industry's approach to IT. Industry is aggressively adopting cloud computing and SOA to reduce costs and increase flexibility. This call to change has been echoed in the Federal Government (White House, 2011) and DoD Cloud strategies (DoD CIO, 2012). Initiatives, such as the Joint Information Environment (JIE) (DISA, 2013), are already under way in the department, and in the Services to implement and expand on these strategies. It is critical for the M&S community to prepare for this major change in how the department does IT business and to take advantage of the new technologies to enhance capabilities and reduce lifecycle costs.

SOA has the potential to reduce costs by delivering M&S as a service (MSaaS) by:

- Delivering capability without the need for physical presence of hardware
- Ensuring current, consistent versioning across the enterprise
- Centralizing expert developer support
- Eliminating local maintenance support

Cloud computing is based on the idea that computing services are the tradable commodity rather than computer hardware and software. The consumer need not be concerned about the mechanics of IT, but only the products. The chief benefits are:

- Lower overall costs to the consumer, because of efficiencies obtained by pooling much of the computing hardware and software;
- IT functions and increased flexibility because there is no upfront investment in infrastructure required by the end user.

APPROACH

In development of the DMSRA, we have established a vision for CTF(s) that builds on past investments and lessons learned, and that leverages advances in technology and DoD IT infrastructure. While past efforts have shown great success, including enabling large, distributed simulations for training exercises, and high-fidelity analysis based on hundreds of thousands of simulation runs in hours to days vice days to weeks, several technical challenges remain. For example, accessible and authoritative sources of data, and composability of models and simulations and all the related concerns of interoperability and validation remain. In fact, some challenges grow even more complex in a composable environment. In addition to the technical challenges, many cultural and organizational challenges persist. In an organization as widespread and diverse as the United States Department of Defense, there are many silos of practice, knowledge, and tools. The current fiscal environment intensifies both the complexities of ordinary cultural and organizational issues, and the benefits of collaboration and reuse between organizations. Furthermore, there has been past resistance to top-down approaches to development of a CTF for M&S, and current barriers to implementation of DoD-wide changes in IT policies and architecture.

Figure 1 provides the OV-1 for the DMSRA. It illustrates how the DMSRA achieves its vision for "robust M&S supporting a full spectrum of DoD activities and operations, delivered to the point of need, within current fiscal constraints, managing schedules and risk enabled by agile composition." Users can produce capabilities as output that achieve the business goals and objectives, by applying inputs from DoD and Service architecture efforts and guidance, in accordance with policy, via DoD IT infrastructure and architectures.

Process

To make the most of available resources, and to address both the technical and cultural barriers, we chose a collaborative, iterative process for development of the DMSRA. Collaboration increases the breadth of experience and knowledge available to the effort, and can establish buy-in from the stakeholders. The iterative approach was

