Test & Evaluation (T&E)/Science & Technology (S&T) Program

New Simulation Techniques for Warfighter Systems T&E

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December 2018

C4I & Software Intensive Systems Test (C4T) Mission

Mission

Develops technologies to test C4I and Software Intensive Systems that operate in complex military environments. With emphasis on automated testing, analysis (real-time and post-test) and evaluating the increasing mass of structured and unstructured data. C4T is divided into the following three domains:

1. Distributed Testing: This domain will address technologies to: reduce T&E infrastructure biases, improve T&E cross domain/multi-level security abilities, advance T&E for platforms employing big data/cloud environments, and create agile/contested/dense communication environments.
2. Test Automation: This domain will address technologies to: advance Test Big Data Collection, Analysis, Reporting, & Visualization; create high fidelity representations of operational systems or net-centric environments; and assess next generation of warfighter managed information objects.
3. Modeling & Simulation: This domain will address technologies to: determine required fidelity in Live and Simulated environments; improve the Validation & Verification and Aggregation techniques; improve run-time performance for real-time applications, and systems, communications, and environmental representations.

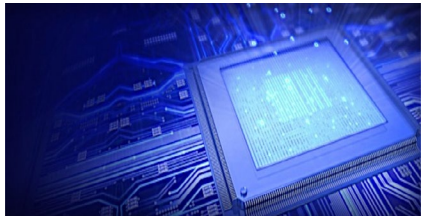
C4I & Software Intensive Systems (C4T)
Overview Technology Domains

Complex Warfare Environments

Innovative approaches to how we fight, posture our force, & leverage our asymmetric strengths & technological advantages*

Battle increasingly sophisticated adversaries in increasingly complex environments*

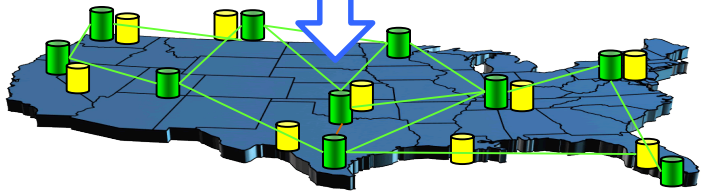
* 2014 Quadrennial Defense Review



Test Automation (TA)

- Advance Big Data Collection, Analysis & Visualization
- Improve Test Execution thru Automation/Cloud Computing
- NextGen Handhelds and Widgets
- Automated Control of Targets

BIG DATA & CLOUD COMPUTING



Distributed Testing (DT)

- Reduce Distributed T&E Effects
- Cross Domain Solutions and Multi-Level Security
- Assess Big Data Warfighter Systems
- Advance Mission Context Data Collection, Analysis & Visualization

Modeling & Simulation (M&S)

- Required Fidelity in Live & Simulated Environments
- V&V Techniques
- Aggregation Techniques
- Run-time Performance for RT Applications
- Systems, Communications, Environmental Representations

