Making Joint and Multinational Simulation Interoperability a Reality

Emilie A. Reitz
Joint Staff, J6
Norfolk, VA
emilie.a.reitz.civ@mail.mil

Kevin Seavey
Alion Science and Technology
Norfolk, VA
kevin.p.seavey.ctr@mail.mil

ABSTRACT

Consider the following hypothetical scenario: As tensions continue to rise in East Asia and with many of her fellow Marines already forward deployed, Captain Smith looks forward to a quiet Saturday as Staff Duty Officer catching up on email before her own unit's deployment. As she scrolls through her inbox, she notices "WARNING ORDER" in a subject line and double clicks. "FM II MEF... OPERATION RAPID FURY... EASTERN POLAND... JTAC/JFO SUPPORT." Captain Smith reads the order a second time while calling her Commander. After hanging up, she starts running through her mental checklist of things to do, "September is right around the corner! How do we shift gears from an exercise in Korea to a quick response, real world show of force in Eastern Europe with NATO partners? The WARNORD mentioned ground units from Poland and Germany, aircraft from the U.S., U.K., France and Italy. How in the world do I get my Marines ready for that?"

Joint Staff J6 has been working to improve distributed simulator interoperability in the joint fires domain for the last five years as part of its Bold Quest series of coalition capability demonstration and assessment events. Despite decades of experience in distributed simulation, warfighters are still unable to rapidly and routinely connect simulators between different Services and nations. What price we are paying for our inability to connect these systems? What could we do better if warfighters were able to train together with their mission partners prior to the chaos of combat?

To better understand the scope of this problem, we conducted a survey of 60 current simulation subject matter experts. This paper provides the survey results and details recommendations to allow LVC systems to operate together in a joint and coalition context.

ABOUT THE AUTHORS

Emilie A. Reitz, M.A., is a Data Integration Analyst with the Joint Fires Division of Joint Staff J6, Deputy Director for Cyber and C4 Integration in Norfolk, Virginia. In this capacity, she is the data collection and analytical working group lead for Bold Quest. Her research focuses on integrating joint capabilities into modeling, simulation, and training, as performance enablers.

Kevin Seavey is a Military Analyst at Alion Science and Technology. He currently leads Live, Virtual and Constructive (LVC) efforts for the Joint Staff's Bold Quest capability demonstration and assessment event.

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Joint Staff J6
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INTRODUCTION

Consider the following hypothetical scenario: As tensions continue to rise in East Asia and with many of her fellow Marines already forward deployed, Captain Smith looks forward to a quiet Saturday as Staff Duty Officer catching up on email before her own unit's deployment. As she scrolls through her inbox, she notices "WARNING ORDER" in a subject line and double clicks. "FM II MEF... OPERATION RAPID FURY... EASTERN POLAND... 2ND ANGLICO... JTAC/JFO SUPPORT." Captain Smith reads the order a second time while calling her Commander. After hanging up, she starts running through her mental checklist of things to do, "September is right around the corner! How do we shift gears from an exercise in Korea to a quick response, real world show of force in Eastern Europe with NATO partners? The WARNORD mentioned ground units from Poland and Germany, aircraft from the U.S., U.K., France and Italy. How in the world do I get my Marines ready for that?"

Despite more than 25 years of experience in distributed simulation, little progress has been made in our ability to rapidly and routinely connect tactical simulators between different Services and nations. Joint Staff J6 has been working to improve interoperability in the joint fires domain for over a decade as part of its Bold Quest series of coalition capability demonstration and assessment events. As live training resources diminish and simulation plays a bigger role in maintaining joint fires readiness, a growing portion of this effort is devoted to distributed simulation interoperability. As we have observed during Bold Quest, numerous policy, programmatic and technical issues limit simulation interoperability. None of these will surprise those with experience in distributed simulation, as these are common challenges to any attempt to connect disparate systems into a compatible whole. As a result, tactical warfighters cannot routinely conduct training using distributed simulators with other Service and coalition partners to build and maintain joint fires proficiency.

