

Complexity of Simulating the Ballistic Missile Defense System (BMDS)

Presented to

**National Defense Industrial Association (NDIA)
Systems Engineering Division M&S Committee**



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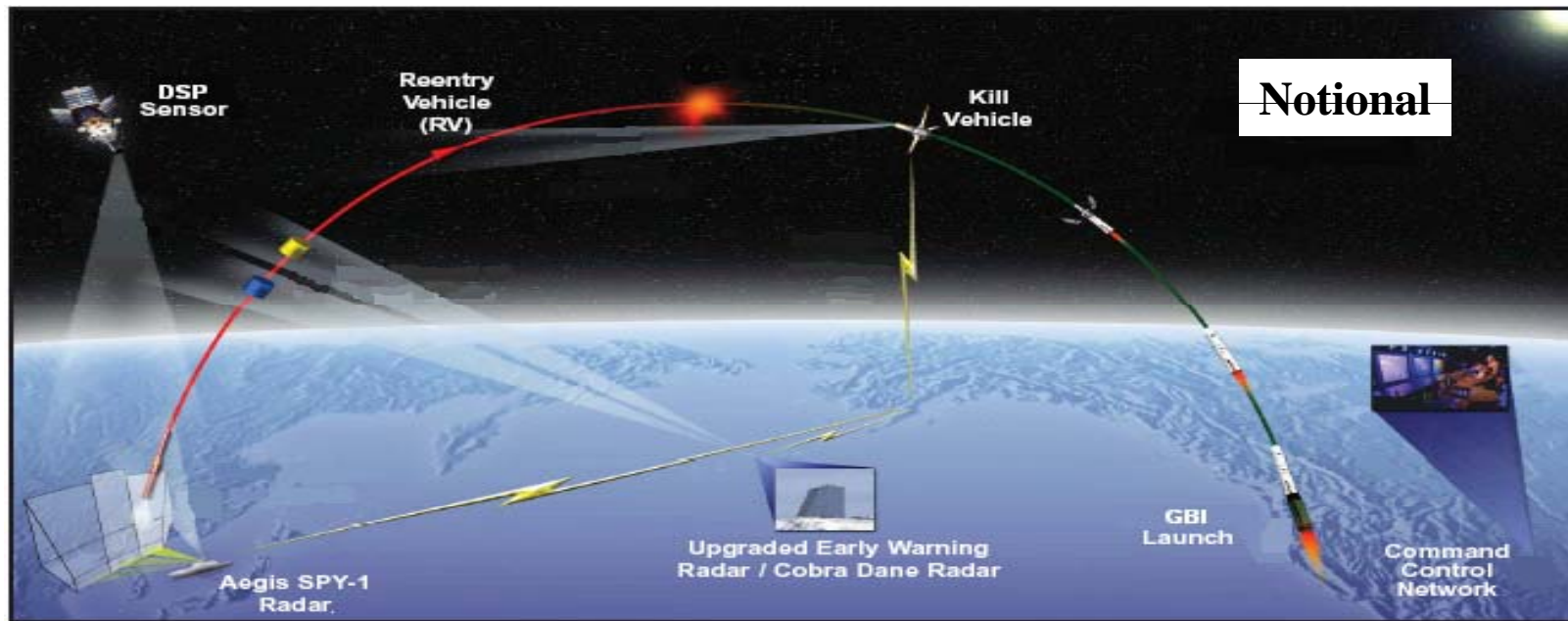
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Models and Simulations Importance to the BMDS

The BMDS performance evaluation strategy is to develop models and simulations of the BMDS and compare their predictions to empirical data collected through comprehensive flight and ground testing to validate their accuracy, rather than physically testing all combinations of BMDS configurations, engagement conditions, and target phenomena.



