Application of Live-Virtual-Constructive Environments for System-of-Systems Analysis

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Outline

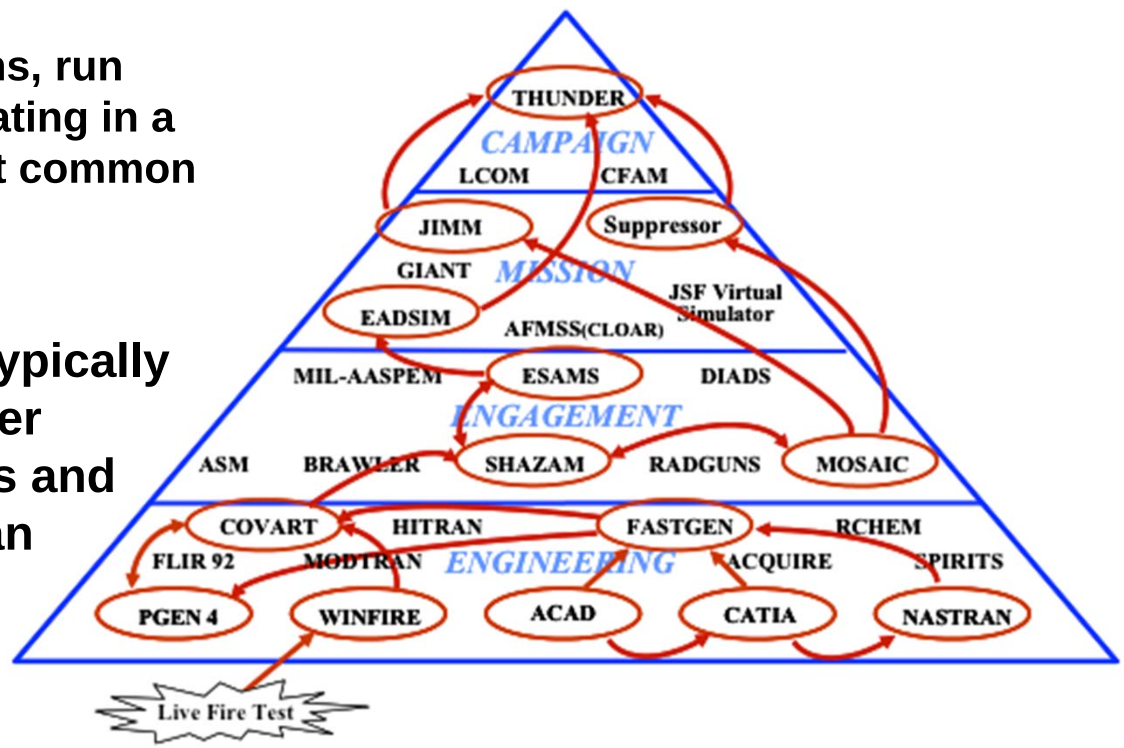
- Need
- System of systems complexity
- Current LVC environment applications
- Analysis requirements
- Applicability of LVC to SoS analysis
- Analysis of benefits and drawbacks
- Recommendations based on analysis of benefits and drawbacks

Need

- Live-Virtual-Constructive (LVC) simulation environments are well established as training and testing solutions.
- Although the DoD has the requirement to perform detailed analysis of complex systems of systems (SOSs) that could be represented by LVC simulations, such an approach is not generally adopted.
- In this presentation, we:
  - Address the complexity of SoS analysis,
  - Compare and contrast the modeling and simulation (M&S) requirements for SoS analysis vs. training and testing, and
  - Use the results to identify the benefits and drawbacks of applying LVC to SoS analysis.
- Specific recommendations for addressing the benefit/drawback analysis are provided at the end.