This gap has been underscored in multiple findings since 2004, yet it still remains (Department of Defense (DoD), 2004; DoD, 2010; Under Secretary of Defense, 2018). In examining current simulation policy documents, neither the DoD or Chairmen of the Joint Chiefs of Staff (CJCS) guidance provides the Services specific guidance to ensure joint simulation interoperability (DoD, 2017; CJCS, 2012). Both DoD and CJCS simulation policies focus on the use of standards rather than interoperability. However, due to the current number of simulation standards, and the various ways that systems can "comply" with these standards, simply adhering to a standard does not guarantee interoperability at a functional level.

As it stands today, the Services may choose from a menu of well-documented simulation standards (e.g., High Level Architecture (HLA), Distributed Interactive Simulation (DIS), Test and Training Enabling Architecture (TENA), etc). Once a program manager selects a standard, he or she must then decide which particular version of the standard to use (i.e., for DIS, an older but more widely adopted version or a newer, less used version). In the case of HLA, a program manager must also decide what particular federation object model and vendor's middleware to use[1]. Once these decisions are made, simulation managers frequently need to document all the many assumptions and nuances of simulation data configuration, typically in a "federation agreement." Not surprisingly, program offices generally field non-interoperable, Service- or program-specific solutions that may work well for a particular Service use case, but do not contribute to broader simulation interoperability goals. Because they do achieve the primary remit for their specific program or Service, it then becomes a challenge to replace something that is arguably fit for purpose on one level, when resources and training have already been deployed.

[1] The HLA standard does not require different vendors' implementations of the HLA middleware (i.e., Run-Time Infrastructure) to be "on the wire" compatible, even though all may "comply" with the HLA standard.

Further exacerbating the challenge, policy differences in cybersecurity, acquisition and information sharing – and, more importantly, differences in Service and national interpretation of these policies – continue to handicap the ability of warfighters to use distributed simulators to their full advantage. With no requirement to ensure simulation interoperability, Services, Combatant Commanders and Defense Agencies are free to "formulate and implement M&S programs and activities to satisfy their assigned missions" (CJCS, 2012).

To determine just how serious a problem this is, we conducted a survey of current and former distributed simulation experts to capture their experiences and lessons learned. This paper provides the results of that survey and highlights the challenges we face in making distributed simulation truly interoperable.

ESTABLISHING THE INTEROPERABILITY BASELINE

The U.S. Joint Staff-sponsored coalition capability demonstration and assessment series, more commonly known as "Bold Quest," is a collaborative joint and multinational enterprise in which nations, Services and program offices pool their resources in a recurring cycle of capability development, demonstration and analysis. The overarching aim is to improve interoperability and information sharing across a range of coalition warfighting capabilities. Since its inception in 2001, Bold Quest has highlighted numerous interoperability issues between joint and coalition systems that effect warfighting performance in joint fires, combat identification and digitally aided close air support. Bold Quest distributed simulation operations began as a relatively simple, infantry squad-based event at Camp Atterbury, Indiana in 2011. Since then it has grown into a complex and distributed air, ground and fires-focused event. During Bold Quest, we routinely observe numerous programmatic, policy and technical challenges that prevent us from rapidly achieving an interoperable simulation environment.

Because we suspect that our own interoperability challenges are just a microcosm of the larger body of distributed simulation challenges, we wanted to see if the larger simulation community struggled with the same challenges. We sent the survey below (Figure 1) to over 200 distributed simulation practitioners to see just how these types of problems affected interoperability for the rest of the community.

1. What is your nationality? *Open-Ended Response*
2. What military Service(s) or organization do you support with simulations? *Open-Ended Response*
3. Years of simulation-related experience: *Open-Ended Response*
4. Which operational roles have you played in support of simulation? *Exercise Planner; White Cell; Response Cell; MSEL Manager; Role Player; Observer/Trainer; Analyst; Model Operator; Other (please specify)*
5. Which technical roles have you played in support of simulation? *Technical Lead; Software Engineer; Systems Engineer; Network Engineer; Cybersecurity; Systems Administrator; Database Support; Other (please specify)*
6. What simulation community do you have experience in? (Select all that apply.) *Training & Exercises; Experimentation; Testing; Analysis; Other (please specify)*
7. I have participated in the following types of Simulation-supported Exercises: *Single Service - Strategic/Theater; Single Service - Operational (e.g. JLVC or other joint federation); Single Service – Tactical; Joint - Strategic/Theater; Joint - Operational (e.g. JLVC or other joint federation); Joint – Tactical; Combined - Strategic/Theater; Combined - Operational (e.g. JLVC or other joint federation); Combined – Tactical; Other (please specify)*
8. Do you have experience in one or more of the following simulation domains? (check all that apply): *Live; Virtual; Constructive*
9. Based on your experience, please describe factors that have caused simulation interoperability problems: *Open-Ended Response*
10. Of the following factors, please rank the top five in order of importance to ensuring simulation interoperability: *Architecture choice (i.e., HLA, DIS, TENA, etc); Enumerations; Federation Agreements; FOM; Force or Parametric Database; Foreign release/disclosure policies; Model Mapping and alignment; Network Issues (e.g., no connectivity, different transport Types, no approval to connect); Restrictive cybersecurity policies; RTI Selection; Terrain Database Correlation; Time Management; Weapons Effects; Other (Please specify)*
11. Specify your other for the question above, if necessary *Open-Ended Response*

