Testing The Untestable

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Keywords: M&S, HWIL, software, testing, VV&A

Abstract
The National Missile Defense system is an integration of weapons, sensors, and battle management command, control and communications into a system designed to provide protection against limited ballistic missile attacks targeted at the United States. The NMD mission includes surveillance, warning, cueing, engagement and post engagement assessment of threat objects prior to impact on US targets. Testing of an operational configuration in a conventional sense is not practical. Such testing has severe safety, cost, and treaty implications. Live testing, for the foreseeable future is limited to the Vandenberg Air Force Base to Kwajalein Missile Range corridor. Using the NMD program as an instance, this paper examines actual and proposed activities associated with live flight tests known as Integrated Flight Tests and simulation-based tests currently being executed, including Integrated Ground Tests, Pre-Mission Tests, and Post-Flight Reconstructions. This paper provides a construct on how the results of these simulation-based activities can be used to “test the untestable”.

1.0 INTRODUCTION

Using the National Missile Defense (NMD) as an instance, this paper, articulates a process and provokes discussion on a methodology that can establish a degree of confidence in the expected performance of a very complex operational system that cannot be evaluated by conventional tests. This "inability to execute an operational test" in the conventional sense, may be dictated by safety, cost, treaty, and test range constraints.

2.0 BACKGROUND: THE NMD SYSTEM

The NMD program is a system designed to provide protection against limited ballistic missile attacks targeted at the United States. The NMD program is executed by the National Missile Defense Joint Project Office (NMD JPO) of the Ballistic Missile Defense Organization (BMDO). The Boeing Company is the NMD Prime Contractor and is responsible for the development and integration of the various elements comprising the NMD System. The NMD System includes Ground-Based Interceptors, Ground-Based Radars, Battle Management, Command, Control and Communications, including the In-Flight Interceptor Communications System, and Space-Based Sensors linked together through a communications framework. In addition, the NMD Prime is responsible for the execution of the developmental tests and system verification programs. In support of these assessment activities, the NMD Prime uses models and simulations (M&S) for analysis, design verification, integration, and test &evaluation (T&E). Since the simulations will be extrapolations of the NMD system, verification, validation and accreditation (VV&A) of the models and simulations will be the key to providing confidence needed to accept the test results.

3.0 THE T&E PROBLEM

Classical testing and evaluation of a new weapon system entails repeated live "firings" by forces that would be employing the system against the expected threats in an environment similar, if not identical, to the expected battlespace.

3.1 An Ideal Case

An example of an ideal case is the testing of a relatively inexpensive short-range anti-tank missile system. In this case there are no range safety constraints preventing traditional operational testing. During developmental and subsequent operational testing, soldiers are used to fire the weapons against a variety of targets, under differing environmental conditions, from different positions, and varying "gunner-to-target" ranges and orientations. Thus, the system can be evaluated under operational conditions.

3.2 The NMD Case

For National Missile Defense however, real world constraints often interfere with "real testing". One of these constraints is the cost and availability of the test resources. This hampers and limits the amount of physical testing that can be accomplished. Similarly, test targets, data collection instrumentation, and range support are expensive and introduce additional constraints to physical tests. Range safety and environmental concerns also influence the test scope, and often limit or preclude, operational tests. In addition to resource constraints, political constraints impact the effective developmental and operational testing of ballistic missile defense systems. For example, international treaties severely constrain the test architecture and execution.

4.0 THE PROPOSED SOLUTION

The basic premise of the proposed paradigm is that things equal to the same thing, are equal to each other, i.e., the transitive property from the axioms of equality with which we are all familiar ***(If A = B, and B = C, then A= C***). (A) represents the execution of a flight test. (B) represents the execution of a simulation under flight test conditions. (C) represents the execution of (B) under expected operational conditions. If (B) accurately predicts flight tests (A), then it is reasonable to expect that (C) would accurately predict flight test under operational conditions. Thus A=C.

5.0 THE PARADIGM IN PRACTICE

The following section describes the Flight Tests and application of M&S to NMD Testing.

5.1 Flight Test

Integrated Flight Tests (IFTs) are executed to demonstrate a hit-to-kill intercept by the NMD system. A payload containing a simulated warhead is launched from Vandenberg Air Force Base (VAFB) toward the Kwajalein Missile Range (KMR). The NMD system tracks the target and launches an interceptor. The data collected during the flight tests are used to validate the models and simulations within the NMD community.

