ANCHORING METHODOLOGY OF THE NATIONAL MISSILE DEFENSE (NMD) INTEGRATED SYSTEM TEST CAPABILITY (ISTC): CORRELATING FLIGHT AND GROUND TEST DATA

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ABSTRACT:

The Integrated System Test Capability (ISTC) is a NMD System Test and Evaluation (T&E) Resource that is intended to be a detailed, high fidelity HWIL simulation with hardware and software components of the NMD Battle Management Command, Control, and Communications (BMC3), Ground Based Interceptor (GBI), Upgraded Early Warning Radar (UEWR), X-Band Radar (XBR), and Space Based Infrared Satellite (SBIRS). The ISTC is a source of NMD system and Element test data to support Developmental Test and Evaluation (DT&E), Operational T&E, Element Program Managers (PMs), the Lead System Integrator (LSI) and Systems Engineer. It is used in the execution of Integrated Ground Tests (IGTs), and Pre-mission and Post-mission support of Integrated Flight Tests (IFTs).

Current Department of Defense (DoD) and Ballistic Missile Defense Organization (BMDO) policies and directives applicable to the ISTC require formal verification, validation, and accreditation (VV&A) of test resources and simulations that support material acquisition decisions. Validation, generally defined as the determination of the degree to which a model or simulation adequately represents the real world from the perspective of its intended use, aids in establishing the credibility of ISTC as a test resource. Validation of ISTC therefore is critical to the overall success of the NMD test program. A primary method to be used in validating ISTC is the comparison, or anchoring, of ISTC outputs (pre-flight predictions or post-flight reconstructions) to data obtained from IFTs, and by extension to IGTs.

The Lead Systems Integrator for NMD is pursuing a policy of anchoring for all of its models and simulations (M&S). Anchoring within NMD is the comparison of M&S predictions with experimental (test) observations (measurements) for the purpose of ensuring the fidelity of the M&S representations of the system/subsystem. Numerical predictions obtained from selected test points within a simulation/model to be validated can be compared to equivalent test data types in order to validate the model. This process, termed Anchoring, compares the respective outputs in detail, and analyzes the causes for differences in outputs.

Using ISTC as an instance, this paper describes the methodology for: 1) determining key variables for anchoring analyses, 2) developing a generic anchoring evaluation process, 3) applying this process to the correlation of pre-flight predictions and post-flight reconstructions, and 4) anchoring, by extension, the "virtual" C-1 architecture within ISTC. This paper also discusses analysis limitations and risks associated with anchoring; as well as schedule, cost, and planning considerations for ensuring the highest level of descriptive validity.

1. INTRODUCTION

1.1 Purpose

Current Department of Defense (DoD) and Ballistic Missile Defense Office (BMDO) policies and directives applicable to the Integrated System Test Capability (ISTC) require formal verification, validation, and accreditation (VV&A) of test resources that support material acquisition decisions. Validation, generally defined as the determination of the degree to which a model or simulation adequately represents the real world from the perspective of its intended use, aids in establishing the credibility of the ISTC as a test resource. Validation of ISTC therefore is critical to the overall success of the National Missile Defense (NMD) test program. A primary methodology to be used in validating ISTC is the comparison of ISTC outputs (pre-flight predictions or post-flight reconstructions) to data obtained from actual Integrated Flight Tests (IFTs). This process, termed anchoring by the Lead System Integrator (LSI), compares the respective outputs in detail, and analyzes the causes for differences in outputs.

As part of the overarching BMDO NMD program, a series of IFTs is being conducted to assess the capabilities and effectiveness of the integrated NMD system. These IFTs present the opportunity to obtain real-world data for ISTC validation and anchoring activities. This paper addresses anchoring analyses performed for ISTC pre-flight prediction tests and post-flight reconstruction tests that are intended to support accreditation of ISTC data for use in the upcoming NMD Deployment Readiness Review (DRR).