Innovate T&E: Joint, Early, Often & Agile

Topics For Discussion

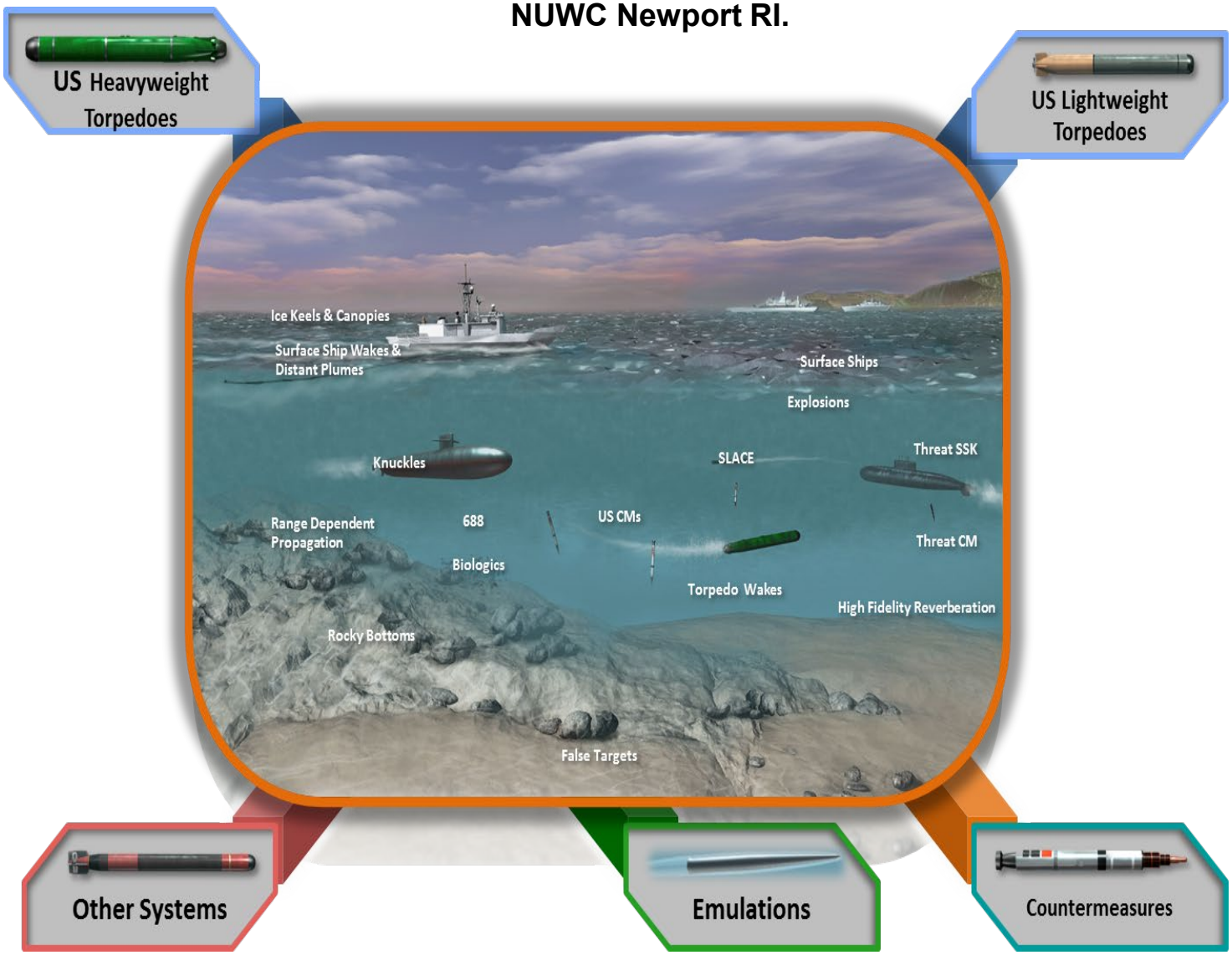
- An Overview of Simulation Requirements for OT/DT Test Environments
- The Weapons Analysis Facility Broadband (WAF-BB) Environment
- The Live Virtual Constructive Test & Evaluation (LVCT) Environment
- The Integrated Planning of Tactical, Test Support, and Tactical Engagement Networks (IPT3N) Test Network Planner
- Verification & Validation (V&V) Techniques
- Summary

Requirements for Consideration in Creating the M&S Test Environment

- **Fidelity: The simulated test environment must have adequate fidelity to both stimulate and stress the System Under Test (SUT).**
  - Stimulation must consider the primary (and in most cases secondary) interactions of the SUT with the environment
  - To effectively provide an OT environment, the simulation must provide those extreme cases that stress the SUT
  - While "aggregations" in the simulated test environment are possible, care must be taken to assure that their impact on the SUT is correctly represented
- **Timing: The simulated test environment must update at rate less than the operational update rate of the SUT**
  - Clearly the simulated environment must run real-time but the requirement for it to update "within the cycle of the SUT" may require that some parts run faster than real-time.
  - There is often a "tradeoff" between environment fidelity and timing (update rate).
- **Hardware/Multithreaded Processing: With strict SUT imposed timing and fidelity requirements, simulation architectures are often built with multiple computational threads representing different parts of the test environment**
  - Broadband sonar computations have required a new GPU architecture for real-time under sea/target reverberation representation

C4T Project: Weapons Analysis Facility: Broadband Capability (WAF BB)
Domain: Modeling & Simulation

BROADBAND RESPONSE
NUWC Newport RI.

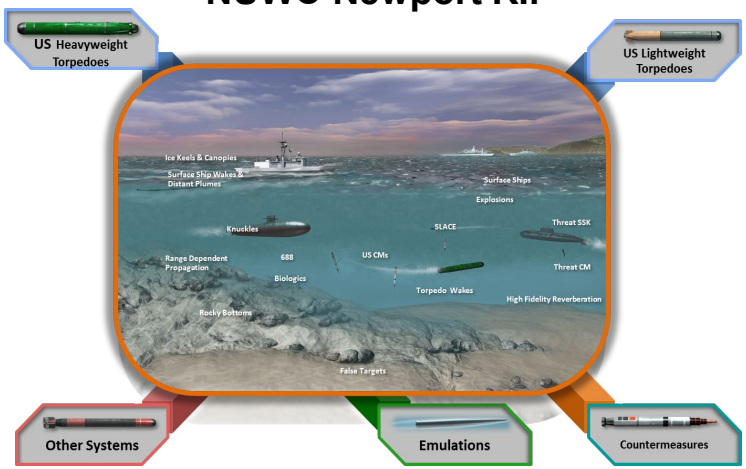


Specific Requirements for Creating an Adequate M&S Test Environment for Sonar BroadBand Testing

- **The WAF-BB simulation architecture must provide a reverberation map to each sensor for the millisecond (s) cycle of the torpedo sensor array.**
- **Reverberation map must have the following characteristics across multiple spectral regions**
  - Reverberation from natural reflections (sea floor, biologics) all depending on water salinity and temperature conditions.
  - Reverberation from man made reflectors (other torpedoes, surface ships)
  - Reverberation from target and friendly subs.
- **Hardware/Multithreaded Processing: With strict SUT imposed timing and fidelity requirements, simulation architectures are often built with multiple computational threads representing different parts of the test environment**
  - Broadband sonar computations have required a new GPU architecture for real-time under sea/target reverberation representation. The simulation was designed in a multiple threaded GPU architecture.