**Models and Simulations are the Basis for the BMDS
Performance Evaluation Strategy**



Agency Emphasis on Modeling and Simulation

- **Established M&S as an Agency Wide Program**
- **Major Re-Plan of the MDA Test Program centered on the Collection of Data Needed to Validate and Build Confidence in MDA M&S**
- **Emphasis placed on the design and development of Frameworks (Hardware in the Loop (HWIL) and Digital), development/refinement of Element Models , and Common Truth Stimuli (Phenomenology, Lethality, Threat, Environments, Communication)**
- **MDA M&S Products support seven user Use Cases (Performance Assessments, Ground Tests, Exercises , Training, Element Integration, Wargames and Concept Analysis)**
- **Implementing Standards Across Agency M&S Development**
- **Instituted a Continuous M&S Validation Program**



Linking M&S Products to Users



Hardware-in-the-Loop Framework (SSF)

Use Cases	Characteristics
<ul style="list-style-type: none"> • Ground Test • Training • Exercises • Pre-flight analysis • Post flight test analysis • Element Integration • System Integration 	<ul style="list-style-type: none"> • Real Time • Processor in the Loop • Operator in the Loop • Tactical Systems

HWIL/Models

Digital Simulation Framework (DSA)

Use Cases	Characteristics
<ul style="list-style-type: none"> • Element Integration • Training • Exercises • Wargames • SSF Digital Models • Concept Analysis • Trade Studies • Performance Assessment • Special Projects 	<ul style="list-style-type: none"> • Highest system model fidelity • Real time • Faster/Slower than real time • Complex scenarios • Complex threat presentations • Monte Carlo (statistical analysis)

Models

Simulation Truth Models

Phenomenology



Threat Generation



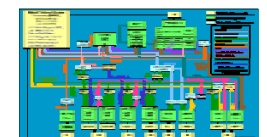
Environments



Lethality



Communications



Engineer and Integrate Simulation Frameworks, Simulation Truth and Component Models with User Applications



Technical M&S Complexity

- **BMDS is a combination of legacy, new development, dual-use sensor, command and control and weapon systems which interact with communications and warning systems outside MDA control**
 - Developed by multiple services and contractors
 - Vast geographic footprint with multiple user organizations
 - The threat is evolving
- **BMDS went from a pure Research and Development state to Operational in less than three years**
 - This led to the need to quickly integrate a wide variety of M&S assets to meet MDA test and assessment needs
- **Prior to deployment each BMDS Element had developed both Hardware-in-the-Loop capability and high resolution digital M&S representations**
- **There was not enough time nor budget to “start over” with any particular representation and we did not want to lose Element engineering expertise**
 - They know their systems best



