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THE ADOPTION OF THE JSE DIGITAL TEST AND TRAINING RANGE (DTTR)

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In 2023, the Joint Simulation Environment (JSE) was used to complete the Initial Operational Test and Evaluation (IOT&E) of the warfighting capabilities of the F-35. The unprecedented nature of JSE and its use came from the general inability to exercise tactical operations in realistic threat environments using our existing open-air ranges (OARs). JSE has now been deployed to other facilities across the nation enabling the standup of Digital Test and Training Ranges (DTTR), which like traditional OARs (i.e. Nevada Test and Training Range, Utah Test and Training Range), provide the space, time, threats, security, and command and control infrastructure necessary to conduct military test and training operations. The concept of the DTTR (or any other JSE based facility) brings unprecedented opportunities to the acquisition and operational training communities that can significantly transform the way we develop weapons systems and boost tactical training efficacy against modern threats. DTTR will effectively address most of the traditional limitations associated with OARs adding significant value to weapon system lifecycle efforts and improving test and tactical training realism. This paper focuses attention on these opportunities by discussing the value proposition of the DTTR and offering a vision of its future use and the enterprise transformation they could bring.

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The Adoption of The JSE Digital Test and Training Range (DTTR)

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INTRODUCTION

In 2023, the Joint Simulation Environment (JSE) was used to complete the Initial Operational Test and Evaluation (IOT&E) of the warfighting capabilities of the F-35. The unprecedented nature of JSE and its use came from the general inability to exercise tactical operations in realistic threat environments using our existing open-air ranges (OARs). JSE has now been deployed to other facilities across the nation enabling the standup of Digital Test and Training Ranges (DTTR)[1], which like traditional OARs (i.e. Nevada Test and Training Range, Utah Test and Training Range), provide the space, time, threats, security, and command and control infrastructure necessary to conduct military test and training operations. The concept of the DTTR (or any other JSE based facility) brings unprecedented opportunities to the acquisition and operational training communities that can significantly transform the way we develop weapons systems and boost tactical training efficacy against modern threats. DTTR will effectively address most of the traditional limitations associated with OARs adding significant value to weapon system lifecycle efforts and improving test and tactical training realism. This paper focuses attention on these opportunities by discussing the value proposition of the DTTR and offering a vision of its future use and the enterprise transformation they could bring.

THE VALUE PROPOSITION OF THE DTTR

Two of the most unique and important attributes of JSE are that JSE is inherently government-owned and that the DTTR facilities are government-operated. By owning the data rights to JSE and having full access to, and control of the architecture and environment modeling software, the DoD becomes an active and contributing partner to defense contractors, reducing overall costs and schedule, breaking down weapon system stovepipes, and significantly streamlining the management and fielding of military capability. In addition, an increasing amount of government personnel will become intimately familiar with state-of-the-art software development standards and modeling architectures that will in turn, help bring modern and novel industry practices to the DoD. But there is a key and intangible value of DTTR, and it lies on its potential to revolutionize the way we develop, acquire, and field weapon systems, which is the focus of this section.

Figure 1 illustrates what has been affectionally known within the developmental test community as the "DTTR Smiley-Frowny" chart. The vertical axis represents an arbitrary relative value added to the weapon system lifecycle. The horizontal axis represents the timeline of traditional weapon system lifecycle, from early design and experimentation to eventual fielding and tactical training. As labeled, the blue curve

[1] The term "Digital Test and Training Range" (DTTR) was adopted by The Air Force Test Center to describe the two test facilities built at Edwards AFB (DTTR-E) and Nellis AFB (DTTR-N). Air Combat Command will adopt the term "Joint Integrated Test and Training Center" (JITTC) for their JSE-based training and tactics facilities.

