

INCORPORATING THE INTEGRATED SYSTEM TEST CAPABILITY (ISTC) INTO SYSTEM INTEGRATED EXERCISES (SIE) FOR THE NATIONAL MISSILE DEFENSE (NMD) TEST PROGRAM

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ABSTRACT: The National Missile Defense (NMD) test program utilizes a variety of tools to support system evaluation, including: 1) digital simulations, 2) Integrated Ground Tests (IGTs) using hardware-in-the-loop (HWIL), 3) distributed exercises known as System Integrated Exercises (SIEs), and 4) Integrated Flight Tests (IFTs). Collectively, these activities assess the capability of the NMD system to perform its ballistic missile defense mission.

The SIEs were proposed and incorporated into the NMD Test and Evaluation Master Plan (TEMP) as a timely and cost effective approach to enhance the test program by providing performance margin and system capacity data via the use of distributed test assets. The SIEs are intended to provide: 1) a significant reduction in the NMD test and evaluation program risks, 2) additional system assessment data in support of the NMD Deployment Readiness Review (DRR), and 3) an opportunity for early user assessment of the NMD system.

The Integrated System Test Capability (ISTC) is an NMD system-level HWIL test resource, a computer-based system for testing actual NMD element data processors and NMD element software in an integrated configuration through the use of simulated environments. Individual elements of the NMD system are represented in the ISTC on individual, stand-alone computer stations known as nodes. This paper will examine how the ISTC, which is a detailed, high fidelity HWIL program with hardware and software components of the NMD Battle Management Command, Control, and Communications (BMC3), Ground Based Radar (GBR), Ground Based Interceptor (GBI), Upgraded Early Warning Radar (UEWR), and Space Based Infrared System (SBIRS) program, may be incorporated into the SIE program to provide greater confidence in the resultant data.

1.0 Introduction

This paper addresses how the National Missile Defense (NMD) may incorporate the Integrated System Test Capability (ISTC) into a System Integrated Exercise (SIE). The definition phase is underway to circumscribe a test architecture using the NMD pieces that are currently available.

The NMD is a combination of elements from several sources that are to be integrated to form a highly responsive system that counters ballistic missile threats against the United States. A significant legacy of sensors, defensive weapons, command and control, threat models, and infrastructure already exist in various states of maturity. The basic NMD concepts have been studied and analyzed for many years yielding a large number of legacy Test and Evaluation Resources, Models and Simulations (TERMS). These also are in various states of maturity and range from special purpose TERMS that address specific aspects of the problem to system level TERMS. Continued use and refinement of these TERMS will greatly enhance, promote, and speed the development of a deployable NMD system and support analysis and testing of the evolving elements that will eventually comprise the NMD.

Because the NMD system is so complex and fully integrated, live-fire testing against realistic threat targets is costly, it is impractical to evaluate the performance of the NMD system entirely through flight testing. As a result, the development of the NMD system and programmatic decisions regarding its development rely heavily on information generated by a variety of sources. The SIEs were proposed and incorporated into the NMD Test and Evaluation Master Plan (TEMP) as a timely and cost

effective approach to enhance the test program by providing performance margin and system capacity data via the use of distributed test assets.

1.1 Purpose

This paper addresses how ISTC may be used in an SIE as an opportunity to assess system performance within threat and environmental envelopes not available in Integrated Flight Tests (IFTs). The concept of how ISTC in an SIE can encompass a full range of integrated activities including end-to-end, Battle Management Command, Control and Communications (BMC3)-to-element, and intra-element exercises will be discussed.

1.2 Overview

This paper includes an overview of the ISTC, an introduction to the SIE program concept, a discussion of how elements are integrated into ISTC for test, and a description of the test architecture currently being considered.