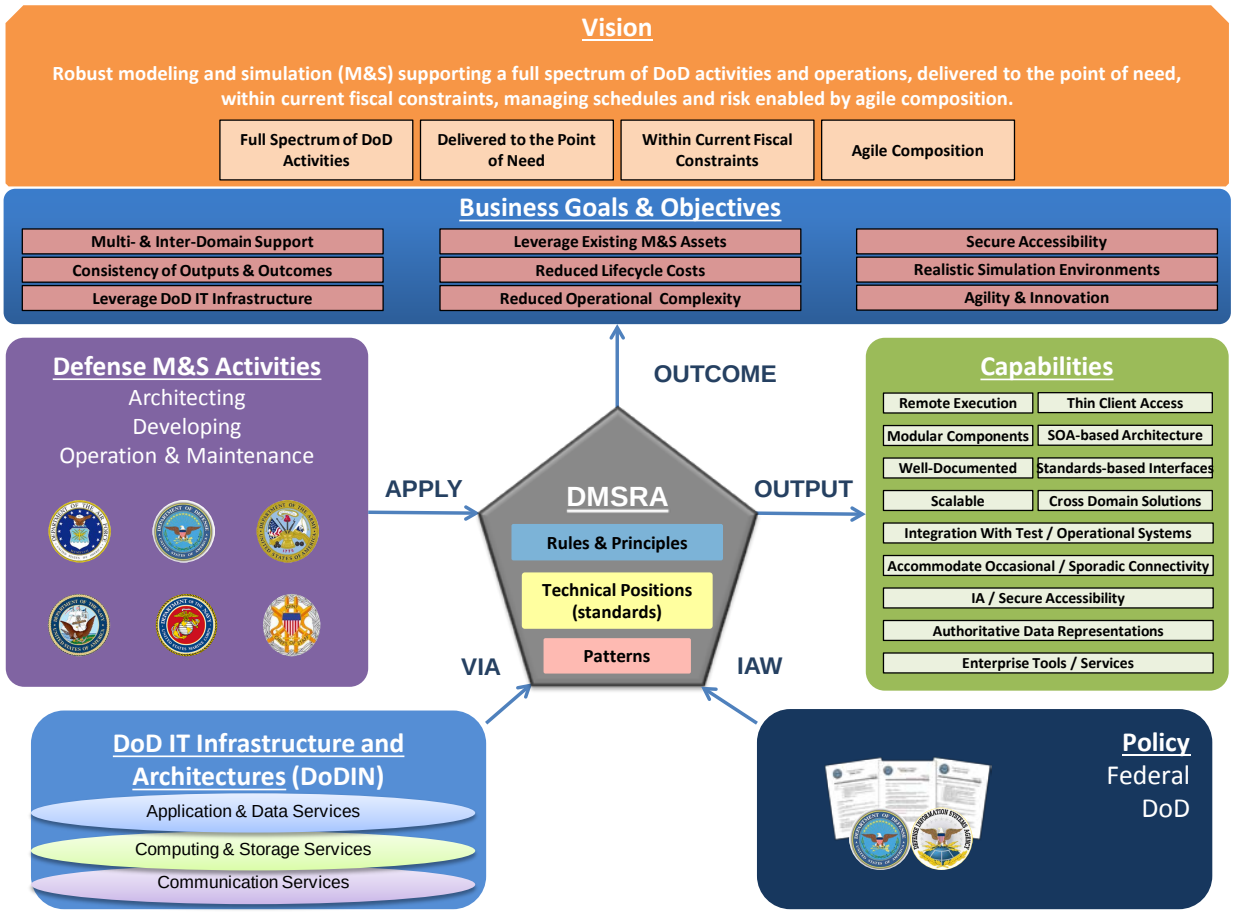

Figure 1. DMSRA OV-1

chosen to allow the activity to focus on an achievable goal, and more quickly provide a usable product.
Two primary tools were used to promote and facilitate collaboration- the M&S Community of Interest's (M&S COI) Architecture Working Group (AWG) and the DoD's online suite of collaboration tools, milSuite (www.milSuite.mil). The M&S COI is a longstanding forum hosted by the Defense Modeling and Simulation Coordination Office to address technical challenges of the defense M&S community. It is comprised of government and contractor personnel from across the DoD, with technical subject matter expertise. Working groups of the M&S COI have tackled issues such as data management, discovery metadata, and enterprise services. Currently active working groups include the Cyber M&S Technical Working Group and the AWG, which was formed to address M&S architecture challenges and support the DMSRA effort. The milBook tool on milSuite has been the M&S COI's tool for posting and archiving meeting materials, and facilitating collaboration between meeting dates.

The AWG provides an ideal forum to reach the defense M&S stakeholders, identify current issues and needs, and provides access to the technical level of expertise and knowledge necessary to build the reference architecture (RA). The AWG serves multiple purposes. First, it facilitates information sharing and collaboration amongst the DoD Components. Second, it provides a forum for DoD M&S architects and developers to receive updates on the policy and guidance regarding the JIE, DoD Information Networks, and enterprise services. There were various levels of understanding and experience with both the policy and the technical capabilities, so the initial step toward identifying best practices and developing a common set of guidance was to baseline current capabilities and information from each of the Services. Table 1 provides a listing of organizations and architecture efforts presented to the AWG. This activity allowed members to share their experience and knowledge, and existing capabilities. Finally, from this information, we could begin to determine the impact of Federal and DoD policy and guidance on cloud computing and consolidated data centers on defense M&S equities and future investments.

From the first meeting of the AWG, we invited members to identify their organization's M&S architecture efforts and nominate briefings to the group. The AWG members also identified three questions to focus subsequent meetings, and ensure the members' needs and interests were met:

- What are your common architecture challenges?
- What are your common costs, processes, products?
- Where should we be building in interoperability and reuse, rather than forcing it after the fact?