1.2 Overview

This paper addresses a Verification and Validation (V&V) anchoring methodology successfully implemented for the NMD ISTC by the LSI. Anchoring is a comparison technique in which analysts use a baseline model (pre- and post-flight data from the ISTC) and real-world data (IFT data) to compare results from similar problems, compare respective outputs in detail, and analyze the causes for differences in these outputs. The confirmation that the processes and outputs from ISTC parallel real-world processes directly bears on favorable accreditation decisions for ISTC to serve as an NMD test resource in support of NMD deployment decisions. This systematic approach to the anchoring of embedded, complex models and simulations (M&S) such as ISTC to real world data is generally extensible to other simulation test beds, Hardware in the Loop (HWIL) and Software in the Loop (SWIL) test resources.

2. BACKGROUND

2.1 What is the NMD?

2.1.1 NMD Management

The NMD Joint Program Office (JPO) of the BMDO is managing the NMD Program. The LSI has the responsibility of managing the development and integration of the NMD Elements to deliver the NMD System. In addition, the LSI is responsible for the execution of the Developmental Test and Evaluation (DT&E) and System Verification programs. In support of these programs, the LSI will use simulation for analysis, design verification, integration, and test and evaluation (T&E).

2.1.2 NMD Description

The NMD is the integration of weapon, sensor, battle management, command, control and communications systems designed to provide protection against limited ballistic missile attacks targeted at the United States, including Alaska and Hawaii. The National Ballistic Missile Defense (BMD) mission provides surveillance, warning, cueing, engagement, interception and negation of threat objects prior to impact on US targets. This capability is achieved through integration of the NMD system with the Integrated Tactical Warning and Attack Assessment (ITW/AA) network to execute the BMD mission.

The NMD system is composed of space-based and ground-based sensors, ground-based interceptors, and an associated Battle Management/Command, Control and Communications (BMC3) capability. The NMD mission functions include detection, discrimination, and tracking; logistics and readiness; and collateral and theater support operations.

The NMD deployment is an evolutionary process based on an initial capability, known as Capability 1. The NMD system architecture employs the following elements:

- Ground-Based Interceptor (GBI)
- Ground-Based Radar-Prototype (GBR-P) (Prototypical of the objective X-Band Radar (XBR))

- Battle Management/Command, Control and Communications (BMC3) including In-Flight Interceptor Communications System (IFICS)
- Upgraded Early Warning Radar (UEWR)
- Defense Support Program (DSP)
- Space-Based Infrared System (SBIRS)

The Deployment Readiness Program incrementally develops interceptor, sensor and BMC3 technology. As the technology matures, the system capability correspondingly improves.

2.1.3 NMD Acquisition Approach

The NMD System is a Simulation Based Acquisition (SBA) program. Simulation is required since it is impractical to perform real world tests to answer many of the performance questions concerning a possible NMD System. Alternative architectures and Elements can be evaluated using accredited simulations anchored to actual test data. Since the simulations will be extrapolations of the models of the objective system, verification and validation (V&V) of the simulation and models provides the confidence needed to accept the simulation results.

2.2 What is the ISTC?

2.2.1 ISTC Description

The ISTC is a NMD system-level, HWIL/SWIL test tool. It is a computer-based system for testing actual NMD element data and signal processors and software in an integrated configuration through the use of simulated environments. The ISTC provides the capability to evaluate the performance of the prototype NMD system, determines the interoperability of the incremental software builds used in the NMD system, and determines the operational suitability of the human interfaces in the NMD system.

To achieve its purpose, the ISTC:

- Provides for the physical incorporation of the actual mission and communications processors of the NMD system,
- Utilizes the actual software that is installed in the mission and communications processors,
- Operates in real-time,
- Drives the NMD system processors with realistic scenarios,
- Subjects the system assets to realistic threat and environment effects in demanding scenarios, and
- Collects data to support post-test system-level performance analysis.

The ISTC has the capability to integrate all of the major components of the NMD system. The test configuration is a representation of individual elements operating in concert, as part of an overall architecture, and its objective is to provide an accurate exercise of the NMD system under realistic stresses that would be encountered in an operational environment. The ISTC is also the only cost-effective means to assess the effects of hostile environments including nuclear effects on the real-time responses of the integrated NMD system's computers.