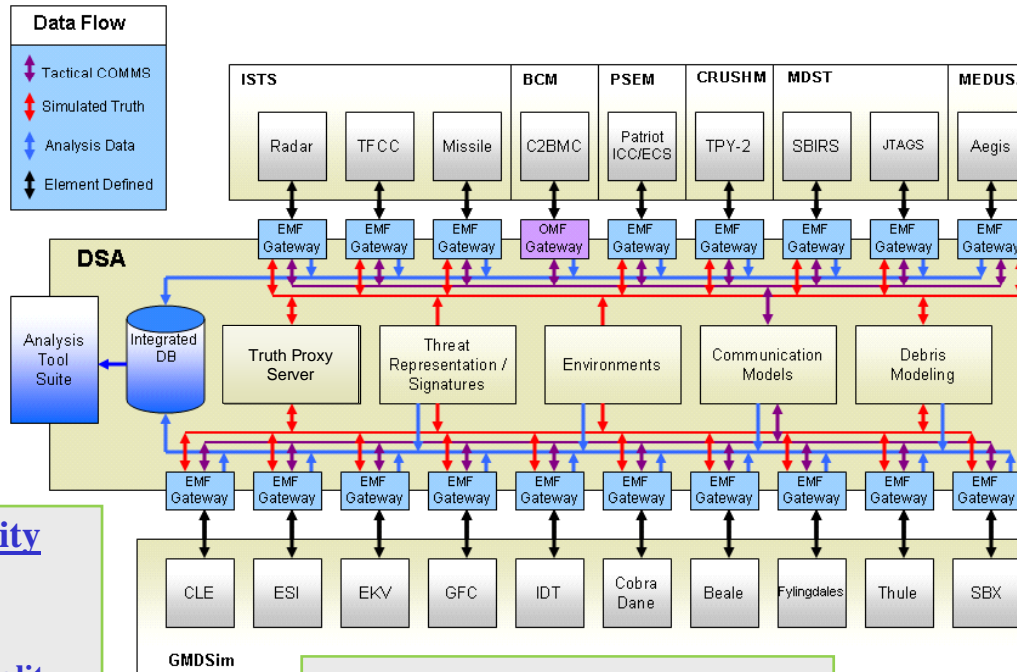
Technical M&S Complexity Example

- **The current high resolution BMDS End-to-End simulation is composed of 7 engineering simulations**
 - “The best the BMDS Elements have”
- **Several were originally developed as stand-alone engineering level models**
 - Now used in tightly-coupled representation of a complex system
 - Differences in resolution, truth processing, data logging....
 - Code changes needed across entire ensemble to enable integration
 - High number of complex scenarios needed to fully assess the BMDS
- **During Integration Testing of the End-of-End Simulations revealed unexpected relationships and couplings of data and simulation code logic**
- **The result reflected the complexity of the BMDS as well as complexity of assembled variety of high resolution models themselves**



M&S Technical Challenges

Example shown from recent high resolution digital Ensemble of BMDS Element, Threat and Environmental Models reflecting the end of year 2009 BMDS configuration



Data Generated

- 5.3 (+) Terabytes
- 820 Databases

Technical Complexity

- New Framework
- Multiple Op Sys & Compilers
- Concurrent functionality development with integration

Size Complexity

- 10 Million lines of total code
- 300K for DSA
- 20 computers per DSA-P
- 6 DSA-P ensembles

Tiered Model Complexity

- System – Element - Component
- Multi-level interfaces
- Disparate Implementation

Program Challenges

- Decentralized, concurrent development
- Staggered functionality drops

Repurposed Model Challenges

- Externalize BMDS Comm
- Integrate Threat and Blue picture
- Integrate Environment
- Integrate Data Collection
- Externalize time management & control
- Common RCS distribution