The briefings in Table 1 and the resulting discussions and sharing of studies, information, and capabilities have been useful not only to the DMSRA development, but also to the individual members and organizations of the AWG. This collaborative approach established buy-in from the AWG members, providing the opportunity to: guide the direction and focus of the AWG; voice their needs; advocate for their efforts; and collaborate on challenges.

Around the time the AWG was re-established, the M&S COI began transitioning its archives to milBook, one of the online applications available on milSuite. The milSuite site uses DoD CAC access, extending the access to the AWG and DMSRA efforts, while limiting distribution of information in accordance with DoD policy. The use of milSuite also promotes direct collaboration and access to information from the website, creating a standing source of knowledge, alleviating the need for staff to be a broker of information. Initially, DMSRA updates and information were posted to the AWG milBook site. Later, a separate milBook page was created solely for development of the DMSRA, including document coordination and change management.

Table 1. AWG Briefings on Architecture/Framework Initiatives

Architecture	Acronym	Briefing Date	Service	Domain
Joint Training Enterprise Architecture	JTEA	9/4/2014	Joint	Training
Architecture Management Integration Environment	AMIE	9/4/2014	USN	Test, Acquisition
Net-centric Systems Test (NST) Evaluation Capability Module (NECM) – Enabling Architecture Interoperability Initiative (EAII)	NST, NECM, EAII	9/4/2014	USN	Test
Army Live-Virtual-Constructive Integrating Architecture	LVC-IA	9/4/2014	USA	Training
Army Live-Virtual-Constructive Integrating Architecture	LVC-IA	10/8/2014	USA	Training
Army M&S/Mission Command Initiatives		10/8/2014	USA	Training, T&E
Live-Synthetic Training and Test & Evaluation Enterprise Architecture	LS TTE EA	10/8/2014	USA	Training, T&E
Live Virtual Constructive Training Environment	LVC-TE	3/3/2015	USMC	Training
Developing an Enterprise Architecture using MBSE in a Systems of Systems		6/23/2015	MDA	Acquisition, Test
Integrating Architecture for Air, Space, Live Virtual Constructive Environments	IA-ASLVCE	10/22/2015	USAF	Training
Orchestrating Simulation through Modeling	OSM	3/2/2016	USN	Acquisition, Training Experimentation
AMIE and Common Development Environment	CDE	3/2/2016	USN	Test, Acquisition
Advanced Framework for Simulation, Integration, & Modeling	AFSIM	5/10/2016	USAF	Analysis

An Iterative Effort

The AWG leadership and DMSRA drafting team initially drafted the Strategic Purpose section of the DMSRA. The AWG was generally in consensus on the vision, scope, goals, and capabilities described in this section. Due to the limited resources available, the drafting team focused their efforts on collaboration with the domain with the most

representation and participation in the AWG, the Training domain. The intent was to allow the effort to focus on producing a usable product for a smaller group, but with long term plans to expand the document to other domains including Acquisition, Test and Evaluation (T&E), and Analysis as time and effort allow. The result proved much more broadly applicable than solely the Training domain, and community interest allowed some briefing and coordination opportunities with theT&E, Acquisition, and Analysis communities.

An initial draft DMSRA was briefed to the AWG in October 2015, posted to the milBook site, and distributed for AWG member review. Briefings from each of the Services and the Missile Defense Agency (MDA) continued about quarterly, to maintain collaboration and sharing amongst the community, while the drafting team addressed the feedback received on the initial draft. A final draft of the DMSRA v1.0 was posted to the DMSRA milBook site in May 2016.

The transition to broad adoption of service oriented architectures and cloud-based infrastructure will take several years, and involves both technical and social challenges. Therefore, the collaboration process is just as important as the end product. The members of the defense M&S community can accelerate the process, improve the rate of success, and make the most of investments, through continued collaboration, and sharing of information and capabilities. As of May 2016, the AWG leadership and DMSRA drafting team plan to continue addressing comments and feedback based on community review of the draft, and begin work on a future version of the DMSRA that will expand the scope of the DMSRA to include capabilities and best practices from other communities.