2.2.2 ISTC Architecture

Individual elements of the NMD system are represented in the ISTC on stand-alone computer stations known as nodes. Each node incorporates actual NMD element mission and communications processors that execute actual element software. The individual element nodes are interconnected by a surrogate NMD system communication network driven by real-time system interfaces, and threat and environmental input data. The nodes are also connected by separate ISTC networks that control the test equipment. The ISTC supplies the autonomous nodes with simulated threat and environments, natural and man-made, that are consistent for each NMD element in the test scenario.

The ISTC architecture is composed of a Test & Control (T&C) Segment, Global Environment (GE) Segment, System Performance Monitor (SPM) Segment, Element Segments consisting of one or more Element nodes, and an External Interface (I/F) Driver Segment. These segments and nodes are tied together via a Tactical Communications Network and Test Networks.

The following NMD elements are currently represented within ISTC - the NMD BMC3, GBR-P, UEWR, Weapon System, and DSP/SBIRS. These Element Representations are on a development path to the objective system.

3. OPERATIONAL ENVIRONMENT

3.1 NMD Test and Evaluation

The NMD test program is structured to provide demonstrated evidence of progress toward the verification of system-level functional capability. The test program is kept flexible so that it may embrace each step or degree of element performance as the elements mature. As element developers produce test articles and prototypes on their developmental schedule, representations of increasing levels of fidelity are utilized for integrated system testing.

3.2 Integrated Flight Testing

Integrated Flight Tests (IFTs) verify integrated NMD system performance and provide fully integrated end-to-end system demonstrations using threat representative targets. They provide test data to assess the level of the integrated element capabilities and verify that system requirements and performance objectives are being met. The IFTs demonstrate that integration and interface effects of the NMD elements, target, and environment variables are accounted for in a flight environment. They contribute to verification of lethality, probability of hit, probability of kill, and target debris predictions. The IFTs replicate, with an increasing degree of accuracy, the actual operational system. Test planning and execution for the IFTs is conducted in three stages, pre-mission, flight test, and post-mission, as depicted in Figure 1.

3.3 Tests Within ISTC

The ISTC primarily supports the NMD T&E effort through the execution of a series of Integrated Ground Tests (IGTs). The ISTC, in addition to serving as a risk reduction tool for integrated flight tests, will provide a capability to exercise the objective C1 systems over a broad range of scenarios with multiple iterations of each scenario in support of IGTs.

Integrated ground testing will be conducted using element hardware (processors) and software. The integrated ground testing using simulated environments and full threat scenarios is performed to evaluate the C1 system performance and effectiveness and provide supporting data required for the deployment decision. Data obtained from IFTs will be used to validate ground testing and to assess the operation of the deployable NMD elements.

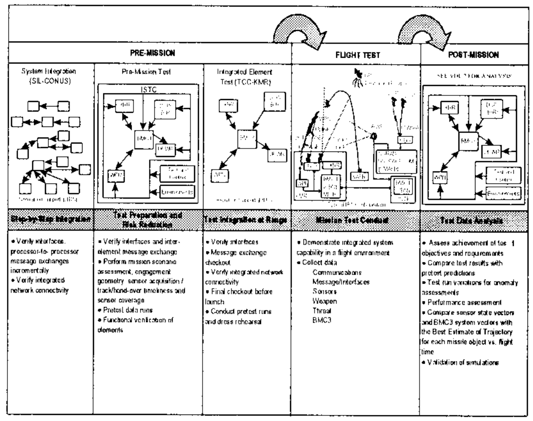

Figure 1. Test Plannin g and Execution of IFTs

The ISTC also serves as an NMD test tool to conduct Pre-Mission Tests (PMTs) and Post-Flight Tests (PFTs) for Kwajalein-based missile tests. In this role, the ISTC serves as a risk-reduction resource for IFTs.