System-of-Systems Complexity

- **SoS analysis is most often performed during the systems engineering process within the technology development and engineering phases of major acquisition programs.**
- **Most of these analyses are performed using monolithic constructive simulations that model multiple systems and the interactions among those systems.**
  - **The use of multiple simulations, run simultaneously and interoperating in a distributed environment is not common practice.**
- **Or, the results of individual, standalone simulations are typically used in conjunction with other engineering level simulations and engagement simulations in an analysis pyramid.**



SoS Verification Challenges

- **Verifying that the fully integrated SoS meets mission requirements in defined tactical or operational situations is a different intended use.**
- **Exhaustive testing is prohibitively expensive, even in circumstances where individual systems are all extant, at least in prototype form.**
- **Standalone M&S tools don't represent the complexity of the full mission space with a degree of fidelity adequate to answer the questions posed.**

Current LVC Environment Applications

- **In the test and training domains, combinations of LVC M&S assets are regularly used to address SoS issues.**
  - **Training frequently mixes LVC simulated forces as a means for creating a realistic common operational picture for a student operator.**
  - **Testing uses a similar mix of LVC assets to provide an appropriate stimulus for a system under test.**
- **The late development phases at which training or testing occur have enabled these M&S approaches to be effective.**
  - **Connecting the simulation to a real-world range with actual human operators provides added realism.**

Analysis Requirements

- **Analysis applications involve examination of a large trade-space of conceptual options.**
  - **They must be evaluated to identify the most promising system concepts to take forward into design.**
  - **There are large uncertainties in how the concept might be implemented.**
  - **The volume of options tend to rule out the type of constrained, well-defined M&S solutions that training and testing have the luxury of employing.**
- **Why not use LVC?**
  - **Determinism is usually the goal.**
    - **Introducing human operators almost always removes that repeatability.**
    - **Uncertainty about latencies and potential data loss in best-effort distributed simulation environments has the same effect.**
  - **Learning curve necessary to apply distributed simulation**

Applicability of LVC to SoS Analysis

- Integrate insight from multiple models and higher-resolution modeling than would be otherwise practical for SoS analysis
- Potentially additional complexity and reduced robustness as compared to a single M&S tool
  - May require extensive V&V effort
- Combine "best of breed" models for each individual system to be represented
- Operation of a federation of simulations must be as quick and straightforward as standalone model operation.
  - Potentially addressed by the application of service-oriented architecture (SOA)
- Significant fidelity from real-world ranges with actual human operators
  - Achieving an accurate representation of human behavior without computationally expensive simulations
- Without taking variability into account, the analyst can't know if the observed effects are due to chance or are statistically significant.
  - The inclusion of real operators offers the potential for emergent behavior.

Benefits and Drawbacks of Applying LVC to SoS Analysis

Benefits	Drawbacks
• Allows reuse of best of breed simulations including system designers' models of future systems • Can create a bigger toolbox through the incorporation of different simulations of the same system or phenomenon • If SOA were employed, infrastructure (and some integration) challenges could be mitigated. • Could improve validation against existing standalone simulations by providing true human-driven variability • Monte Carlo simulation can be retained within the constructive aspects. • LVC better represents the reality of the complexity and interaction of a SoS than standalone simulations. • Enables integration of operational systems	• Effort/cost to integrate LVC environment • Introduction of human-driven variability that could negatively impact validation • Validity of composed simulations does not directly follow from the validity of the individual simulations; time and effort to validate • Training costs associated with paradigm shift • Operating cost

Relationships Between Individual Benefits and Drawbacks (1 of 2)