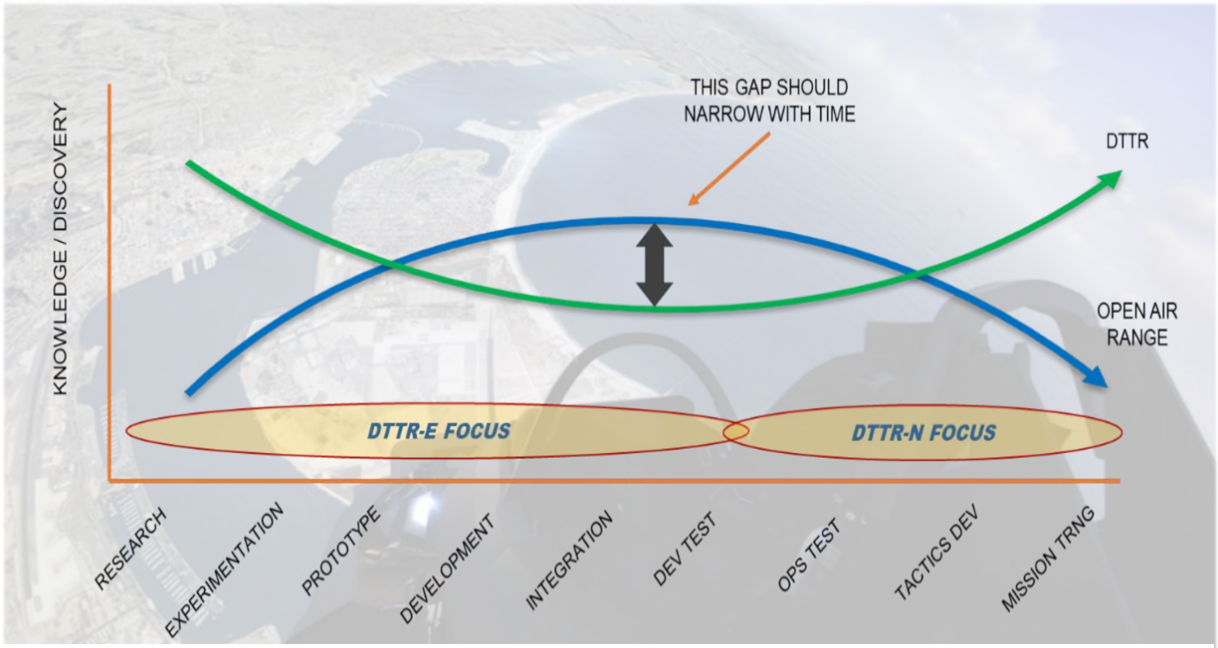

Figure 1. The DTTR "Smiley Frowny" Chart

represents the lifecycle contributions or value of OAR test and training operations, while the green curve represents the expected additional contributions of DTTRs.

At first glance, note that there is no suggestion or assumption that DTTR will eliminate the need of OARs in the future. Quite the opposite, it is the aggregate of the two approaches that provide opportunities for transformational change to the way we develop, acquire and field military capabilities. DTTR brings opportunities to execute test and operations in environments where OARs typically fall short. Conversely and in this framework, OARs will still provide real-world data to support traditional acquisition processes and milestones, but will also be critical to the continuous validation and refinement of the models used in their digital counterparts.

The value of OAR Test and Training (Blue Line)

Beginning on the far left of the chart, concept exploration matures in the research phase. At this point, the only resemblance of a weapon system is usually in drawings, concept of operation narratives, some simulation data, and idealistic or aspirational papers on use cases. There is very little value of OARs at this point because there is no physical article to test, only ideas and some models. As experimentation progresses into the fabrication of a prototype, the OARs increasingly add value by providing the right environment to demonstrate the maturity and feasibility of the underlying technologies. By the time the system reaches integration and development test (center of chart), OARs provide maximum value by providing the "*real world*" laboratory to verify that the system under test (SUT) operates and functions per contract specifications (i.e., the power and cooling systems work correctly, the transmitted power is adequate, integration deficiencies get corrected, etc.). However, beyond this point, where military utility and tactical employment increasingly becomes the focus, the value of OARs decreases.

There are several reasons the value of OARs decrease as the programs progresses towards operational test and fielding. First, it has become impractical and often impossible to replicate an accurate adversarial threat or "red" environment. The threat systems of our most formidable adversaries are becoming highly complex and their capabilities difficult to assess. In addition, the threat density required for effective test and training would not only be too expensive to replicate, but severely constrained by the available physical space of our national ranges. Second and most importantly, the proliferation of commercial and Foreign Intelligence Entity (FIE) surveillance systems have significantly limited our ability to utilize our weapon systems in OARs without being "seen". The latter imposes severe restrictions on our ability to develop and train with the war mode techniques and tactics that will ultimately give us the military edge on a "Night One" conflict with a peer or near-peer adversary. Lastly, there is limited capacity of OARs to host the high demand of test and training events expected to come with the development and fielding of our next generation of exquisite weapon systems like Next Generation Air Dominance, B-21, F-35 Block 4, F-22 Capability Pipeline, Collaborative Combat Aircraft, and hypersonic weapons among others.