3.3.1 Pre-Mission Tests

Pre-Mission Tests (PMTs) are nondestructive, system-level tests representing the use of NMD Element Test Assets in their IFT configurations to provide pre-flight prediction data in support of flight test risk reduction. The PMT test configurations include a mix of element nodes that are actual Hardware-in-the-Loop (HWIL) test articles, element models, or ISTC test drivers. Test drivers provide limited representations of their associated elements and may be utilized by ISTC as placeholders until the HWIL test article element nodes are delivered and integrated.

The PMTs focus on the engagement envelope for the system given the range constraints and flight test scenarios. A number of different flight test scenarios are exercised to establish risks to the successful execution of the flight test. PMTs are conducted to demonstrate the interoperability of the flight software and processors slated for use in IFT; but do not address anomalous system behaviors that might be associated with hardware failures.

The primary objective of pre-mission testing is risk reduction for the IFT. While it is possible that the IFT could closely follow what transpired in the pre-mission testing, chances are there will be differences and that these differences will significantly effect the pre-mission/IFT data comparisons. Post-mission testing has a substantially higher probability of replicating the IFT and providing good data for comparison.

3.3.2 Post Flight Reconstructions

Post-Flight Reconstructions, or Post-Tests (PTs), are designed to replicate the IFT as closely as possible, given available data and resource constraints. Conduct of a PT requires the LSI to hold or freeze the PMT configuration for both the Elements and the test framework within the ISTC. Test scenario trials are then conducted running the ISTC from end-to-end with initial flight conditions based on the Best Estimated Trajectory (BET) data and Radar Cross Section (RCS) signatures from the flight test.

The primary rationale for the conduct of post-mission reconstructions is the likely inadequacy of pre-mission tests to support rigorous validation of the ISTC. That is because the primary purpose of pre-mission testing is to serve as a risk reduction for the associated integrated flight test. Consequently, collecting pre-mission test data for validation against IFT data is an add-on, and the priority for scenarios to be run will be based on achieving the greatest probability of success with the IFT, not the data requirements needed for anchoring. Also, it is unlikely that any pre-flight scenario will exactly match the actual flight test initial conditions and timeline, and thus, post flight reconstructions enable the correlation of data sets in which initial conditions are nearer.

4. ISTC ANCHORING APPROACH

4.1 Rationale for ISTC Anchoring to IFTs

Anchoring is the comparison of model predictions with experimental (test) observations (measurements) for the purpose of ensuring the validity of the M&S representations. It is one of several techniques used to establish the validity of ISTC by correlation of ISTC results to live test data captured during IFTs. The IFTs are the only scheduled NMD test events to provide relevant data on integrated system-level behaviors that can be used as the reference data for anchoring the ISTC.

Several directives, policies, and related publications released by the DoD and each of the Services stress the importance of a formal V&V program for M&S and provide guidance for the simulation and modeling community in developing a V&V program. A review of these policies and directives indicates a growing consensus on the necessity to subject M&S to a formal, structured V&V program. Because the BMDO, the Army Test and Evaluation Command (ATEC) and Air Force Operational Test and Evaluation Agency (AFOTEC) each intend to independently accredit the ISTC, the associated BMDO, Army and Air Force VV&A policy guidance is particularly pertinent to the ISTC anchoring process implemented by the LSI. Overall guidance from these policy directives regarding validation and anchoring prescribes a comparison of the test resource processes and output against real-world physical data such as flight experiments, component tests, or combat experience

Numerical predictions obtained from selected test points within a simulation/model to be validated can be compared to equivalent test data types in order to anchor the model. Anchoring can be accomplished in three main ways: statistically, technical judgement, or a combination of both. The statistical approach can be used under certain somewhat ideal conditions to obtain a degree of mathematical confidence, but the statistical results must be assessed carefully by the engineering or technical experts in order to avoid erroneous blind conclusions. Technical judgement on the other hand is not as formally rigorous, and introduces extensive engineering, scientific or mathematical judgement into the assessment of the reasonableness of both the test data and simulation/model output.