12. In your experience do Federation Agreements play a role in joint and multinational interoperability? If so, what standard format would you recommend? *Open-Ended Response*
13. What are the reference documents you have used to help establish simulation interoperability? *Open-Ended Response*
14. What are the software tools you have used to help establish simulation interoperability? *Open-Ended Response*
15. In your experience, are gateways/bridges desirable or helpful? *Open-Ended Response*
16. Based on your experience, what would be required to make simulation interoperability more "plug and play?" *Open-Ended Response*
17. What standards do we need to establish true joint and coalition simulation interoperability? *Open-Ended Response*
18. What organization or process should be the venue for developing and promoting those standards? *Open-Ended Response*
19. What do you believe is the impact of non-interoperable simulation systems? *Open-Ended Response*
20. What organization(s) do you believe should be responsible for making simulations interoperable across joint and coalition partners? *Open-Ended Response*
21. On a scale of 1 to 100, how critical would you rank the issue of simulation interoperability? *Open-Ended Response*

Figure 1. Survey on making joint and multinational LVC interoperability a reality.

Of the 200 simulation experts reached out to, 60 ultimately provided detailed responses to the questions. These respondents were from the United States, Canada, the United Kingdom, New Zealand, and France, and represented almost all potential forces within each nation, spanning their nation's Army, Air Force, Navy, Marines, Special Operators, Joint, Acquisition, Test and Intel services. The surveyed respondents (Subject Matter Experts or SMEs) had a wealth of experience in simulation, with an average of 19 years of experience in the field. All respondents had experience in constructive simulation or virtual simulation, with most having participated in both. 68% had experience with live integration into simulation (Table 3). The technical roles and operational roles played by respondents were evidence of their board experiences, with most having played multiple roles (a minimum of 3 or 4) in their careers. This breadth of experience helped assure us that respondents were able to look at the questions from multiple perspectives.

Table 1. Operational roles played by SMEs.

Which operational roles have you played in support of simulation? (n=60)	
Exercise Planner	53.33%
White Cell	41.67%
Response Cell	21.67%
MSEL Manager	20.00%
Role Player	33.33%
Observer/Trainer	33.33%
Analyst	31.67%
Model Operator	38.33%
Other (please specify)	28.33%

Table 2. Technical roles played by SMEs.

Which technical roles have you played in support of simulation? (n=60)	
Technical Lead	53.33%
Software Engineer	33.33%
Systems Engineer	41.67%
Network Engineer	13.33%
Cybersecurity	10.00%
Systems Administrator	15.00%
Database Support	26.67%
Other (please specify)	15.00%

Table 3. Domain SME has participated in

Do you have experience in one or more of the following simulation domains? (check all that apply) (n=60)	
Live	68.33%
Virtual	88.33%
Constructive	90.00%

RESPONSES

SMEs were asked to rank, in order of importance, barriers to simulation interoperability. The number one item was Network Issues; the number two item was a tie between enumerations and terrain database correlations; the number

three item was network issues, again, followed by terrain database correlation; model mapping and alignment was a strong number 4, and tied for fifth was enumerations, model mapping and terrain database correlations.

Table 4. Barriers to Simulation Interoperability.