Drawbacks / Benefits	Integration effort / cost	Human-driven variability	Validity of composed simulations	Training cost	Operating cost
Best of breed / higher resolution	The increased effort may be ameliorated by the benefit of more accurate models.	N/A	Whether the value of more detailed models offsets the challenges of validation of the composed simulations would have to be determined on a case-by-case basis.	The costs of training analysts to use a new suite of tools would be non-recurring.	Whether the value of more detailed models offsets the cost of additional staff to operate the simulations would have to be determined on a case-by-case basis.
Bigger toolbox	Having access to a wider range of tools is a key benefit of using an LVC interoperability architecture.	A bigger toolbox with multiple simulations would allow the analyst to make different choices when human-driven variability is less tolerable, e.g. choosing a constructive simulation rather than a live human.	Whether the ability to choose different models offsets the challenges of validation of the composed simulations would have to be determined on a case-by-case basis.	The costs of training analysts to use additional tools would be non-recurring and may be offset by the value of the additional functionality.	Whether the ability to choose different models offsets the cost of additional staff to operate the simulations would have to be determined on a case-by-case basis, but one of the model choice criteria could be operating cost.
SOA	SOA could lower integration costs.	N/A	N/A	A consistent interface to SOA-based models allows new models to be integrated without incurring the costs associated with training analysts to use a new suite of tools.	The cost of operating a SOA is offset by establishing governance rules that simplify connection and communication. Operating costs can be amortized across multiple users.
Improve validation of existing models	N/A	Whether these validity considerations offset each other would have to be determined on a case-by-case basis.	Improving the validation of existing simulations improves validity of the composed simulation.	N/A	N/A

Relationships Between Individual Benefits and Drawbacks (2 of 2)

Drawbacks / Benefits	Integration effort / cost	Human-driven variability	Validity of composed simulations	Training cost	Operating cost
Monte Carlo	Retaining the ability to use Monte Carlo in an LVC environment can lower the cost and time to conduct events with that environment, and thus offset the integration	If repeatability is a critical requirement, then the ability to retain Monte Carlo in an LVC environment offsets this issue.	Whether the ability to choose continue to use Monte Carlo offsets the challenges of validation of the composed simulations would have to be determined on a case-by-case basis.	There is no additional training cost assuming the Monte Carlo simulation is the one currently used by the analyst.	The retention of Monte Carlo can lower operating cost by reducing some of the need for live operators.
Represent complexity of SoS	The ability to provide a selective-fidelity representation of system and operator effects offsets the cost of integration.	If SoS complexity must be represented, but human variability introduces intolerable uncertainty, then stochastic constructive is the solution.	SoS simulation suffers from validation complexity issues whether LVC is applied or not. However, the introduction of human variability may produce a more valid simulation.	N/A	If SoS complexity representation is a key requirement, the achievement of this representation offsets the additional operating cost.
Integration of operational systems	The increased integration effort may be ameliorated by the benefit of the realism of the operational systems.	Integration of operational systems implies the introduction of human operators and their inherent variability.	Validation is more challenging with the integration of operational system, but may be ameliorated by the value of the realism of operational systems brings to the SoS.	N/A	If operational system realism is a key requirement, the achievement of this realism may offset the additional operating cost.

Recommendations Based on Analysis of Benefits and Drawbacks

1. Identify the set of existing, broadly-used analysis simulations.
   a. Create an analysis-specific conceptual modeling framework.
   b. Map existing analysis capabilities to the conceptual modeling framework.
2. Identify gaps in the conceptual modeling framework and other existing simulations that may fill the gaps.
   a. Determine the interoperability capabilities of existing analysis simulations.
3. Assess these interoperability capabilities against potential interoperability architectures.
4. Determine the feasibility of defining metadata standard(s) to support discovery and composition.
5. Establish metrics for interoperability, e.g. technical and substantive interoperability, and evaluate the extent to which existing analysis simulations meet them.
6. Perform cost/benefit analysis of wrapping or migrating other existing simulations (gap fillers) to an architecture requiring less direct staff support, e.g. SOA.

References

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Additional Resources

- **M&S Catalog**
  http://mscatalog.msco.mil/

- **Related Standards**
  - **1730-2010 - IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP)**
    http://standards.ieee.org/findstds/standard/1730-2010.html
  - **Simulation Interoperability Standards Organization (SISO) Federation Engineering Agreements Template (FEAT) Programmer's Reference Guide**
    http://www.sisostds.org/FEATProgrammersReference

QUESTIONS?