4.2 Identification of Validation Parameters

The focus of anchoring analyses is to establish confidence in the ISTC as a test resource to evaluate NMD element and integrated NMD system performance, as well as to provide validation data to support accreditation of ISTC as a test resource. The anchoring activities are primarily designed to assess and determine the degree to which the IFT target representation, NMD element representations, BMC3 message traffic, and NMD system behaviors in the PMTs and PTs are representative of real world phenomenology when compared to IFT test data. Anchoring activities are performed supporting assessments in the following four major areas:

1) Target Representation

2) NMD Element Representation

   a) Sensors
   b) Weapons (GBI/EKV)
   c) BMC3

3) NMD Element Integration (BMC3/Element Message Traffic)

4) NMD System Behavior (Event Timelines, etc.).

For each parameter, the average predicted value from the simulation (PMT or PT) and actual value from the range (IFT) are compared to assess ISTC's ability to generate comparative real-world data.

4.3 Methodology and Approach

A generic evaluation process model for output validation for IFT, PMT and PT activities is illustrated in the functional flow block diagram provided in Figure 2. This activity / data flow diagram illustrates the components of a generic evaluation process applicable to any evaluation enterprise, but particularly pertinent to IFT and PMT/PT correlation studies.

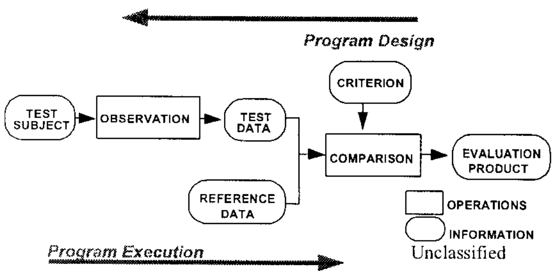

Figure 2. Generic Evaluation Process Model. (U)

This process involves the following components and associated activities:

1) an observation of a test subject or M&S within ISTC, their predictive results, or the attributes of particular interest,

2) a comparison of data derived from the Test Subject or unit-under-test (UUT) to reference data established by independent means; i.e. IFT data,

3) evaluation against acceptance criteria, and

4) generation of an evaluation product (results).

The activities undertaken in the ISTC validation process are focused on collecting NMD ISTC and Element specific data and provide for comparison applicable reference data from IFTs or other NMD system test events. This flexible validation paradigm is universally applicable and serves as the assessment template for the ISTC validation activities. An example of the application of this generic process is executing the ballistic missile model for a threat representation in the ISTC, observing the resultant trajectory, and comparing it to the real-world trajectory of the flight test target. Evaluating and confirming the expected similarities in the trajectories to within some established degree of precision completes the validation process.

The overall methodology and assessment approach employed for anchoring ISTC pre-flight prediction and post-flight reconstruction data to IFT-4 truth data consists of the following activities/process steps:

- *identifying* ISTC and IFT data parameters to be evaluated;
- *analyzing* ISTC data from PMTs and PTs activities to ensure completeness and correctness;
- *analyzing* IFT data to ensure completeness and correctness;
- *assessing* data generation/collection differences between the IFT and PMT/PT to determine which data comparisons should and should not be made;
- *identifying* configuration differences between IFT and PMT/PT and assessing impact, if any, to data comparisons;
- *comparing* ISTC data from PMT and PT activities and IFT data to assess whether or not differences between variables/parameters fall within allowable/acceptable ranges;
- *generating* data comparison tables and graphical data displays (data plots);
- *analyzing* results and findings;
- *identifying* any anomalies and significant data comparison differences; and
- *annotating* any implications of data comparison differences.

4.4 Correlation Techniques

Correlation analysis, via the use of statistical hypothesis testing, is aimed at performing pair-wise comparisons of data sets for selected ISTC validation parameters and flight test reference data collected by range instrumentation, so that differences may be identified. Two sample data sets are said to correlate, or equate, if it can be determined that they are analogous with respect to certain distribution parameters. Hypothesis testing provides a means of determining how well the distribution shape, location, and dispersion parameters of two data sets are equated. For each distribution parameter, an appropriate comparison test is selected. The underlying hypothesis of each test is that the two data samples are equivalent, that is, that they represent the same true population. The two data sets are determined to correlate if, in performing the test, the hypothesis cannot be rejected with reasonable confidence.