Legacy Challenges

- Reuse of Element Engineering Models
- Change from element to system execution

Time Challenges

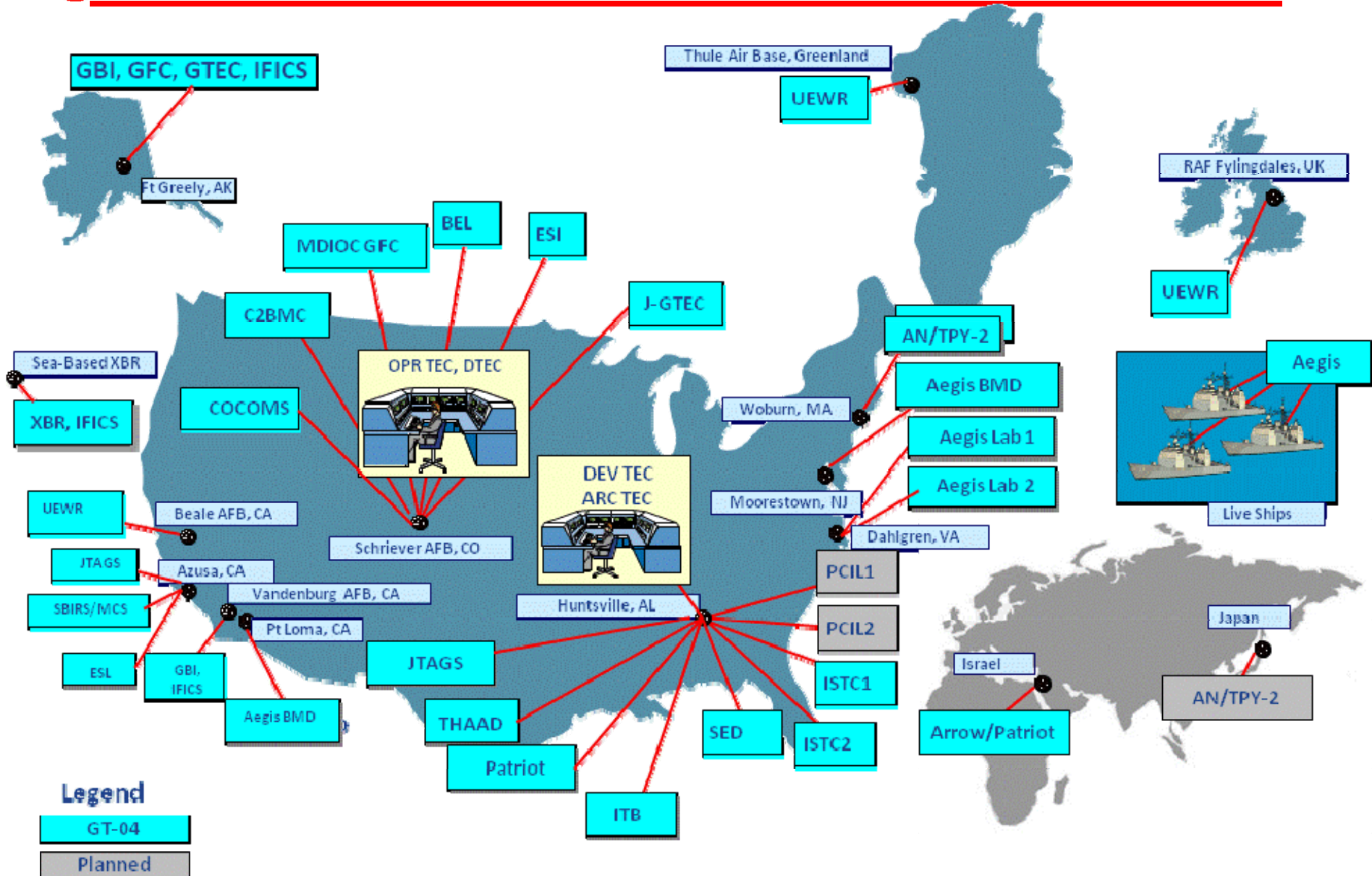
- Sim Initialization: 1- 6 Hours
- Execution: 2 -144 Hours
- Database Transfer: 1 - 6 Hours
- Quick Look Analysis: 2 Hours

New Development

- Framework
- Element models
- System level data collection
- Interfaces for common threat, environment, RCS
- System Intercept Debris



BMDS Distributed HWIL Architecture

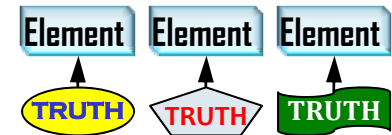




BMDS M&S Truth Complexity

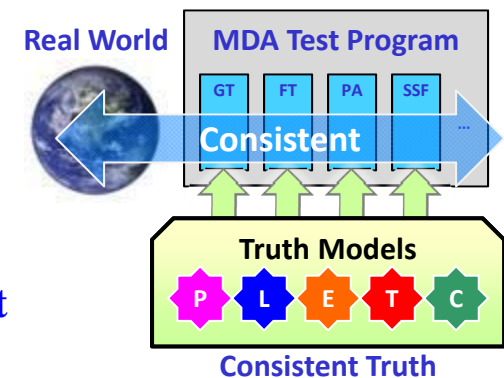
All BMDS Use Cases require truth information