Leveraging Existing Investments

One of the inherent goals for development of the DMSRA, for both logical and resource reasons, is leveraging and building upon previous investments of the Office of the Secretary of Defense (OSD), Services, and other components, including international partnerships and collaboration. In many ways, the DMSRA effort builds on the LVCAR efforts of 2009-2014, focusing on planning for and adoption of advancements in DoD IT infrastructure and guidance. The DMSRA applies the LVCAR principles in the following ways:

- Do no harm: inform migration planning and transition decisions
- Interoperability is not free: SOA and cloud are not a magical fix for interoperability and reuse; long term, incremental investments in standards and design/redesign work is required
- Start with small steps: identify and implement SOA and cloud-based solutions where migration brings the most value
- Provide central management: leverage the centrally managed DoD IT infrastructure allowing organizations to focus resources on capability development, rather than IT infrastructure management

Several other investments to address enduring challenges in M&S interoperability and reuse have had a major influence on the development of the DMSRA. Many of the findings and recommendations in RAND's *Improving the Composability of Department of Defense Models and Simulations* (Davis, 2003) are still relevant, as we take a fresh look at composability, this time enabled by cloud-based IT infrastructure. The Dynamic Multi-level Modeling Framework feasibility study revealed the limitations of interoperability between M&S at different levels of the M&S pyramid, i.e., of differing resolution, aggregation, and run-times (Mullen, 2013). Recent studies on cloud-based M&S service models have documented the potential benefits and perceived risks associated with these architectures and business models (Henninger, 2015). Additionally, updates to enterprise services and best practices such as the updated software and business model of the Defense M&S Catalog and the addition of risk-based methodologies to the VV&A RPG have highlighted the value of these common services and enterprise guidance.

The briefings on Service level initiatives, capabilities, challenges, and lessons learned from studies and projects from each of the Services, MDA, and the Joint Staff served as the primary source for best practices, allowing us to draw on experience from across the DoD. For example, the USAF conducted a study on cloud computing. Though we were not able to directly use the findings of the study, the study methodology included steps that we were able to convert into questions useful for the reader to understand the benefits, challenges, and readiness factors applicable to cloud migration. Concurrently, DMSCO is working closely with M&S forums within NATO and other international organizations. Studies and experimentation within these forums have also provided useful contributions to the DMSRA best practices, standards, and capabilities.

The DMSRA Product

The DMSRA v1.0 is not a completely formed CTF, but is a step forward. The DMSRA provides a unified vision, identifies key technologies and begins to outline those principles, rules and standards necessary for a CTF. For DMSRA v1.0, the focus was generally on the Training community, with the intention to later expand to other domains (e.g. Acquisition, T&E, and Analysis) as resources allowed. However, several of the Service level initiatives are intended to support multiple domains within their organization, which helped ensure that the scope of DMSRA v1.0 is not limited to the Training community. Knowing the end goal of enterprise-wide guidance, we deliberately scoped the DMSRA to principles and guidance that is appropriate for multiple domains, leaving domain-specific implementation to a lower-level reference or solution architecture.

The initial draft DMSRA, in October 2015, was structured based on the guidance in the Reference Architecture Description (DoD CIO, 2010) following standard DoD Architecture Framework (DoDAF) v2.0 (DoD Deputy CIO, 2011) practices, and conforms to its conventions as well as the DoD Information Enterprise Architecture (DoD IEA) (DoD CIO, 2012). It is composed of the five elements: strategic purpose, principles, technical positions, patterns, and vocabulary; further described in Table 2. The Strategic Purpose section was drafted and refined via the early meetings of the AWG. The principles and patterns were distilled initially from best practices captured from the simulation architecture efforts and briefings we received via the AWG. The Technical Positions are collected from three sources, the DoD Information Technology Standards Registry (DISR), the Acquisition Streamlining and Standardization Information System (ASSIST) database, and the NATO M&S Standards Profile.

Table 2. Applicable DoDAF Views

Content	DoDAF 2.0 Views/Models
Strategic Purpose: introduction, overview, context, scope, goals, purpose, why needed, and when and how used	• **AV-1 Overview & Summary Information** • **OV-1 High Level Operational Concept Graphic** • **CV-1 Vision** • **CV-2 Capability Taxonomy** • **CV-4 Capability Dependencies**
Principles: foundational organizational rules, culture, and values that drive technical positions and patterns	• **OV-4 Organizational Relationships Chart** • **SvcV-10a Operational and Service Rules and Principles**
Technical Positions: technical guidance and standards	• **StdV-1 Standards Profile** • **StdV-2 Standards Forecast**
Architectural Patterns: generalized patterns of activities, service functionality and system functionality.	• Guidance and best practices for the implementation of the Operational and Service Rules and Principles.
Vocabulary: acronyms, terms, and definitions	• **AV-2 Integrated Dictionary**

The DMSRA v1.0 includes a reorganized and closer mapping of principles to the DoD IEA, and ties to other RAs that align to the DoD IEA. Specifically, the Joint Command and Control (JC2) RA shares similar goals, and because M&S systems are often required to emulate or operate with JC2 systems, the architecture principles and rules are closely aligned. Furthermore, the architectural patterns were restructured, and modularized from the rest of the document to promote involvement from the AWG members, and to ease maintenance and updates.

