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This paper presents a potential approach within the T&E as a Continuum paradigm which uses LVC and model-based environments to enable evaluation of joint all-domain concepts and facilitate more efficient T&E. Currently, there are limited options to perform end-to-end SoS engineering in a virtual, constructive cloud-enabled environment. Virtual assessment tools cannot be focused on a single system that just tests interoperability. A full SoS testbed is necessary to verify the integration of a given system and preserve the modularization and accountability of a constituent system.

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Modeling and Simulation as a Service (MSaaS) as part of the "Test & Evaluation as a Continuum" Paradigm

Information Paper

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Background

Success in future conflicts depends on multiple systems integrating and operating as a broader System of Systems. Joint All Domain (JAD) missions inherently require a System of Systems (SoS) approach due to Services, Agencies, Allies, and Partners contributing capability in different domains. However, System of Systems Engineering (SoSE) is not straightforward due to many moving parts (Mittal and Martin 2017). Given the complexity to conduct SoSE, the need to integrate T&E with systems engineering throughout the SoS evolution becomes critical to provide timely information to evaluate the behavior and performance of SoS (Dahmann 2012).

"Test and Evaluation as a Continuum" introduces Developmental Test, Evaluation, and Assessments (DTE&A)'s vision for a new paradigm where T&E will continuously inform the entire capability life cycle (Collins and Senechal 2023). T&E as a Continuum serves as an integrative framework to support SoS architecture, testing, and sustainment through application of various approaches characterized as key attributes and enablers. This framework includes three key enablers: (1) robust Live, Virtual and Constructive (LVC) testing environments; (2) a model-based environment; and (3) a digital workforce.

This paper presents a potential approach within the T&E as a Continuum paradigm which uses LVC and model-based environments to enable evaluation of joint all-domain concepts and facilitate more efficient T&E. Currently, there are limited options to perform end-to-end SoS engineering in a virtual, constructive cloud-enabled environment. Virtual assessment tools cannot be focused on a single system that just tests interoperability. A full SoS testbed is necessary to verify the integration of a given system and preserve the modularization and accountability of a constituent system.

Recommended Modeling and Simulation as a Service (MSaaS) Approach

A foundational capability for future systems development is an open modular systems architecture that allows integration, interoperability, and composability of software/systems tools. As we shift from traditional testing to T&E as a Continuum, another key enabler is model-based environments. Modeling and Simulation (M&S) has been considered as a key instrument to facilitate integration, interoperability, and T&E at various phases of SoSE (Mittal et al. 2008). SoSE through service facades and hybrid container architectures is an approach that enables M&S-based T&E.

Any system (both natural and artificial) can be expressed as a collection of service interfaces at different fidelities and resolution. Fidelity can be construed as a set of features (or services) that a system uses to provide the functional aspect of that system. Resolution can be construed as the data precision required for each of the features (or services) to furnish detail about that feature. An efficient system model strikes a good balance between fidelity and resolution, and experienced modelers select appropriate fidelity and resolution to answer the question that the model is designed for, albeit with cost/labor tradeoffs.

Modeling and simulation are two distinct activities. Consequently, Modeling as a Service (MaaS) and Simulation as a Service (SIMaaS) are distinct as well. In the current effort reported here, we take these two distinct activities and together call them Modeling and Simulation as a Service (MSaaS). MaaS deals with model engineering and managing fidelity and resolution through layered service specification architectures. SIMaaS deals with development of services that offer and control various simulator tools (as black-box systems) as simulation servers, along with the underlying hardware infrastructure that runs these servers.

Figure 1. Layered Modeling as a Service (MaaS) for Agent Based Modeling (Mittal et al., 2023)

Figure 1 depicts this MSaaS concept for an SoS model for a multi-agent system. A constituent system/asset/agent/tool is represented as System Service Application Programming Interfaces (APIs)1 and is decomposed into a multi-layered service APIs. MaaS API specifies behavioral fidelity in a layered manner. Each layer on the right side (Figure 1 in blue) is built from the foundation of the layer beneath it. The annotations on the right side also show an example of various services for a typical leader-follower multi-agent system. The System / Asset / Agent Model / Tool layer (in black on the right side) is the SIMaaS layer that makes the tool control possible through various service functions.