The value of DTTR (The Green Line)

The value of the DTTR lies precisely on its ability to address the aforementioned limitations of the OARs. At the far left, where only drawings and models of future blue systems exist, the DTTR provides an environment where the enterprise can assess the military utility of concepts via early models of expected capability utilizing easily tailorable digital surrogates to match desired specifications. In the DTTR, weapon system program offices have access to a variety of adversarial threats and threat densities based on the most up-to-date intelligence-generated models of red systems, as well as tailorable threats to desired characteristics. The only program office products needed in this phase are idealistic and sufficiently adequate models of the proposed capability. In this construct, the high-fidelity model attributes of JSE provide unprecedented early information on blue system design performance in the face of the most realistic threat environment possible. DTTR data in this phase will optimize the early Analysis of Alternatives (AOAs) acquisition process before any prototypes are designed or built. The existence of highly realistic government owned and government operated digital ranges has the potential to radically transform this portion of the acquisition lifecycle by providing a common environment in which different contractor proposals can be evaluated with an elevated degree of confidence.

During *Development, Integration, and Development Test*, the DTTR becomes less valuable. Notably, there are fewer opportunities during these acquisition phases to employ the DTTR when the focus is on building, fabricating, and ensuring the hardware and software integration is accomplished adequately and within the required specifications. However, it is during these phases that "*real-world*" data becomes available to help develop, refine, validate, and verify the system "*digital twin*" models that will be necessary for the later phases of development, fielding, and training. In that sense, the focus of early developmental test (DT) should be expanded to include the deliberate collection of the right data sets to validate models. One can see test plans specifically designed to address uncertainty of models in areas where limited data exists. The gap between the value of OAR and DTTR in these phases should decrease with time as hardware-in-the-loop labs gain exposure to JSE sites and innovative test techniques get developed through regular DTTR use. However, the OARs remain indispensable as a "reality check" agents.

By the time system maturity reaches operational test (OT), Tactics Development, and Mission Training, the blue digital twin models have been created and validated. At the same time, the JSE environment itself has been continuously improved via new intelligence reports, integration of additional red systems, and fidelity upgrades of the physical world models (atmospherics, weather, electromagnetic transmission phenomena, etc.). The DTTRs become invaluable in our ability to employ war modes, conduct operational evaluations, develop novel tactics, and create mission training systems informed by our absolute *best guess* of the adversarial ability to wage war; all of this is done in a highly secured and controlled environment, adding in turn uncertainty to our adversaries calculus. Note that the utility of the DTTR does not end at system fielding, but it becomes the tool used to continuously upgrade the mission tactics and training focus based on emerging intelligence and ever-changing red system capabilities.

Another benefit of leveraging the DTTR is the newfound ability to manage the system operational effectiveness risk throughout the entirety of the program life cycle. Figure 2 shows the risk assumed in traditional acquisitions approaches. Since there is no meaningful way to perform operational evaluations in the early phases of the life cycle, programs assume increased risk to mission assurance until the system is ready to enter operational test and evaluation. Moreover, by the time the system reaches maturity, the threat has most likely evolved, restarting the increasing risk cycle in follow-on upgrades.

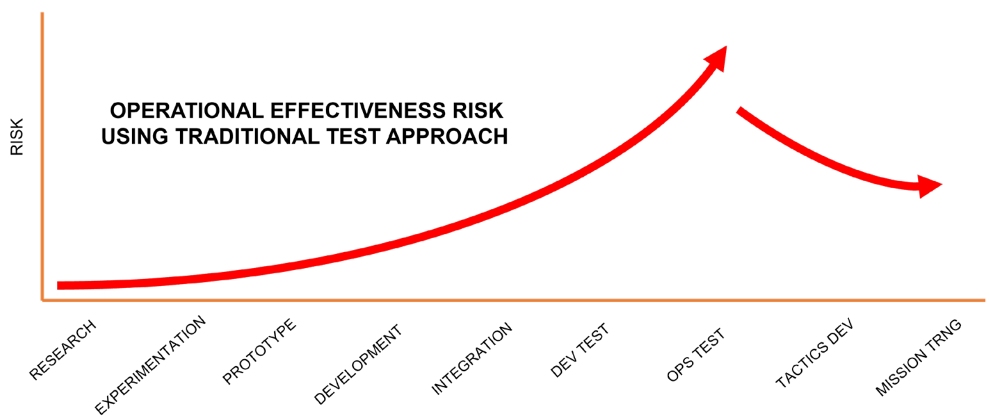

Figure 2. Operational Effectiveness Risk of Traditional Acquisition Approach

By leveraging the DTTR (Figure 3) using system digital twins, the operational effectiveness risk can be assessed at any time using updated threat information and system performance data. In this construct, the risk is assessed and mitigated by identifying and implementing continuous corrections in design before reaching formal developmental and operational test, leading to lower overall mission assurance risk.