The long term objective is a composable enterprise architecture (EA), both structure and governance, in which models are coded once into reusable modules. Individual simulations reuse the existing modules along with simulation-unique code to satisfy their individual missions. This concept is illustrated in Figure 2. The lowest level represents models at an algorithmic level. This is not computer code, but the mathematics and logic used to represent the phenomenon. These models are translated into computer code that is made accessible to simulation developers, represented in the second level from the bottom. The third level is the simulations layer; individual simulations use pre-coded computer models to compose a final simulation. And that simulation fulfills the mission or customer requirements shown in the top level. Both technical and governance challenges to implementing a composable EA currently exist. Table 3 identifies some advantages and disadvantages of the composable EA.

The idea of combining reusable models (composing) to form a simulation is the core concept of composability. Composability should result in simulations development being quicker, cheaper, and more robust. As such, it is more likely that tailored simulations will be created for individual missions. The concept of federations would not be necessary because instead of creating a federation to meet specific mission needs, a new simulation would be

composed. By creating a new simulation, the user eliminates the extra code that existing simulations bring along that does not contribute to specific mission needs. This extra code adds to maintenance costs and inhibits interoperability.

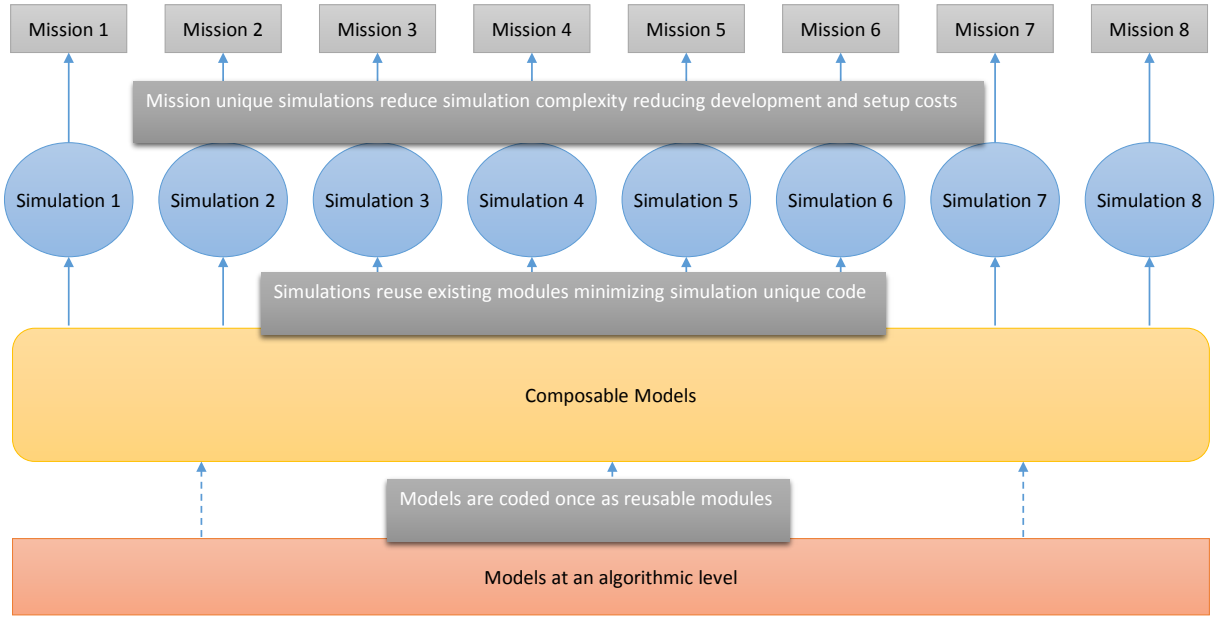

Figure 2. Composable EA

Table 3 - Advantages and Disadvantages of a Composable EA

Advantages	Disadvantages
• Models are coded once, reducing development time and cost. • Easy to replace models with newer versions that use the same interface. • Smaller simulations should lead to easier use and reduced maintenance costs. • Conducive to cloud computing infrastructure.	• Existing simulation base would need to be rewritten. • Simulation developers are dependent on model developers that may not be in their program chain. This will require simulation program managers to accept some risk. • New governance structures required. • New standards required to facilitate composability of models.