Each of the API layers, for both MaaS and SIMaaS, need to be developed through standards-based specifications. Having an API-first approach (OUSD 2020) allows the software systems (both models and simulators, in our case) to publish the functional aspect of the *system* and facilitates rapid development, integration, and interoperability. The benefits of API-based systems engineering are manyfold (Mittal et al. 2023). API-enabled systems allow other community players to design their systems to the advertised APIs for plugin development, facilitating extensibility of API-enabled system specifications. APIs serve as contractual agreements for system contractors and subcontractors to preserve their intellectual property behind a service facade and offer functionality that is extensible. APIs, when organized through a layered architecture, such as MaaS here, offer performance and instrumentation for different functional categories of an API-enabled system. The layered API structure offers additional advantages where dedicated computational resources can be assigned to specific API layers. Last, but not the least, APIs employ strong-typed specification which removes any ambiguity from the data exchange requirement. This allows rapid data integration ensuring syntactic interoperability. API-enabled SoS ensure semantic interoperability at the functional SoS level.

MITRE has developed this MSaaS capability across LVC simulation and experimentation capabilities across individual and team-oriented tasks to complex mission focused engagements using REST APIs. Using MSaaS brings speed, automation, and rapid integration of LVC environments across large scale SoS T&E events. MSaaS demonstrates interoperability across platforms and missions, and it can be used to test new concepts and ideas for innovation. MSaaS helps identify interaction points, causes of failure in a SoS setting, and highlight semantic gaps within the models to support T&E for LVC integration. It allows for the implementation of T&E as a Continuum enablers at the Joint level by shifting-left. It enables earlier "insertion-checks" to ensure logical data flows are operable and effective during development through sustainment. It brings focus to data-centricity via efficient, targeted, and iterative data collection and dissemination across the LVC system. This is particularly critical for enabling T&E of Joint All Domain systems – where the services will be conducting their testing and evaluation

[1] APIs allow interacting with a system with defined input/output specifications made available as a set of service functions. An API marks the functional boundary of the system, and computationally can be implemented through standards such as Web Service Description Language (WSDL) in the client-server paradigm. The functional description of the system can be decomposed in a layered manner and accordingly, APIs can be organized in layers.

asynchronously and yet need to be testing how their capabilities can integrate with other services' capabilities. This approach will enable data capture from these asynchronous events with proper meta-tagging of the data, data storage, and on-demand data sharing to all users who have the authorities to access the data. Furthermore, MSaaS preserves vendor Intellectual Property (IP) to inform contractual updates and facilitates interoperability across platforms and missions.

The path to employing MSaaS will require well-understood and jointly-accepted operational planning scenarios (and their M&S artifacts), the will to develop APIs over models, tools and simulations, and long-term support to implement a persistent T&E as a Continuum capability.

Current Status

As of June 2023, and at the direction of the Test Resource Management Center (TRMC), MITRE is deploying components of its on-demand, cloud-enabled MSaaS computational infrastructure to TRMC's Joint Mission Environment Test Capability (JMETC). With greater refactoring and extensibility, experimentation can be expanded to wholly different models and simulations while also creating other opportunities for analysis, collaboration, and joint exercise. MITRE has demonstrated the MSaaS capability to the satisfaction of TRMC, as an initial capability; it is now time to employ the capability in support of DOD R&E, Combatant Commands, and the Services. While MITRE has demonstrated the MSaaS capability to the satisfaction of TRMC, as an initial capability, it has yet to be employed by experimenters.

Way Ahead & Next Steps

MITRE will engage and collaborate with the Government's, Federally Funded Research & Development Centers' (FFRDCs), and University Affiliated Research Centers' (UARCs) multi-domain experimentation initiatives to achieve Combatant Command and multi-Service objectives. DTE&A will support R&E and INDOPACOM in real-world application of MSaaS operational environments and campaigns of experimentation evaluations. MSaaS adoption is expected to reduce acquisition, applied Science & Technology, Research & Development, and employment timelines through improved test processes. Employment of MSaaS in support of R&E and INDOPACOM will inform DTE&A MSaaS future investments needs.

In addition to the operational MSaaS pathfinder, MITRE is gathering Subject Matter Expertise (SME) input on current JAD events which may inform the MSaaS approach and validate its feasibility at a larger scale. This informal event questionnaire collects information on exercise objectives, planning, technologies, T&E, data, and M&S/virtual testing. Based on the collected input, the MSaaS approach will be refined for how it can be effectively and rapidly adopted by the T&E community as a methodology to addressing early assessment of risk and interdependencies for SoS testing. The MITRE team welcomes input on the event questionnaire from the ITEA community throughout July and August. Please contact Zoe Henscheid (zhenscheid@mitre.org) for more information.

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