2.0 Background

2.1 What is ISTC?

The ISTC is an NMD system-level Hardware-In-The-Loop (HWIL) test resource. It is a computer-based system for testing NMD system element data processing hardware and software in an integrated configuration through the use of simulated environments. Each element of the NMD system is represented in the ISTC on individual, stand-alone computer stations known as nodes as shown in Figure 2.1-1. Each node incorporates actual system element mission and communication processors running actual element software.

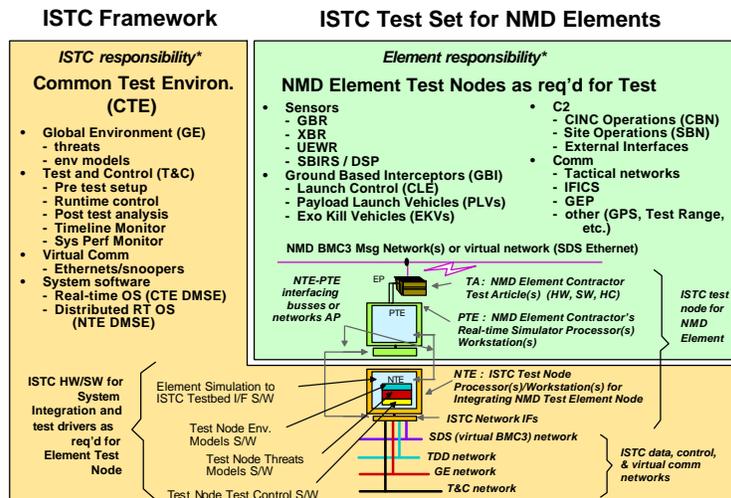


Figure 2.1-1 Element Node Definitions: CTE, NTE, PTE and EP.

The individual element nodes are interconnected by an NMD system communications network which is driven by real time system interfaces, and threat and environment input data. The nodes are also connected by separate ISTC networks that control the test equipment. The ISTC supplies the autonomous nodes with simulated threats and environments, natural and man-made, that are consistent for each NMD element in the test scenario. In this manner, ISTC exercises the entire NMD system simultaneously.

ISTC development progresses in a series of “builds” with each successive build increasing ISTC test/test support capabilities. Hardware and software components of the NMD BMC3, Ground Based Radar (GBR), Ground Based Interceptor (GBI), Upgraded Early Warning Radar (UEWR), and Space Based Infrared System (SBIRS) program are integrated into the ISTC as they are developed.

The ISTC currently operates closed loop via a Tactical Communications Network and Test Networks within the Advanced Research Center (ARC); but, there is an emerging requirement to support distributive testing in the FY99 time frame to incorporate other NMD Element representations which cannot be duplicated and placed into the ARC, such as UEWR and SBIRS.

2.1.1 ISTC Framework

The function of the framework is to make the aggregate NMD Test Configuration behave as though all the test elements were operating in a real NMD scenario with real-time, real-world dynamic interactions and conditions. The framework supplies each autonomous test node with its own simulated threat and associated environments, natural and man-made, that are uniquely tailored to the dynamic conditions of the node, yet globally consistent across all elements in the test scenario. In this manner, ISTC exercises all NMD system elements simultaneously under a common set of synchronized battle conditions.

The framework consists of the Common Test Environment (CTE) nodes and distributed software as well as assignable-resource processor nodes and Man-Machine Interface (MMI) displays, and any test data and control networks as required to control the test and collect data.

Framework nodes provide common test services in support of the operation of the testbed. These nodes and

their associated software are collectively called the CTE. The primary nodes of the CTE are:

- the Test & Control (T&C) Node,
- the Global Environment (GE) Node,
- the System Performance Monitor (SPM) Node, and
- the System Timeline (TL) Node.

In addition to these nodes, surrogate element test driver models of individual elements are represented. These digital models can be used to facilitate testing of the tactical elements.

