Using Simulation—The Past as Prologue…Probably

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The use (and the utility) of simulation as a complement to physical testing is a historical fact. More to the point is the question: "What can we expect of the future?"

From a few historical examples and with an appreciation for today's technical and programmatic environment, we are confident that, in addition to "more of the same," we can expect certain new types of modeling and simulation (M&S) usage to evolve naturally and inevitably from past practices and current circumstances.

Relationship of M&S to testing (and evaluation)

A simple but effective indication of the fundamental relationships among simulation, testing and evaluation is provided in *Figure 1*. Simulation and physical testing are symmetrically related to evaluation—being influenced by evaluation requirements and providing information for the evaluation-decision-action process. Likewise, they are both clients to one another's information-server functions: simulation supports test planning and analysis; and testing supports simulation validation. These static relationships have occurred progressively in both technical variety and in programmatic scope.

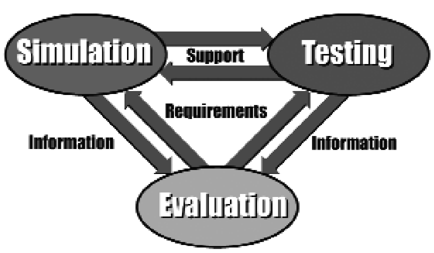

Figure 1. Fundamental relationships among simulation, testing and evaluation

By looking at the past, wherein this simple paradigm has become progressively richer, and by considering the present (with its immanent pressures and opportunities), we expect to see a little way over the horizon to a regime of continuing evolution of simulation use that complements physical testing.

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Experience domain

To survey the use of simulation's constructive relationship to physical testing, we confine ourselves to consideration of hardware-in-the-loop (HWIL) simulation of Army missile systems where the history is rich and suggestive. We are careful, however, not to let this focus-of-convenience artificially foreclose the validity of subsequent conclusions and recommendations.

Appreciating the past

As early as the late 1970s, the simplest uses of simulation and the exercise of the constructive relationships between simulation and test were clearly evident. Chaparral and Stinger air-defense missiles were represented in real-time HWIL simulations, often with test-article hardware, to provide predictions of test behaviors for range safety involving sophisticated guidance and infrared counter-countermeasures phenomena.

Conversely, telemetry and dynamic flight test data, gathered from test operations intentionally crafted for that purpose, were assiduously collected, analyzed and provided to simulation laboratories to provide a realistic basis for comparison of simulation prediction and real-world behaviors. Such simulations were (eventually) accepted as admissible for generation of performance-assessment data—one significant determinant of acquisition/deployment decisions. Subsequently, similar HWIL tools, often with digital signal processor HWIL components, were used in support of target acquisition, countermeasures and guidance precision product improvement programs.

Similarly, Hawk missile product improvement modifications came to be accepted primarily on the basis of simulation studies and analyses, sometimes corroborated with only a single physical test intercept. In addition, simulation facilitated covert exploratory development of Hawk-based variants throughout the 1970s and 1980s.

Patriot system PAC-2 missiles were subject to extensive HWIL simulation investigation to educe their electronic countermeasures performance with respect to design requirements. As usual, a continuous process of simulation validation with respect to physical test results was pursued. As Patriot progressed into its PAC-3 version, simulation took on greater effective significance for system development. On one hand, simulation was accepted as a form of "entry criterion" for physical flight testing. On the other hand, however, simulation came to be explicitly accepted as a viable, economical substitute for some physical flight tests. Today, Patriot initial operational test and evaluation (IOT&E) decisions are being predicated partly on simulation results, including those generated by HWIL and other techniques.

In an uncommon, but not unique, bit of serendipity, the use of HWIL simulation in support of the millimeter-wave Longbow missile system revealed unappreciated operational capability and thus facilitated missile production. This occurrence thereby extended the influence of HWIL simulation operations beyond the system's intended domain of application and consequently beyond its expected range of utility.