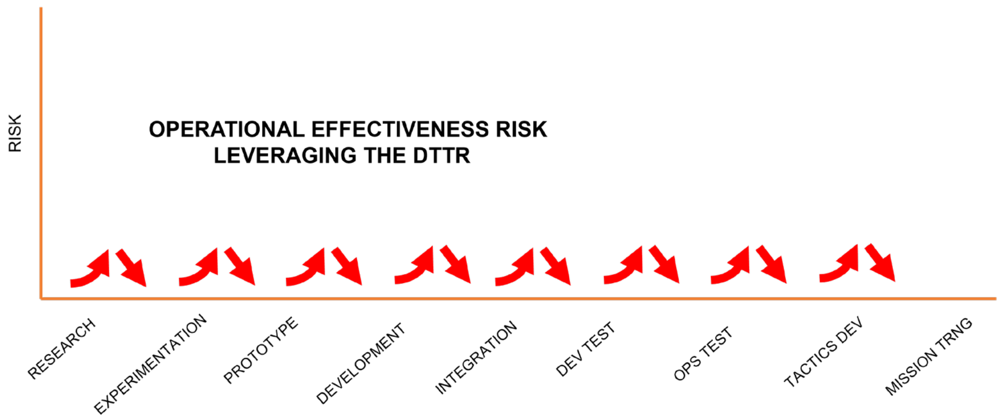

Figure 3. Operational Effectiveness Risk Leveraging the DTTR.

Despite the potential benefits JSE could bring to the test and training enterprises, the fact remains that computer-generated simulations are not reality and will always suffer from imperfections of the models and the lack of real-world randomness. The next section goes deeper into the role of model fidelity and the proper use of DTTR data for decision making.

MODELING, SIMLUATION FIDELITY, AND DECISION MAKING

A well-known Test Pilot School instructor liked to say "*all models are wrong, some are useful*"[2]. Although many models of physical phenomena are exceptionally good and may seem to act the same in simulations as in real life, the fact remains that they will always be at best, useful approximations of reality. In general, high-fidelity models will outperform lower fidelity ones any day and in most applications. However, it would be unrealistic to think we can develop, integrate, and maintain the highest level of fidelity possible on every single model integrated into JSE and the DTTR. DoD and industry will always be resource and capacity limited to be able to do so. It is important then, that we prioritize high fidelity where it matters the most.

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[2] Phrase attributed to a British statistician named George Box in 1976. (Wasserstein, Ron 2010. "George Box, a model statistician", *The Royal Statistical Society*). https://rss.onlinelibrary.wiley.com)

Figure 4. Risks Associated with Model Fidelity

Figure 4 presents a notional contrast of the potential risks associated with model fidelity in the context of model development and envisioned operational use of DTTR data. Although it would make sense to develop lower fidelity models to accelerate integration and fielding, saving precious resources (the top line in the chart), the reality is that doing so would generally increase the risk in about every other aspect of modeling utility. The most critical example would be a military commander who will make battlefield decisions based on lessons learned during DTTR-based tactical training and exercises. The lower the fidelity of the models used to test and train in the environment, the higher the risks of encountering unexpected challenges or mission failures in real world operations.

Another consideration related to fidelity is the ability of the model architecture to accommodate other uses. For example, JSE architecture was designed to run real aircraft software in real time. This high-fidelity feature prevents altering the speed of the simulation and the instant rewind and replay of scenarios. The training data are available for post-mission debriefs only (as in real ranges), making it less suitable for more basic aircraft training functions where instruction is maximized by demonstrating and correcting "on the spot".

Having an understanding that all models are "wrong" and the risks associated with different levels of fidelity, attention is now turned to how to use the data produced at the DTTR for decision making at all levels. The *verification*, *validation*, and *accreditation* (VV&A) concepts are used below to address the question.

