Benefits & Challenges of applying Digital Twins & Hybrid Analytics in Testing & Evaluation Programs

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Testing & Evaluation (T&E) Programs are always looking for opportunities to reduce cost and risks while accelerating time to field. However, applying a solution towards one of these objectives often impacts others adversely. It's well understood that most time, costs, and effort in a Program is associated with the T&E phase. Hence, the recent push on Programs to shift-left with the intention of minimizing some of these by bringing modeling and simulation (M&S) capabilities earlier and earlier in the process.

Digital Twins are an up-and-coming technology focused on connecting real-world operating assets to their digital counterparts and back at a desired frequency and fidelity. The goal is to maintain them synchronized and collect additional insights on how these assets are operating for monitoring, control, and optimization, as well as predicting when services are needed to keep them running. Fulfilling this goal is not a trivial task, but recent advancements in technology (such as M&S, IoT/Edge platforms, AI/ML, Data Analytics, High Performance Computing, Cybersecurity, GPU Processing, amongst others) have made Digital Twins more tangible and accessible. DoD Programs in general are always looking to develop and operate at the edge of technology and give the highest levels of advantages over adversaries. This is certainly true with adopting Digital Twins, but how, where, when and why?

The main challenges with Digital Twins are associated with a balance between accuracy and speed, an element of flexibility, adaptability, interoperability, and scalability. The holy grail of Digital Twining today is Hybrid Digital Twins that benefit from both physics and data. To achieve models that operate at high fidelity from the combination of physics and data, as well as high frequency, several "twin enabling" techniques have been adopted, such as reduced order models, Bayesian inference, gaussian methods, amongst others… This work will focus on examples and the value of applying Hybrid Digital Twins as well as twin enabling techniques to T&E Programs to accelerate virtual prototyping, enable virtual validation and virtual testing, as well as provide a new avenue for test augmentation.

Virtual Prototyping → Hybrid Digital Twins rely on techniques to combine and solve models of different sources and fidelity, as well as speeding up the runtimes of higher fidelity models through reduced order modeling workflows. Once you can combine system models with detailed design models at system level runtimes performance, engineers are empowered to run detailed system/sub-system/component performance simulations for different operating conditions in a fraction of the time. This opens possibilities to perform more iterations with the same amount of time, link results back to requirements and increase the readiness of the design for subsequent testing phases.

Virtual Validation → Hybrid Digital Twins rely on techniques to combine physics models and test data to compensate for missing physics and quantity uncertainty. This opens a possibility for test data to be utilized to enhance the fidelity of its associated digital model counterpart to a point that the virtual model can be trusted to represent real-world behavior. Then, less critical tests may be selected to be performed virtually while leaving more critical tests to be performed physically.

Virtual Testing → Hybrid Digital Twins rely on techniques to package the final models in platform agnostic deployable units that can be shared in the shape of applications that can be ran by testing engineers without the need for simulation expertise. This is the concept of simulation democratization and allows testing engineers to have a virtual environment to execute testing and link results back to requirements.

Test Augmentation → Finally, Hybrid Digital Twins can be connected to a physical prototype and its testing harness to provide additional testing insights and minimize the required infrastructure with physical sensors. This is the concept of virtual (soft) sensors, where the twin can be fed telemetry data in specific locations and predict measurements virtually in additional spots within the prototype, some of which may not be feasible at the risk of affecting prototype behavior and/or represent additional costs, time and effort that can be saved.

To summarize, Hybrid Digital Twins and associated enabling techniques are being deployed to various stages of T&E Programs and are reducing cost, risk, and accelerating time to filed through enhanced virtual prototyping, virtual validation, virtual testing and test augmentation. Once a system is manufactured and deployed, a collection of associated Digital Twins can also be used to capture augmented operational insights to monitor, control and optimize these assets, as well as bring in back additional data streams to feed new development programs, but that is a whole other paper!