At about the same time, program managers typically came to accept use of the HWIL simulation for the sophisticated SADARM multimode, precision-guided submunition. Simulation became progressively more appreciated—and consequently more valuable—by virtue of being planned in accordance with the needs of the weapon's life-cycle development program. The value of the HWIL simulation supporting preplanned product improvement of the BAT system (another multimode precision-guided weapon) is so firmly established that HWIL simulation operation is practically on the critical path of development-program execution.

Most recently, systems such as the Missile Defense Agency's Theater High-Altitude Area Defense (THAAD) missile system and the Ground-based Midcourse Defense segment have extended HWIL simulation beyond representation of missile fly-out and intercept, to end-to-end operations involving ground support equipment ballistic missile command, control, communications, computers and intelligence (BMC^{4}I) processes. Single simulation components are being used in federations of simulation ensembles, and distributed collaborative operations are becoming common.

Summary analysis

Even in our relatively limited historical review, it is apparent that a few trends are influencing the use and utility of simulation in conjunction with physical testing and evaluation. Increasing M&S feasibility, illustrated in HWIL examples by the evolution of practical multimode environments, distributed assets and collaborative operations, motivates more simulation investment and expectation of recovery of investment. Economic pressure, together with expanding missionary responsibility within the Department of Defense, motivates simulation use when it is the "best investment."

The evolving credibility of simulation, based on practical successes and on more deliberate establishment of an appropriate basis of confidence for simulation accreditation, removes long-standing inhibition of the use of simulation. Finally, the growing perception of simulation in the context of broader missionary and weapons systems life-cycle management, and the expectation of new kinds of value to be recovered, invite new prospective simulation uses.

Extrapolation to the future

What sort of future does this description suggest? Will we have more of the same (simple extrapolation of instances, confidence and influence of simulation), or some new *kind* or whole new *level* of relationship between simulation and testing?

More of the same

Certainly, we might reasonably expect that the trends illustrated here will continue and diversify. More modes of simulation, applied more systematically, more intensively and more expertly—and in ways more intimately related to physical testing and evaluation/decision processes—must be employed in order to recover more kinds and degrees of cost benefit. Such a future is not undesirable—but it is not necessarily all there is to look forward to!

A new deal?

In addition to this progressive future, it is most likely that we may reasonably expect to see a significant new concept of operations, signifying a more highly integrated systems engineering paradigm than has typified the past.

Several factors today are influencing the uses of simulation in all of its manifestations and relationships, not only to physical testing and evaluation, but to all facets of systems engineering: requirements, development, manufacturing, testing, training, operations and maintenance. These factors are best conceived as part of technical cultural changes that are "bigger than both of us" (that is, simulation and testing). The potential exists, consequentially, for significant changes in the future of test-simulation relationships.

A variety of technical architectures are being developed and used that may well provide the structural context for significant unification of simulation and testing. High-Level Architecture (HLA) standards, as well as synthetic virtual environments for simulation-based systems development, training and evaluation, are clearly analogous to Test and Training Enabling Architecture (TENA) and Virtual Proving Ground (VPG)–type initiatives for testing facilities investments and operations. Collaborative maturation of these complementary architectures is already underway.

The pervasiveness of simulation applications across all phases of objective-system life cycles is already commonplace. More explicit relationships of simulation with developmental and operational testing and evaluation over this life cycle might reasonably be expected.

Finally, the place of simulation and testing in the context of the rapidly evolving defense acquisition enterprise perspective is of mutual concern to both constituencies. Simulation, testing and the relations between these will be influenced significantly by enterprise-echelon concerns. Some of these concerns are attention to broader economic issues, maturation of materiel acquisition strategies, full life-cycle systems engineering processes, collateral investment in facilitization, operations and maintenance and distributed, collaborative behaviors.

The challenge

The future will be what we make it. Our intentions, invention and influence will define tomorrow's uses of simulation in relation to physical testing and evaluation. That there is considerable opportunity to recover value from the constructive use of simulation and testing in explicitly complementary forms is incontestable. That we will, in fact, reap this harvest, is less certain. It is unclear whether simply taking the "high ground" perspective of systems engineering, acquisition and interoperability will alone yield the value we seek. More likely, a deliberate and methodical collaboration between the simulation and physical testing communities will be necessary. How will *you* contribute to *making this relationship work?* ❑

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