Numerous hypothesis tests are available for comparison of the sample data sets. However, valid application of a test necessitates meeting its underlying assumptions and data requirements. Successful application is predicated on selection of a test that is both valid and powerful in determining the extent to which the data sets correlate.

Regardless of the type of hypothesis test selected, an identical methodology for performing the test is employed, i.e. a test statistic value is computed by inserting the collected data values from the two samples into a mathematical equation. However, it must be noted that when using statistical hypothesis testing, it is *not* possible to conclude that two sets of sample data are the same *with absolute certainty*. Instead, the underlying hypothesis must be accepted or rejected based on the probability of obtaining the generated test statistic, along with the evaluator's desired confidence level.

5. ANCHORING CHALLENGES

5.1 Data Constraints and Caveats

Data constraints and limitations impact how the anchoring assessment is conducted. These limitations also bound the results and conclusions and impact how those results are interpreted and applied to future LSI system and element analyses. This section attempts to help place the data, analyses and recommendations derived from the anchoring analyses in proper perspective.

In general, there are several limitations in formally validating NMD system behaviors observed in the ISTC during PMTs and PTs using IFT data. Each of these limitations affects the scope and breadth of these validation correlation analyses and is discussed more fully in the following paragraphs.

Replication of Environment, Initial Conditions, and Elements. Decisions regarding the test scenario and initial conditions potentially cause differences to occur between the actual IFT environment and that used in the ISTC for PMTs and PTs, that could adversely affect anchoring comparisons. However, a degree of confidence in the ISTC global environment models, gravity model, propagator, etc. has been achieved through separate V&V activities delineated in the LSI ISTC V&V Plan. Specific caveats designated for PMT and PT test scenarios are detailed in PMT accreditation or certification documentation. Examples are as follows:

1) Modeling nominal environmental effects, i.e. not varying environmental effects;

2) Modeling nominal element performance, i.e. not varying of the noise, biases, thrust misalignments or previous IFT IMU errors; and

3) Modeling nominal target dynamics, i.e. not implementing excursions in coning angles, tumbling, and deployment anomalies.

Lack of Breadth and Depth of Test Data. This limitation involves the ability to both generate and collect the necessary data for the anchoring comparisons. Portions of the data supporting validation parameters may not be available for assessment because the data was either not generated, or not collected. For example, if EKV internal data was not able to be collected in the IFT, portions of the EKV correlation analysis would be limited as well. Similarly, in some instances, data may not be assessed uniformly across test cases due to test event anomalies or insufficiency of collected data.

Potential for Unsuccessful Intercepts in IFTs. An unsuccessful intercept during an IFT will greatly limit the scope and breadth of the correlation analyses that can be accomplished for the end-game data that is collected in PMTs and PTs. While the primary objective of the pre-mission testing is risk reduction for the IFT, hardware failures will not be represented in any of the test scenarios scheduled for execution in PMTs and PTs. For example, the EKV anomaly experienced in IFT-4 was not anticipated or predicted in the PMT-4, nor was it replicated in PT-4. Consequently, this limited the comparison of the EKV end game performance and subsequent analysis of weapon tracking and discrimination performance.

Collectively, the preceding limitations identified bound the analyses and the statistical significance of anchoring analysis findings.

5.2 Data Variability in ISTC

Correlation analyses supporting anchoring assessments are based on limited data sets and also constrained by the total number of runs conducted in PMTs and PTs. This results in a set of sample test data that limits the capacity to make definitive conclusions that the ground test data are the same as the flight test results with absolute certainty, or even statistical significance. Instead, this underlying hypothesis must be accepted or rejected based on the test statistics that are generated along with the confidence level desired (required) by the evaluator (accreditation authority).

However, these correlation analyses between PMT and PT test cases and actual IFT-4 results are affected somewhat by run-to-run variability that exists within each test case. This run-to-run variability may be due to several factors that can cause subtle differences in the test scenario being executed within the ISTC. Each of these factors which contributes to run-to-run variability within ISTC is discussed in the following paragraphs.