The Defense Acquisition Encyclopedia (https://acqnotes.com/) defines VV&A terms as:

Verification: *The process of determining that a model implementation and its associated data accurately represent the developer's conceptual description and specifications.*

Validation: *The process of determining the degree to which a model and its associated data provide an accurate representation of the real world from the perspective of the* ***intended uses*** *of the model.*

*<u>Accreditation:</u> The official certification that a model, simulation, or federation of models and simulations and its associated data is acceptable for use for a **specific purpose**.*

In the above definitions, the words "*intended uses*" and "*specific purpose*" are highlighted because these terms directly drive the criticality of the VV&A data requirements. In other words, the intended use of the models will dictate what level of fidelity will be acceptable and what data are needed to validate the M&S system as "good enough". For example, if a research organization wants to use the DTTR to explore early utility of new or novel technologies, the accreditation authority may fall as low as the researcher themselves, but if the M&S systems is to be used as the vehicle for Operational Test & Evaluation "runs for score", then the AFOTEC Commander or the Director of Test and Evaluation (DOT&E) are probably the right levels of accreditation authority. For M&S data supporting an acquisition AoA, the program PEO or the program managers themselves would be the most-likely accreditation authorities. The accreditation authority will be based on the criticality of the decision and the importance of the intent. In all cases, the accreditor will need more than just JSE-produced data to properly mitigate the decision-making risk.

To properly assess the risks of M&S-based decisions, one needs to also understand the underlying system that produced the data artifacts presented, its capabilities, and limitations. Ideally there would be a set of standard definitions that can adequately characterize M&S system shortfalls and uncertainty in the models that the V&V process doesn't necessarily capture. In the case of JSE DTTRs, consider a red threat system for instance. Unless the modelers have the actual system and direct knowledge of how it is operated, there is no way to validate that the behavior model is close to the real one. That level of confidence on the threat models needs to be captured and communicated so the accreditation authority understands the risks associated with his or her decision. The same approach should be taken for other aspects like fidelity of weather models (wind, sun flares, clouds, etc.), simplification of models for implementation, and real-world technical maturity of blue and red systems to name a few.

One can significantly improve the risk-based decision process by comprehensively understating the DTTR mission data in concert with the characterization of the blue and red models used to produce them. Thus, it is important that the enterprise develops ways to package and present these data products that are easy to understand, widely acceptable, and inclusive enough for non-technical decision making.

CONCLUSION

By addressing most of the traditional limitations associated with OARs, the adoption of the DTTR (or any other JSE-based facility) brings transformational opportunities to the acquisition and operational training communities that can redefine the way we develop weapons systems and boost tactical training realism and efficacy against modern threats. JSE and associated DTTRs and JITTCs can become the underpinning "glue" that will truly integrate developmental and operational worlds across the entire weapon system lifecycle.

To date and in general, the research, development, test, and fielding of systems are treated as separate activities loosely coupled by early warfighter (user) involvement. The ability to employ a weapon system in our best guess of the real-world threat environment during early design, provides an unprecedented opportunity for user feedback that can significantly enhance the integration between distinct lifecycle development phases, accelerate weapon system fielding, and lower the risk to mission assurance.

Furthermore, the development of the weapon system that leverages JSE will also be concurrently building the high-fidelity tactical and intelligence-driven training environment needed post-fielding. The *ONE* JSE system built during and for system development and test will directly transition to support a variety of warfighter operational requirements. Real-world experience gained by using the new weapon system will help refine the JSE models, driving continuous upgrades to the program baseline, streamlining future system development, improving tactical training efficacy, and informing strategic war planning.

As we build the JSE enterprise and adopt the use of DTTR facilities for test and training, it becomes critical that the end users and decision makers understand the capabilities and limitations of the simulation system and its models. Having a clear understanding of the attributes and uncertainties of the data generated in the DTTR will help mitigate the risks associated with decisions made using imperfect information. It is recommended that the user and JSE communities quickly develop and adopt a standard set of characterization terms to address and communicate the uncertainty in model-based data.

One last thought; other than the success of F-35 IOT&E, there is no data at the time of this writing to validate the claims and vision in this paper. As we learn to employ virtual environments to augment the real ones, only time will inform us of the challenges and validity of our assumptions. But there is one thing the author is absolutely convinced of, there is no turning back. This the first real attempt to realize a vision had by many for decades. Tools may change, architectures evolve, but the transformation Is bound to happen, and the time is now.