2.2 What is an SIE?

As outlined in the Test and Evaluation Master Plan (TEMP), the NMD test program is a continuum of simulations, Integrated Ground Tests (IGTs), Targets of Opportunity (TOOs), Hardware-in-the-Loop (HWIL) tests, System Integrated Exercises (SIEs), and Integrated Flight Tests (IFTs) to assess the capability of the NMD system to perform its ballistic missile defense function. SIEs were proposed by the System Engineering and Integration Contractor and incorporated into the TEMP as a timely and cost effective approach to enhance the test program by providing performance margin and system capacity data.

SIEs are classified as another category of system-level distributed test. At the core of the exercise configuration are the NMD element representations or prototypes enhanced to include embedded test, training, and exercise (TT&E) capabilities as specified in the NMD Operational Requirements Document (ORD) and the Capability 1 (C1) System Requirements Document (SRD). SIEs encompass a full range of integrated exercises (end-to-end, BMC3-to-element, and intra-element). These exercises will be driven by pre-generated threat and environment scenario stimuli that are synchronized and injected into the configuration by the TT&E capabilities. Threat scenarios may represent either the one-on-one targets of the integrated flight test program or the many-on-many target scenarios of the Design-To Threats for NMD.

This series of exercises provide:

- a significant reduction in the NMD test and evaluation program risks,
- additional system assessment data in support of the Deployment Readiness Review (DRR), and

-an opportunity for early user assessment of the NMD system.

In addition, the initial SIEs will be structured to support the DRR by “dry-running” IFTs and the Integrated System Tests (ISTs).

The test objectives for a particular SIE event will vary due to the degree to which the system is completely or accurately represented, the manner in which specific objectives are allocated and the nature of the specific issues to be resolved. In the early stages they will be more developmental versus operational in nature and oriented more towards investigating interoperability and element/element or element/system integration issues. For some elements the HWIL realism and the target/environment driver modeling will be minimal, e.g., SBIRS which is represented by a low fidelity model within ISTC. As the SIE architecture matures, actual prototype hardware will be used and higher-fidelity TT&E drivers will be incorporated. In the future, the SIE resource will be able to provide a tool to test the NMD C1 operational effectiveness and suitability in the most operationally realistic environment possible.

3.0 ISTC Integration Approach

Element integration into the ISTC is a joint effort between the NMD Element Project Offices with their development contractor teams and the ISTC Project Manager (PM) with his development, Verification and Validation (V&V) and Systems Engineering and Technical Assistance (SETA) contractor team. The

integration of NMD element representations into the ISTC is based on the system engineering approach which considers top-level requirements that are allocated into the ISTC architecture. The integration of new components into the ISTC follows a general process that is appropriate for rapid prototyping development. Each NMD Element PM is responsible for accreditation of their element representation in ISTC prior to its use in any formal system performance assessment. The objectives of the PM’s accreditation of the respective element representation include:

- documenting the information necessary for accrediting the use of a particular M&S or HWIL configuration for use in a particular test;
- identifying its configuration;
- documenting its capabilities and limitations;
- identifying the element representation’s development and use history, if any;
- understanding the implications of its limitation and constraints in the test design.

There are four phases in the element representation accreditation process as indicated:

- 1) Delivery to ISTC.
- 2) Integration into the ISTC Framework.
- 3) Integration into the test configuration.
- 4) Test configuration ready for the SIE.

Figure 3.0-1 depicts the progressive integration process and associated incremental accreditation of the ISTC and element representations within it.

