Towards an Enterprise All-Domain M&S Environment for T&E: Overcoming M&S Challenges within the DOD

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Table of Contents

Introduction

The need to maximally leverage modern M&S solutions for the T&E of multi-domain warfighting capabilities is manifest, as comprehensive live testing of these capabilities is not possible due to environmental, fiscal, safety, classification, and ethical constraints. Nevertheless, we must overcome a multitude of challenges to most effectively utilize M&S for the T&E of these capabilities.

Several challenges we see within our department that target a DOD technical audience to overcome are:

Providing policy, guidance, best practices, executable examples, and training an M&S V&V/Uncertainty Quantification (UQ) workforce within the DOD.

Using M&S to credibly extrapolate outside of the operational envelope covered in live test.

Rigorous lifecycle approaches to V&V that are centered around quantitative estimates of uncertainty.
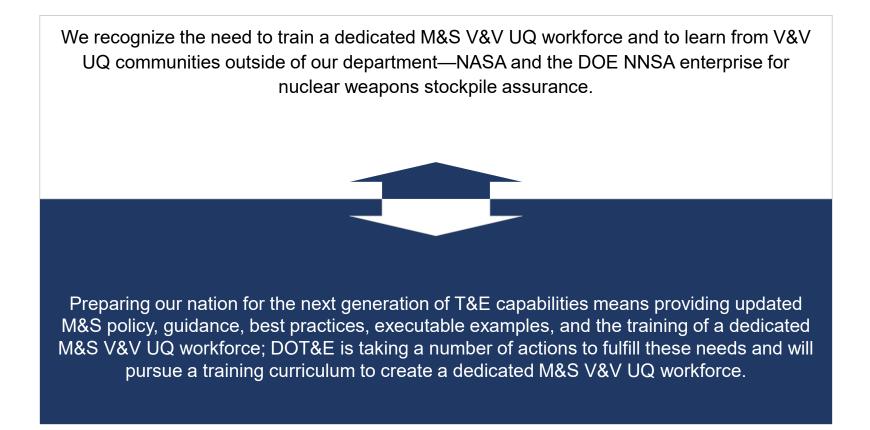
Accelerating M&S processing times.

The risk that we do all of this rigorous work and our models still turn out to be wrong.

Providing policy, guidance, best practices, examples, and training an M&S V&V/Uncertainty Quantification (UQ) workforce within the DOD

DOT&E is taking action to provide updated policy, guidance, best practices, and executable examples for M&S V&V and UQ.

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We recognize the need to train a dedicated M&S V&V UQ workforce and to learn from V&V UQ communities outside of our department—NASA and the DOE NNSA enterprise for nuclear weapons stockpile assurance.

Preparing our nation for the next generation of T&E capabilities means providing updated M&S policy, guidance, best practices, executable examples, and the training of a dedicated M&S V&V UQ workforce; DOT&E is taking a number of actions to fulfill these needs and will pursue a training curriculum to create a dedicated M&S V&V UQ workforce.

Using M&S to credibly extrapolate outside of the operational envelope covered in live test

In general, the fact that a small handful of physical laws can be used to accurately characterize and predict phenomena across a vast—even infinite—set of input conditions is a crowning achievement of science. And one with strong implications for T&E since it means: *It is possible to apply firmly-established physical laws joined to a limited number of live test observations to credibly assess system performance in regions of the operational envelope not directly covered in test.*

National Aeronautics and Space Administration (NASA)

NASA Langley's subsonic wind tunnel

- Ideally suited for low-speed tests to determine high-lift stability and control, aerodynamic performance, rotorcraft acoustics, turboprop performance, and basic-wake and flow-field surveys

- Data is used to both calibrate and validate the model, while the model can then be used to provide accurate results scaled to the full-size platform as well as help identify important design constraints, air flows, and the like which in turn can then be tested in the wind tunnel

TACTICAL

Examples

National Nuclear Security Administration (NNSA)

Advanced Simulation and Computing (ASC)

- Developed and validated advanced simulation capabilities based on well-known physics of magnetohydrodynamics, inertial confinement fusion, structural dynamics, etc.