Random number generation. Although the ISTC software builds used in PMT and PT supports re-entrant random number generation for parallel processing functions, this software may not be the random number source across the entire, integrated ISTC configuration. Element Representations within ISTC may utilize their own random number generators, and consequently, although the ISTC is intended to be deterministic, there may be Element processes that are not controlled by the framework software. As a consequence, this introduces the potential for differences in run-to-run behaviors that were observed in the set of runs for each particular test case.

Data latencies. The ISTC configuration used for PMT-4 and PT-4 included a surrogate representation of the prototype tactical communications network. Additionally, the ISTC LANS and NTE/PTE interfaces used for PMT-4 and PT-4 transport information to each Element. This network, as is any network, may be subject to introducing data latencies due to network loads that are a function of the Element processor behaviors. Consequently, in a closed-loop simulation experiment like PMT-4 and PT-4, when Element behaviors differed from run-to-run, the network loads would potentially be impacted, and thus contribute to the introduction of data latencies, which could then introduce even more differences in Element behaviors.

Human-In-Control within the BMC3 Element. Although each test case is pre-defined and scripted for PMTs and PTs, there are opportunities to introduce run-to-run variability due to the Human-In Control feature of the BMC3 Representation integrated into the ISTC. Human operators sitting at BMC3 consoles must interact within the pre-scripted scenario, but man-machine interfaces in which operator delays in responding to screen prompts, or differences in keying data can potentially have profound impacts on the actual run. Even minor differences in the timing of operator cues and reactions to screen prompts may affect subsequent Element behaviors within the closed-loop environment of the ISTC.

5.3 Limited Resources to Perform Sufficient Post Flight Reconstruction

While it is possible that the IFT could closely follow what transpired in the pre-flight testing (PMT), the opportunities for differences between the simulation and the actual flight test can significantly affect the data comparisons. For example, a minor change in velocity profile for either the target or interceptor adversely affects any time-series data correlation. Therefore, post-flight reconstructions generally have a substantially higher probability of accurately replicating the IFT and providing better data for comparison and validation analyses by matching the actual, initial test conditions. Unlike pre-flight predictions, post-flight reconstructions consist of events tailored to the generation of data for comparison of ISTC results to the actual IFT results.

To sufficiently conduct post-flight reconstructions, the LSI must manage the configuration of the Elements and the test framework within the ISTC, or be able to "fallback" to the Element configurations used in the IFT for post-flight reconstruction. Current ISTC testing plans and associated integration and test schedules prescribe changes in the Element representations soon after completion of either the pre-mission tests, or the IFTs. If Element and framework configuration changes within the ISTC are not managed well in support of the post-flight reconstructions, it is likely that replication of the conditions present during IFTs will not be possible in the ISTC.

The necessity to manage the configuration of the ISTC has an impact on the overall ISTC schedule. Two to six weeks for ISTC configuration "lock-down" are estimated to be required for each post-mission reconstruction. That timetable could also be impacted by the time required to obtain IFT data from the range.

Another factor of significant importance is the cost for execution of post-mission reconstructions in both time and labor.

5.4 Limitations of IFT Anchoring Analyses

The IFTs are centered on the Kwajalien Missile Range with support from the Vandenberg Air Force Base and the Joint National Test Facility. There exist two major limitations with this live test environment available for NMD system level testing:

1) Limited live flight testing opportunities. There are only a few live flight tests planned for the

NMD system prior to DRR and 8 planned for post-DRR.

2) The inability of KMR to replicate the complete operational requirements of the NMD system at C-1 and beyond. The objective C-1 system calls for several functional behaviors that cannot be evaluated by the existing KMR and Vandenberg test facilities.

5.4.1 Extension of Flight Test Anchoring to Address C-1 Architectures

Standard anchoring practices involve the comparison of data from live tests and evaluation to simulation runs using the same architecture and test criteria. If a live test and corresponding simulation use the same architecture, and execute the test in the same way, and the same data can be gathered from both, then the data sets share common features. An evaluator is then able to assess how accurately the simulation represents the real world through the shared features of the data set. Confidence in testable circumstances is derived from the deductive and inductive inferences applied by the evaluator as engineering judgment and experience.