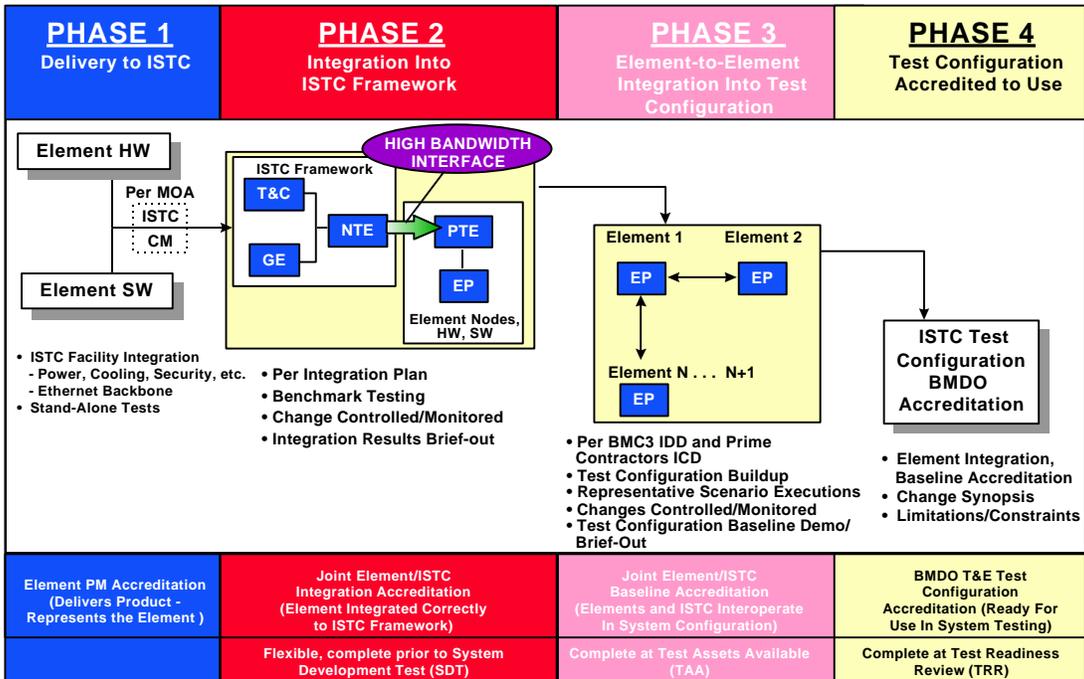


Figure 3.0-1 Element Representation Accreditation Process.

3.1 Phase 1 – PM Delivers Element Representation To ISTC

The PM delivers the Element software/hardware for use in ISTC. The PM accredits the Element as representative of element product within specified limitations and usage constraints. The Element hardware and software configuration is loaded and verified by the element and ISTC Configuration Management (CM) representative. The Element representation is received into ISTC CM per Memorandum of Agreement (MOA) for specific test support.

During phase 1 (see Figure 3.1-1), the element developers will conduct tests using a series of drivers to stimulate the processor test environment (PTE) and element processors (EP) or real-time simulations (RTSim). The final step in element integration is the test of the standalone node. The ISTC development test at this level is the responsibility of the ISTC Development Team. During tests at this level, the ISTC V&V team monitors the testing activity as part of its preparation for later test executions.

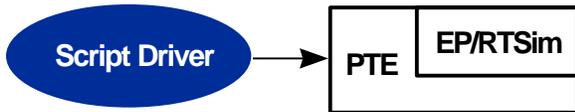


Figure 3.1-1 PTE-EP/RTSim Stand-Alone.

3.2 Phase 2 –Element Integration Into ISTC

The Element representation is then integrated into the ISTC Framework in accordance with a jointly defined ISTC/Element Integration Plan. The integration progress is tracked through a series of integration steps identified by benchmarks or milestones. The ISTC CM Team tracks any modifications to the Element representation and/or ISTC Framework. During this step script files are initially used to test the node and verify the integration of the node test environment (NTE) with the PTE/EP (see Figure 3.2-1).

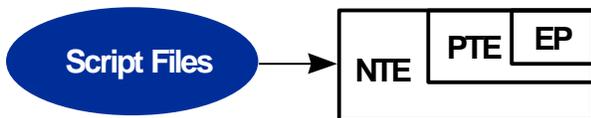


Figure 3.2-1 Element Node Stand-Alone.