FINDINGS

One of the greatest scoping challenges the team faced was what we came to call the "meta-problem." But this is not a problem about a problem, but rather the problem of defining a RA whose scope is a level above most reference architectures.

> "*A reference architecture in the field of software architecture or enterprise architecture provides a template solution for an architecture for a particular domain. It also provides a common vocabulary with which to discuss implementations, often with the aim to stress commonality.* (Davis, 2003)"

So, an RA is a meta-architecture, hence the limited number, and only high-level DoDAF views identified in Table 2. RA architects should be mindful not to be over-prescriptive, but provide the minimum level of detail necessary to

achieve the purpose of the RA. The DMSRA provides guidance for developing domain RAs (e.g. for Service training). This is reflected throughout the DMSRA in the identification of applicable standards and policy, and most clearly in the architectural patterns. Here we provide questions for the user to answer and associated guidance, standards, and policies to find the applicable guidance based on the answers to the questions. For example, rather than directing the user to use a particular cloud service provider (CSP), the cloud migration pattern identifies relevant documentation on CSPs available to DoD organizations and policy on making a selection. For example, it directs the reader to relevant policy and guidance to help the reader make informed cybersecurity decisions:

> *"What cloud deployment model meets operational requirements including cybersecurity? When making this decision, review the DoD Risk Management Framework (RMF), the special considerations outlined in NIST 800-144, and levels of data sensitivity as described in DoD Cloud Computing Security Requirements* Guide (CC SRG)*..."*

Unique M&S Challenges to SOA

The concept of model composability has been around for over 20 years, but has been difficult to implement in full. SOA provides a template for dealing with the technical interoperability problems with composable models, however there still exist some composability challenges unique to models and simulations. Since models and simulations are representations of reality, there are approximations and assumptions that must be compatible between models that are composed. This challenge was identified by Davis and Anderson (2003) and was given the name "Conceptual Interoperability" by Turnitsa and Tolk (Turnitsa, 2005).

This can be illustrated by the example shown in Figure 3. In a typical business case, a user or application may use a service to check an account balance. The user provides an account number to the service. The service queries the bank's account database and returns the current balance. In a typical simulation case, the simulation may use a line of sight service to determine if an observer has an unobstructed path to a target. The service is given the coordinates of the observer and target; it can then query a terrain database and do the necessary calculations to establish whether line of sight exists.

In the bank example, the bank keeps the definitive record of the amount of money in the account. There is no ambiguity; the user could withdraw that amount without fear of an overdraft. While in line of sight example, the terrain database is a representation of the terrain based on a set of simplifying assumptions. Those assumptions affect the suitability and accuracy of the results. The earth model, coordinate system, and terrain fidelity are all approximations that may affect whether or not line of sight actually exists on the real terrain (if it exists). These assumptions need to be understood by the service user before using the service to determine if it is appropriate for the intended use. As SOA makes technical interoperability easier, we still need to improve our methods and standards in this area of conceptual interoperability to achieve truly composable simulations.