5.2 Models and Simulations

The Integrated System Test Capability (ISTC) is a NMD system-level, Hardware-in-the-Loop/Software-in-the-Loop (HWIL/SWIL) test resource. It is a computer-based system for testing actual NMD element data processors and software in an integrated configuration through the use of simulated environments. The ISTC framework architecture is composed of a Test & Control Segment, Global Environments Segment, and Element representations connected via the Tactical Communications Network and a test infrastructure network. To achieve its purpose, the ISTC operates in real-time and drives the NMD system processors with realistic scenarios and environments. The ISTC is used to execute three types of testing: Integrated Ground Tests (IGTs), Pre-Mission Tests (PMTs), and Post-Flight Reconstructions (PFRs).

5.2.1 Pre-Mission Test (PMTs) PMTs are ground tests that are conducted as pre-mission risk reduction measures using the ISTC test framework set up with the NMD configuration for a particular flight test. PMTs provide confidence in IFT execution by predicting element performance and exercising element interfaces.

5.2.2 Post-Flight Reconstruction Test (PFRs)

PFRs are conducted subsequent to an IFT. The PFR uses the corresponding PMT configuration, modified to represent the actual environmental conditions and target dynamics observed in flight. The results of this testing are used to increase confidence in the NMD models and simulations.

5.2.3 Integrated Ground Tests (IGTs)

ISTC configuration for an IGT is comprised of the identical element representations used in PMTs/PFRs. However, IGTs use simulated environments and threat scenarios representative of operational conditions. The test data is used to demonstrate system performance under operational conditions.

6.0 APPLYING THE PARADIGM

The basic premise of the proposed paradigm is that things equal to the same thing, are equal to each other.

6.1 Establishing A = B

The initial effort in applying this acceptability paradigm is the generation of simulated test cases replicating the limited flight test samples. So, for each NMD IFT (A), there is a corresponding PMT/PFR (B) set of data that can be analyzed. Results of these analyses can establish the degree to which a given IFT (A) is equivalent to the corresponding PMT/PFR (B). The output of this analysis validates models and simulations within each element representation, as well as the target generation process. Therefore, A=B.

6.2 Establishing B = C

The element representations in both IGT (C) and PMT/PFR (B) configurations are the same. Collection of test data further supports the comparison and correlation of these configurations to one another. It is then reasonable to assume that B=C.

6.3 Establishing A = C

The data processors and tactical software used in IFTs (A), PMTs/PFRs (B) and IGTs (C) are the same. The models and simulations used in the PMTs/PFRs (B) and IGTs (C) are the same and have been validated against the IFTs (A). The test target generation process used in the PMTs/PFRs (B) was also validated against the IFTs (A). Finally, the environmental models must accurately reflect the operational space; therefore NMD uses a suite of community accepted environmental models in both PMTs/PFRs (B) and IGTs (C). Thus, if a given simulation (B) under flight test conditions (A), accurately reflects the observed performance of the flight test, then it is reasonable to expect the simulation to provide an accurate prediction under operational conditions(C). Therefore, A=C.

7.0 KEY VV&A CONSIDERATIONS

Inherent in the proposed paradigm is the execution with due diligence of commonly accepted M&S VV&A practices. These include verification and validation; identification of caveats and limitations; and formal accreditation of the test resource.

7.1 Verification and Validation

The simulation V&V activities are driven by data requirements that support accreditation decisions. Verification of a simulation is the confirmation that all data inputs, logic, calculations, and engineering representations within the simulation accurately portray the intended characteristics and interactions. Validation is the confirmation that a simulation reflects real world expectations. This is accomplished by comparing simulation results with flight test results.

7.2 Caveats and Limitations

The key feature of any accreditation is the identification of the caveats and limitations associated with the test configuration. Caveats provide advice to the analysts on the use of the test data, while limitations identify capability shortfalls of the test configuration. These caveats and limitations are keyed to the objectives and requirements of a given test.

7.3 Accreditation

M&S are abstractions and may not duplicate all actual observed phenomena; however, they can provide reasonable approximations. Based on V&V activities and integration testing, an assessment is performed to determine the extent to which the test configuration can meet test objectives and requirements. Accreditation is the official determination that the test resource provides credible data that can be applied to meet the intended uses with given caveats and limitations.

8.0 SUMMARY AND CONCLUSION

This paper articulates an approach of utilizing accredited M&S to “test the untestable”. Using the NMD program as an instance, an assessment paradigm formally linking simulation-based activities to real world tests is demonstrated. Fundamental to the paradigm is the notion that things equal to the same thing, are equal to each other; i.e., the transitive property from the axioms of equality, ***(If A = B, and B = C, then A=C***). Due diligence to commonly accepted M&SVV&A practices must be exercised. Care must be taken in executing a program of activities to establish relationships between test data sets. This paradigm supports the evaluation and assessment of systems like NMD, which cannot be tested in the normal sense.

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