After successful integration of the NTE with the PTE/EP the integrated product called the element node is then integrated into the ISTC framework. As illustrated in

Figure 3.2-2, this system level element-to-element verification test completes the element integration process. The Element Node is dynamically stimulated via the ISTC framework T&C and GE in lieu of the pre-scripted files. During this phase of the element integration process the other NMD elements are represented by ISTC test drivers or surrogate models. Upon completion of Element/ISTC Framework integration activities, the Element and ISTC PMs will jointly review the integration results and accredit the integration, subject to identified limitations and constraints.

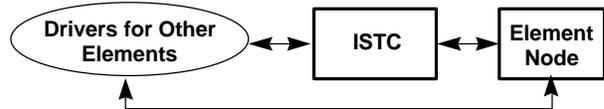


Figure 3.2-2 Single Element Integration.

Once the standalone node has been integrated correctly into the ISTC framework, the development test is the responsibility of the ISTC development team’s system integrator. During tests at this level the ISTC Test Team monitors the testing activity.

3.3 Phase 3 – Element-to-Element and System Level Integration

Upon completion of element/ISTC Framework integration activities, the ISTC/Elements configuration will undergo initial testing of the baseline configuration to verify the connectivity to other Element Nodes participating in the test. As illustrated in Figure 3.3-1, the Element Node is then integrated into the ISTC Framework. The Element Node is dynamically stimulated via the ISTC Framework T&C and GE in lieu of pre-scripted files. Elements participating in the test incorporate available HWIL representations. Other Elements not participating in the test are represented by the ISTC test drivers/surrogate models.

Scenarios representative of those planned for the “MOA Specified Test” will be executed, within the constraints and limitations that are specified by the participating elements and ISTC framework. Any modifications to element representations and/or ISTC framework will be tracked by ISTC CM. Upon completion of the baseline testing, all PMs with products participating in the “MOA Specified Test”, will jointly review the baseline test results and accredit the configuration for testing, subject to specified limitations and constraints.

ISTC integration tests are conducted following each build increment to establish the degree of system

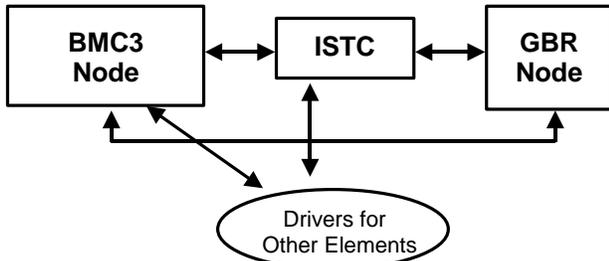


Figure 3.3-1 Element-to-Element and System Level Integration.

integration as a checkpoint in the development process. Test drivers are used for all elements not incorporated into the framework or not participating in the test. ISTC integration tests are the responsibility of a designated Integration Test Director. During ISTC IGTs, the equipment is operated by NMD Test Integration and Execution (TIE) operators and the data is evaluated by Test Planning and Analysis (TPA) support staff.

3.4 Phase 4 – BMDO T&E Configuration Accreditation

Upon joint accreditation of the test configuration baseline by the ISTC and participating element PMs, the ISTC PM will establish and deliver to the NMD JPO, System T&E Director an Accreditation Recommendation and Assessment Technical Report consisting of:

- 1) Element Accreditation Statements
- 2) Joint Element/ISTC Integration Accreditation Data
- 3) ISTC Test Configuration Baseline Accreditation Data
- 4) Synopsis of Change/Modifications from ISTC CM Records
- 5) Synopsis of Baseline Scenario Executions
- 6) Identification of Configuration Limitations/Constraints for Use
- 7) Endorsement of Readiness of Test Organization to Perform Test provided by Readiness Test Assessment (RTA) Results
- 8) Results of V&V Assessments executed on ISTC Framework (T&C, SPM, GE)

4.0 Incorporating ISTC Into An SIE

The primary objective in using ISTC in an SIE is to inject pre-generated, synchronized threat stimulus as the driver for system exercises of integrated NMD prototype test articles in support of the NMD T&E program. The secondary objective is to demonstrate the collection, recording and reporting of system performance assessment data that cannot be generated in any other category of planned NMD T&E activity or test.