- Calibrated and validated against current experiments and historical data from live underground testing to credibly assure our nuclear weapon stockpile in the absence of live nuclear explosion tests

STRATEGIC

Rigorous lifecycle approaches to V&V that are centered around quantitative estimates of uncertainty

It is DOD policy that Models, simulations, and associated data used to support DoD processes, products, and decisions shall undergo V&V throughout their lifecycles.

The National Academies 2012 report Assessing the Reliability of Complex Models recognizes:

> **" The ubiquity of uncertainty in computational estimates of reality and the necessity for its quantification. "**

The report provides treasure trove examples and methods for our DOD M&S community to learn from and apply.

Uncertainty Analysis Demonstration: A Missile Case Study
DOT&E, 2022

Provides a primer on uncertainty and a case study demonstrating uncertainty quantification that is packaged with the executable code for our community to use and adapt.

Advanced Simulation and Computing Simulation Strategy
NNSA, 2022

Delves into their mature uncertainty quantification capabilities and framework. That strategy recognizes the need to integrate uncertainty quantification into their analysis workflows in a more routine and user friendlier way; although our community's uncertainty quantification capabilities are less mature than the NNSA's, the need for us to do the same is apparent.

Accelerating M&S processing times at the hardware and tactical performance levels

Custom tactical hardware and their associated integrated circuit boards such as Field Programmable Gate Arrays (FPGA) and Application-Specific Integrated Circuits (ASIC) are much faster for their dedicated purposes than more generalized computer processors such as Central Processing Units (CPU) and Graphical Processing Units (CPU).

To alleviate this technical challenge to the development of an enterprise all-domain M&S environment for T&E:

1 Achieving performant M&S at the low levels and high fidelity of hardware necessitates that CPU/GPU-based M&S capabilities be augmented with tactical hardware in the loop (HWIL).

2 From there, these HWIL-integrated capabilities can be used to feed machine learning and other advanced methods to generate reduced high-level tactical performance models that can run in real time.

3 Beyond the low level of hardware, the large computational workloads and high throughput required of M&S can be accelerated by sharing the workload across a large number of CPU and GPU cores operating in parallel.

4 Furthermore, both CPU and GPU-based parallelized computing capabilities can be distributed across large geographical areas and have disparate, asynchronous workflows integrated and brought into harmony using modern, enterprise software architectural solutions such as RESTful APIs.

7

The risk that we do all of this rigorous work and are models still turn out to be wrong

Using M&S for the rigorous T&E of our military systems and future joint warfighting concepts, with the ultimate goal of reducing the risk posed to our warfighters.

Warfare is wrought with risk and uncertainty; real-world combat data may prove our models wrong despite our best efforts.

To truly be prepared for these critical risks, we need to move out with agility now to build and stress this enterprise all-domain M&S environment.

The discoveries we make along the way could be surprising and profound for warfare; after all, they have been before.

Conclusion & Questions

DOT&E's SIPET division—Strategic Initiatives, Policy, and Emerging Technologies—is shaping the T&E of future multi-domain warfighting. We understand that comprehensive Live testing of multi-domain capabilities currently under development is not possible due to environmental, fiscal, safety, classification, and ethical constraints and so our evaluations will become more dependent on modeling and simulation (M&S) to test the efficacy and interoperability of our systems.

Any Questions?

The exposition of these challenges was not academic; alternatively, the discussion was pragmatic and centered around already-mature or rapidly maturing technologies, advanced methods, and real-world use cases pertinent to the M&S required for the T&E of future joint warfighting concepts. DOT&E and our partners will soon have multiple R&D projects underway to advance our M&S and V&V/UQ capabilities for T&E and position us to meet this critical challenge.