- Traditionally, truth is provided separately by each element



Truth Services provides independent, integrated, common truth for BMDS Use Cases

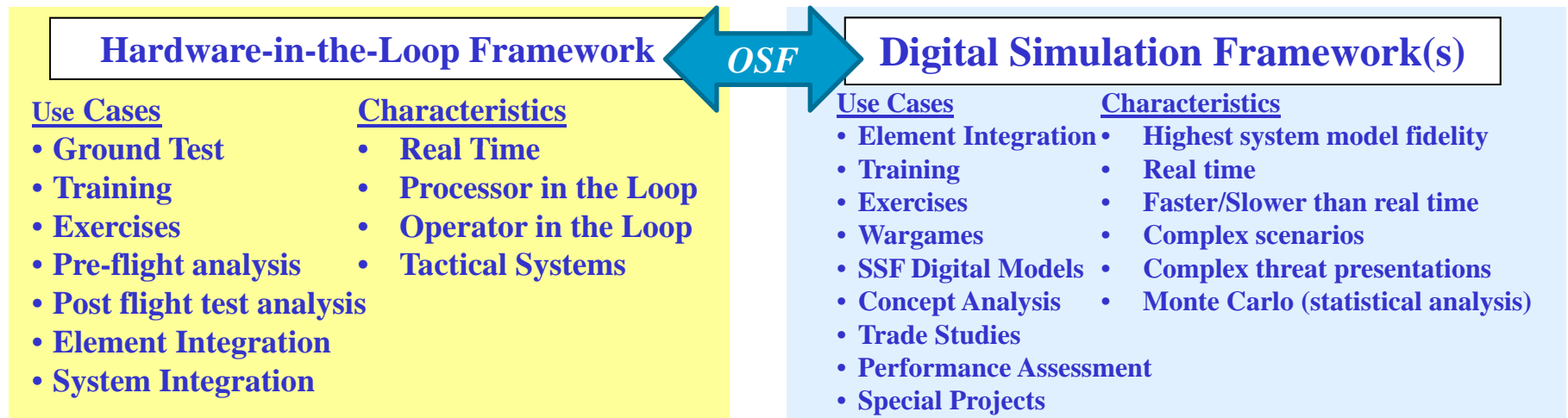
- Provides simulated truth to digital and hardware-in-the-loop (HWIL)
- Advantageous over disparate truth servers:
 - Assures consistency and reduces conflict
 - Cost and schedule effective
 - Streamlines VV&A efforts
 - Facilitates Integration change, and expansion
 - Community-wide collaboration ensures high quality product
- Covers five categories of simulation truth:
 - Phenomenology – integrated picture of the IR/RF/Visible scene
 - Lethality – effects of collision and/or termination of objects and resulting debris
 - Environment – effect of the natural environment on BMDS Use Cases
 - Threat – simulation of kinematics and signatures of red force objects and assets
 - Communications – simulation of information transfer through communications systems and the impacts of hardware, environment, and man-made factors





M&S Vision: ONE Single Framework

- **Combine HWIL “stimulation” and Digital simulations with analysis-caliber fidelity**



- **By combining HWIL and Digital capabilities, we will:**
 - ... be able to augment training environments with near-limitless assets
 - ... combine the rich data collection of digital models with the realism of HWIL models
 - ... provide the Agency with seamless end-to-end representation of BMDS



Verification, Validation & Accreditation is Serious

- **Validated M&S are a Requirement for BMDS Capability Fielding Decisions**
- **Performance means that the model represents (to a specified level of detail) physical reality**
- **Functional Traceability from requirements through Accreditation**
- **Testing to provide referent data is limited**
 - Each test requires meticulous M&S involvement to ensure the correct data, in the correct format under the correct conditions
 - Thousands of data parameters need to be collected under many operationally realistic conditions, assessed, and where necessary implemented in a variety of M&S representations

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The Future

- **Evolve the M&S Program to meet Agency Challenges**
- **M&S Standards Across Agency**
- **Continuous M&S Validation and Accreditation Program**
- **The Digital and Hardware-in-the-Loop M&S Frameworks Will Be Interoperable**
 - Digital Representations will be used to “fill out” BMDS configuration in Ground Tests when Hardware-in-the Loop capability is not available
- **M&S Validation Will be the Center Piece of Test Planning and Data Collection**
- **M&S Will Continue to be a Primary Interface With International Partners**

Collaboration is the Key to M&S Success