Specific goals supporting these objectives will be demonstrated by the use of T&E resources including:

- responding to exercise control,
- providing element timing and synchronization,
- injecting threat drivers and scenarios,
- performing data collection and recording,
- facilitating post-test analysis,
- demonstrating system connectivity and communications using actual communications lines, and
- authenticating End-to-End and BMC3-to-Element categories of SIEs.

Figure 4.0-1 details a possible architecture for a distributed SIE involving ISTC and the JNTF.

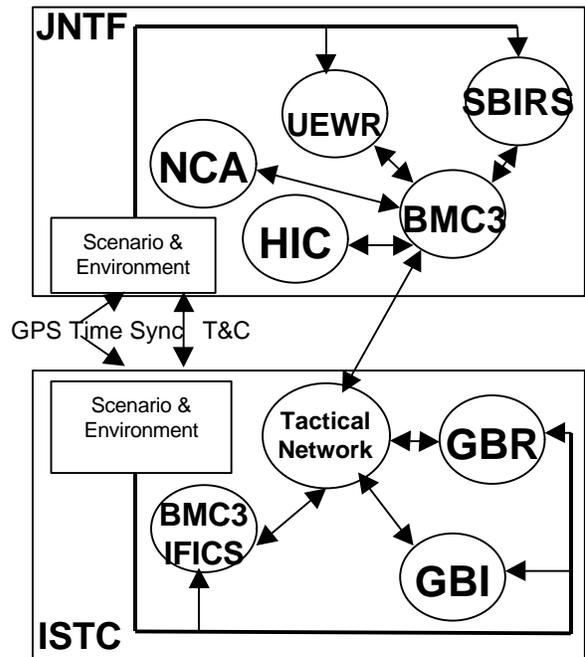


Figure 4.0-1 Distributed System Integration Exercise.

5.0 Summary And Conclusions

Several observations are supported by AEGIS Research with respect to using ISTC in an aggregation of simulations and element prototypes, including an SIE.

5.1 Observations

In March of 1997, the NMD T&E Division created an Integrated Product Team (IPT) to levy requirements on ISTC for distributed testing making it necessary to

provide risk reduction for flight tests. Incorporating ISTC into the SIE program would fulfill the following requirements:

- 1) Planned tests need to consider evolving operational configurations (e.g., operational physical locations and operational communications, tactical hardware and software, and environmental conditions).
- 2) Tests need to demonstrate collateral mission interoperability and external systems interfaces, such as simultaneous UEWR support of Integrated Tactical Warning/Attack Assessment (ITW/AA) and NMD missions, and BMC3 support of the NMD and Cheyenne Mountain Operations Center (CMOC) missions.
- 3) Must integrate into Cheyenne Mountain Complex.
- 4) Support user needs such that the operator can gain insight into the current NMD system.
- 5) The facility must be convenient to the operator and equipment must be available for training and crew drills. This enables the operational tester and operator to refine procedures, measures of effectiveness (MOE) and measures of performance (MOP) as the NMD system evolves.
- 6) The system must improve user participation with development efforts and add flexibility to support user requirements (e.g., enhance Command and Control Simulations (C2Sims) and Concept of Operations (e.g., CONOPS) development, and support BMC3 Capability Increment (CI) User Assessment activities).

5.2 Conclusions

SIEs are a series of distributed system-level integrated exercises planned to support cost analysis, operations upgrade, life cycle infrastructure development, and checkout. The NMD representations and drivers for use with the SIEs will evolve over time from models and simulations to actual hardware and software. With ISTC as a test driver, the SIEs can exercise the entire NMD, end-to-end.

6.0 References

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