An anchoring challenge exists in the conceptualization and methodology to extend correlations of ISTC PMT and PT data from flight test comparisons to untestable C-1 architectures utilized in Integrated Ground Tests (IGTs). This approach must leverage on practical connectivity and shared features to ensure that the ISTC can capture a C-1 data set from the same elements at the same capture points as was accomplished during the comparison to IFT data. Once the accuracy of the ISTC is established by comparisons to live test events, the use of the ISTC can then be used to extend the battlespace to untestable scenarios involving the C-1 architecture.

5.4.2 Challenges Associated with Utilizing ISTC-2 for PMTs

The ISTC presently serves in two capacities as an NMD test tool. First, the tool is used to conduct PMTs and PTs for Kwajalein-based missile tests. In this role, the ISTC serves as a risk-reduction resource for IFTs. Secondly, the ISTC is being used for IGTs in order to predict the performance of the NMD objective system.

ISTC participation in both IGT and PMT/PT activities has resulted in an increased demand on the ISTC resources. Increased testing in both areas in support of upcoming deployment decisions has taxed the schedule utilization of the existing tool. The proposed hardware/software solution is to expand the current ISTC capabilities to include a second ISTC hardware and software suite solely allocated for performance of PMT and PT tests. The first ISTC (ISTC-1) will continue to focus on IGT testing as a primary role, with a secondary role of PMT/PT support. This concept is designed to reduce overall program risk (schedule) by allowing PMT/PT and IGT test configurations to exist and be tested in parallel, rather than sequentially.

Anchoring challenges exist in:

1) Confirming that ISTC-2 produces the same results when compared to ISTC-1 data using the same test scenarios; and

2) Ensuring that utilization of ISTC-2 and ISTC-1 for PMT/PT and IGT test events, respectively, does not significantly compromise the extension of IFT anchoring to IGTs.

6. OBSERVATIONS AND CONCLUSIONS

Current Department of Defense (DoD) and BMDO policies and directives applicable to the ISTC, such as DoD Directive 5000.59 and BMDO Directives 5002 and 5011, require formal verification, validation, and accreditation (VV&A) of test resources that support material acquisition decisions. Validation, generally defined as the determination of the degree to which a model or simulation adequately represents the real world from the perspective of its intended use, aids in establishing the credibility of ISTC as a test resource. Anchoring, the primary means used to validate the ISCT, therefore is critical to the overall success of the NMD test program.

Explicit specification of the acceptance criteria for anchoring is imperative for tailoring and applying the generic validation process to the individual models and simulations within ISTC. The determination of evaluation criteria values (i.e., what constitutes 'good enough') will be derived logically from the need for confidence in the characteristics of the respective M&S in close coordination with the NMD Element representatives.

The availability of sufficient test (comparison) data and the information needed for accreditation decisions may have an impact on the ISTC validation evaluation activity and resultant Technical Assessment Reports (TARs). Where IFT data is limited, Element tests may have to serve as alternative sources for reference data.

When real world, IFT or Element tests data is not available then other validated, high fidelity models or simulations may have to be used as information sources in order to benchmark and validate ISTC performance.

Detailed anchoring assessments for ISTC PMT-4/PT-4 and IFT-4 have recently been completed by AEgis Technologies. This analysis, as might be expected, demonstrates that post-flight reconstructions have a substantially higher probability of more closely replicating the IFT than PMTs and providing data necessary for anchoring ISTC to flight tests. Consequently, if sufficient post-flight reconstructions are not conducted within ISTC, there is a very real risk to the NMD program. Inadequate or inconclusive anchoring of ISTC to flight test data could lead to much, or all of the ISTC data supporting the deployment readiness review being rejected by the Government, particularly the operational test agencies. The inherent risks to the Government in using ISTC data to support an acquisition decision, if the ISTC is not demonstrably anchored to flight test data, may be so high that skepticism over the quality of the results provided by ISTC-based testing and the validity of the entire ground test program could be compromised.

7. REFERENCES

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7.1 Authors' Biographies

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