Of the following factors, please rank the top five in order of importance to ensuring simulation interoperability.(n=60)	**Most Important**	**2**	**3**	**4**	**5**
Network Issues (e.g., no connectivity, different transport Types, no approval to connect)	13	6	11	4	2
Architecture choice (i.e., HLA, DIS, TENA, etc)	7	4	5	7	5
Terrain Database Correlation	6	8	10	8	6
Enumerations	6	8	6	4	6
Federation Agreements	5	4	1	5	4
Model Mapping and alignment	4	3	6	13	6
Foreign release/disclosure policies	4	2	2	3	3
Other (Please specify)	4	1	0	0	3
Restrictive cybersecurity policies	3	7	3	2	4
Time Management	3	2	1	2	5
Force or Parametric Database	2	4	1	2	4
FOM	0	6	3	0	3
Weapons Effects	0	2	4	4	4
RTI Selection	0	0	3	2	2

This correlates to our own experiences over multiple years of attempting to bridge network and approval authority challenges, which will be discussed below. When putting this question to the community, we were curious if architecture differences and enumeration challenges were leading candidates for barriers to interoperability, in a hope that our experiences weren't representative.

"Based on your experience, what would be required to make simulation interoperability more "plug and play?" The wide range of answers provided have led us to highlight those answers most representative of the varied user responses:

- Accurate Mappings & Translations in gateways. Underlying issue is human interactions - communications, cooperation, coordination, ease of data exchanges.
- Categorize simulations to the level of fidelity that they play, e.g., entity vs aggregate, low resolution vs high resolution; scale (small area vs theater vs global), size (a few entities vs 10 million), and then develop standards to bridge these opposing properties.
- I disagree with the question. Creating large tactically correct LVC events is a complex problem and will never be plug and play. Even if all the simulations used the same object model and architecture there would still be interoperability issues. The key to reducing the cost and schedule for integrating events is to use a well-defined process. This requires going through all of the planning steps and a systemic integration approach.
- Move Simulation to the Cloud. Develop simulations in a common framework. Move the databases to the cloud, establish common API standards(s) for developers, where the underlying format & data configuration management is controlled at the database layer. From a centralized data repository that can be managed by the right groups (Army manages Army, USMC manages USMC, etc), existing validated CM managed data needed can be pulled into a scenario during exercise planning. Tools can be used to build upon this scenario during planning, and near execution that scenario database is moved to a runtime database. All simulations pull the data from that runtime database during execution via APIs, and if an update needs to be done to the database, that update will be done in one place and all simulations immediately get the update. This would move us from interoperability to integration at the data level.

- The elimination of multiple types of players down to one or two and that there be a common DB that everything is built from. This would ensure a correlated DB and a Fair Fight. Sim SW, Models, SW releases are so varied, it often times makes it impossible.
- Use the DIS standard for all model maps and DIS enumerations. If there are different standards between services, combine them.

To address the question of work-arounds as currently employed by the community, the following question was asked: *"In your experience, are gateways/bridges desirable or helpful?"* 28 SMEs provided an answer of "Yes" to desirable and helpful; 21 deviated to say that they found gateways and bridges necessary, rather than desirable but unavoidable. One respondent offered, **"**Currently they are the only viable solutions to non-standard data types."

Table 5. What do you believe is the impact of non-interoperable simulation systems?

Resource heavy training	3
Negative impact on real world performance	14
No Impact	4
Degraded Training	6
Wasted resources	19
Frustration	5

Table 5 shows an analysis for free text responses to the question *"What do you believe is the impact of non-interoperable simulation systems?"* These responses are in line with the challenges experienced while working with non-interoperable systems across multiple exercises and multiple events over years of time.

Table 6. What organization(s) do you believe should be responsible for making simulations interoperable across joint and coalition partners?

Joint Staff	36
SISO	21
Community	8
DMSCO	6
Industry	3
NATO	3
Service	3
IEEE	2
Unknown	2
OSD P&R	2
OSD R&E	2
CAF-DMO-SDWG	2
OGC	1
Department of the Army	1

The SMEs were asked "*What organization(s) do you believe should be responsible for making simulations interoperable across joint and coalition partners?*" and "*What organization or process should be the venue for developing and promoting those standards?*" There was significant overlap in the answers provided for both questions; the answers are provided in table 6. As additional comments, the survey participants expressed concern about where such a document would come from, and the enforceability of any interoperability-related bodies that were not positioned to be a 'coalition of the willing.' Another item brought up was that due to the complexity of the larger community, any solution constructed in extensive detail would be outdated by the time it was launched.