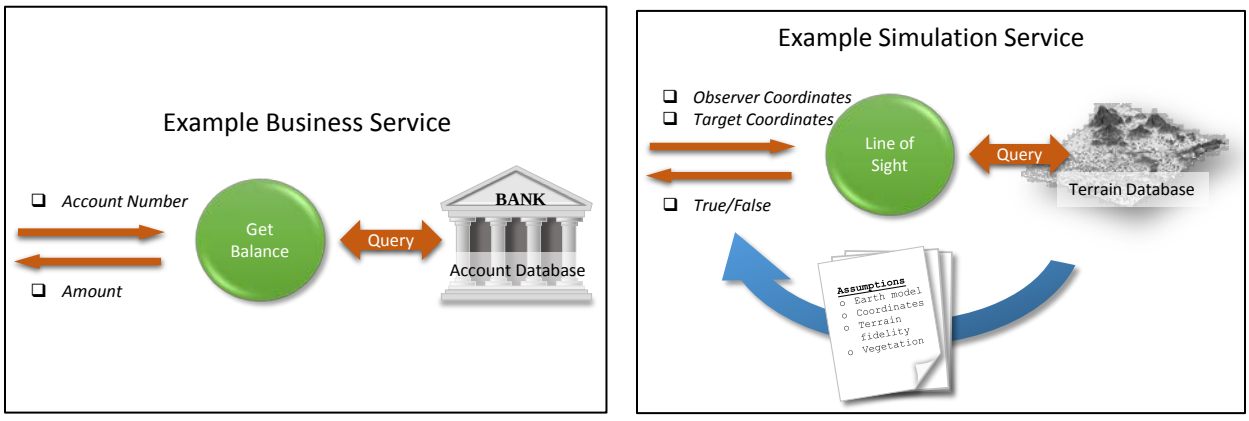

Figure 3. Service Example

Hybrid Architecture

It is relatively straightforward to implement a composable architecture in a new simulation development effort where you are starting from scratch. However, that is rarely the case in the DoD today. To manage project costs, maintain compatibility with existing hardware and software, and continue to provide capability to the user base,

programs must reuse significant portions of legacy code and existing simulators. We envision the transition to the new cloud-based SOA paradigm will be gradual at both the program level and for the enterprise as a whole.

Individual programs may choose to migrate pieces of the simulation environment as they are being revised or updated. Over time, programs and communities may implement larger scale composable model frameworks to support their combined needs. But to gain maximum enterprise benefits, coordination and joint decision-making is required during this evolutionary period in order to minimize the cost of compatibility in the future. The DMSRA is one means to effect that coordination. Failure to coordinate will almost certainly result in non-compatible architectures that will take large investments in the future to harmonize. This is the case today where simulations have been written to support various interoperability protocols and require significant efforts to federate. In any case, it is likely that non-composable simulations and federations will continue to exist for a significant time as long as they fulfill a need and there is no compelling reason to change.

Insights

Although the vision of open architectures for composing modular simulation components within the DoD is not new, there is some hope that the shift to SOA and cloud computing will accelerate its achievement. First, SOA adoption requires the adoption of standardized interfaces; non-standardized interfaces are a significant barrier to modular composition. Second, the shift to cloud computing distances simulation software from its native environment, giving it more visibility and encouraging support of remote users and environments. Finally, we might anticipate that both of the preceding trends will encourage new business models that favor reuse, and that, in turn, will encourage better documentation in metadata to support discoverability.

CONCLUSIONS

While developing the DMSRA, the team identified some technical gaps to achieving its vision. Addressing these gaps is outside the scope of the DMSRA itself and is recognized more broadly as technical requirements for the future of M&S.

Standards

Identification, adoption and management of standards for interoperability of M&S (and other systems) remains a challenge within the DoD. Functional standardization approaches to management of standards for service delivery and interoperation are not new (e.g. ISO TR 10000, 1998), but many changes would be required in DoD policy, tools and management processes and structure to enable this approach for a composable architecture in the DoD. Furthermore, the AWG and DMSRA efforts have identified several standardization gaps that limit the growth and implementation of cloud and SOA-based solutions. Composability has long been a technology gap for M&S (Morse, 2004); it isn't unique to delivering MSaaS and / or in the cloud. But the vision for reaping the benefits of SOA and cloud computing for M&S makes the resolution of this gap more urgent than ever.

Best Practices

An additional challenge to potential advances in composability is verification and validation (V&V). Weisel, et al (2003) have proven that the composition of models is not necessarily valid despite the composed models being valid themselves. Finally, V&V of simulations generally happens on a particular suite of hardware and supporting software. When a simulation is migrated to the cloud, the user may not know what the supporting infrastructure is, potentially calling into question the validity of the results it produces.

DMSRA Plans

At this writing, DMSRA v1.0 has been disseminated. Because it is intended to be an evolving document supported by input from the community and Architecture Working Group (AWG), the DMSRA is hosted on milSuite. The team is actively soliciting inputs, especially on architectural patterns. The team has identified the need for the following ten patterns, the first four of which (marked with an *) are complete:

- Cloud migration *
- Documentation *
- V&V of modular components *
- Decomposition of Simulations into Modular Components *
- Accommodating occasional / sporadic connectivity

- Cross domain solutions
- SOA primer
- Distributed simulation and federation engineering
- Data
- Assessing the feasibility of remote execution

Based on the team's efforts developing the first few patterns, each one is approximately four to five pages and takes a couple of days to develop for a knowledgeable individual. It is our hope that the modularity of this construct and the interactive nature of the process will encourage stakeholders to contribute actively.

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