One particular enforcement concern voiced was the impact of U.S. Code Title X on Service simulation acquisition spending outside of a joint context.

The overwhelming response to the question "*What standards do we need to establish true joint and coalition simulation interoperability?*" was that no new standards needed to be established. The standards that already exist were stated to be more than sufficient; what was really needed is application of the actual standards, appropriate documentation, and not allowing systems to apply proprietary work-arounds that violate the standards.

Free-Text Responses

So much additional information was collected in the free-text responses offered in addition to the multi-select or targeted questions that we wanted to make sure no interesting outcomes were missed. Free-text responses for questions 9, 12-17 and 21 were encoded using the Descriptive Coding method with associated sub-codes (Saldaña, 2013). The primary topic codes included: (1) Policy (2) Programmatic (3) Technical and (4) Recommendations. The sub-codes under each topic varied, based upon each respondent's specific comments. In total, 47 different topics were encoded collectively under the four major headings. Topics on which five or more comments were made are shown below (table 7).

Table 7. Most frequent topics offered by survey respondents.

Topic Category: Policy Problems	**Instances**
• **Interpretation of Cybersecurity Policy**	**9**
Topic Category: Programmatic Problems	**Instances**
• **Requirements derivation**	**5**
• **Support for the systems long term**	**5**
Topic Category: Technical Problems	**Instances**
• **Implementation of common data standards**	**11**
• **Proprietary systems**	**10**
• **Terrain mismatch**	**7**
Topic Category: Recommendations	**Instances**
• **Adhere to any standard**	**14**
• **Correct conceptual misalignments**	**18**
• **Create Policy to enforce compliance**	**15**
• **Start from scratch**	**9**
• **Use SISO standards**	**20**
• **Use gateways**	**5**
• **Correctly use the standards we have**	**12**
***Note: Not all topics were discussed by each respondent. Hence, items with fewer numbers do not necessarily imply that the other respondents hold opposing opinions**	

The main policy challenge discussed by our respondents were differing interpretations of cybersecurity policy; in this context, they described the challenges faced by being in an organization with one policy, while trying to reach simulators whose organization had a different interpretation of the policy.

Programmatically, our respondents found the initial requirements derivation process to have been a sticking point that caused long-term interoperability problems, due to not highlighting well-known needs such as interoperability with other networks and systems during the initial acquisition process. On the other side of the acquisition process was a perceived lack of support for the systems post-fielding, whether that was with adequate support staff, or appropriate training for those staff on how to use the systems and what they were capable of.

The technical problems have been well discussed in the above questions, but analyzing the free text brought forward the additional complication of systems that 'adhere' to a SISO data standard while putting proprietary wrappers or non-standard data outputs onto the network; these outputs often carry additional information important to the communication of the simulation system, and they often are filtered out by gateways or cross domain solutions.

Much of the free-text comments focused on recommendations and actions that the SMEs wished they could implement themselves. This ranged from the ongoing struggle with standards – for the community to pick one, to only use SISO standards, or to appropriately implement the existing standards – to a clearly voiced frustration to just rebuild the structure of the military modeling and simulation community over from scratch. 15 of the 60 respondents stated that they wanted to see a policy to enforce compliance with a standard, regardless of which standard it was going to enforce.

TOWARD INTEROPERABLE SIMULATIONS

Based on our experiences in Bold Quest, our literature search in simulation policies and the frustration expressed by survey respondents, we see top down guidance from DoD and/or Joint Staff as the only way to ensure simulation interoperability in the U.S.. However, since interoperability is always a multinational problem, we need to work through our existing alliances and partnerships to ensure we move forward in lock step with our international partners. Additionally, any top down guidance must address the full range of simulation practices (i.e., acquisition, analysis, experimentation, intelligence, planning, test and evaluation, and training communities). Until Service program managers are required to deliver interoperable simulations, not just use a particular simulation standard, we do not see a way that this problem will be resolved.

Current efforts, such as the Senior Steering Group for Simulation Interoperability recently chartered by the Under Secretary of Defense for Acquisition, Technology and Logistics (USD ATL), offers a glimmer of hope. While this effort is still early in its work, it reflects the senior level involvement required.

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