C4T Project: Weapons Analysis Facility: Broadband Capability (WAF BB)

NUWC Newport RI.



Providing a Broadband Response

Description: Devise an M&S framework technology for use in a fully broadband federation of models operating in real time. Establish credibility of simulator predictions by developing a rigorous uncertainty quantification framework for constituent M&S

Enables: A WAF-type hardware-in-the-loop simulator that supports assessment of systems employing broadband waveforms with fully coherent signal processing

Current Status: Using CASS BB to define architectures, identify computational loads & new technologies. Integrating GPU's into WAF to support target modeling.

Transition Partner/Date: NUWC EC WAF, PMS 404 support of Advanced Program Build (APB 6) /1QFY19

FY17 Accomplishments:

- ✓ Showed feasibility of using GPU's to address current and expected computational challenges
- ✓ Completed and provided an early transition of CASS BB to the APB 6 torpedo development team
- ✓ Implementing Target model in Graphic Processing Units (GPUs) and transitioning early capabilities
- ✓ Demo statistical technology enabling the quantification of a model accuracy lower bound.
- ✓ Successful end of phase 2 program review

Deliverables (Mo/Yr):

- ✓ Completed CASS BB Simulation (March/18)
- ✓ NUWC TR's on CASS BB and Integration of HFTAM into CASS BB (Being published)

Phase/Mos.	Mo/Yr	TRL	Status
Ph 1 / 9	Aug/16 to Apr/17	4	Complete
Ph 2 / 12	Apr/17 to Apr /18	5	Complete
Ph 3 / 6	Apr/18 to Oct/18	6	Current

Key Events (3/18 – 9/18):

- ❑ Demonstrate real time computation of Volume reverberation (10/18)
- ❑ Using WAF demonstrate TRL 6 for technologies developed. (9/18)
- ❑ Using CASS BB support APB 6 developments (3/18 – 9/18)

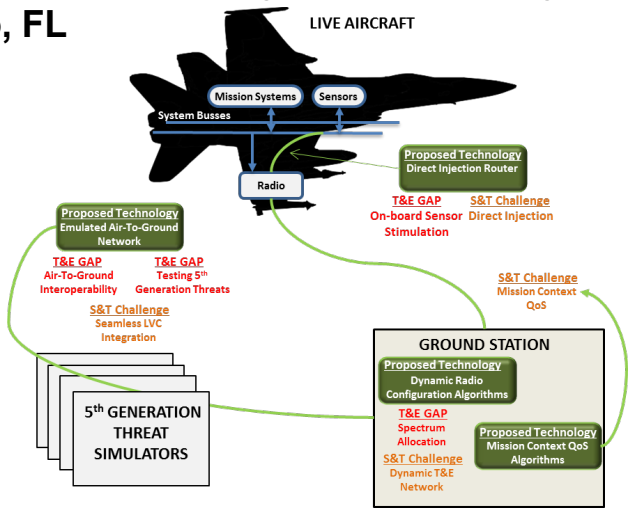
The Live, Virtual, Constructive (LVC) Environment for T&E

In the case of an LVC environment, the system is tested, with "Users in the Loop" presenting the Simulated Environment with new problems.

- **Broadness/Fidelity of the Simulated Environment.** The LVC simulations must focus on stimulating both the SUT and the live actors (often a user) in the test environment.
- **Impacts of the LVC Infrastructure.** In cases of LVC testing, pieces of the tests simulated environment are often distributed by a WAN or RF communications.
  - Simulation of enemy Air Craft facing a pilot in flight may be on the test air craft or the ground station communicating with the test aircraft. Problems include;
    - Latency of the communications structure stimulating the SUT
    - Bandwidth of the communications structure stimulating the SUT
  - TENA 6.2 is useful in creating a distributed LVC infrastructure and explicitly addresses the latency/bandwidth problems

C4T Project: Live platforms with Virtual & Constructive simulation for distributed Test (LVCT)

Lockheed Martin Rotary and Mission Systems / Orlando, FL



Description: Develop technologies to provide a reliable, fast, and cost-effective approach that enables Live Virtual Constructive (LVC) testing of next generation platforms through a set of reusable and reconfigurable technologies.

Enables: Live assets to sense and respond to stimulus without regard for whether the stimulus is real or synthetic in a realistic operational scenario

Current Status: Developing RF Test Bed and Models, Link Manager, Direct Injection Router application and QoS algorithms. Preparing for SWIL/HWIL tests.
Transition Partners / Date –Nellis AFB 1QFY19

FY17 Accomplishments:

- ✓ Completed Quality of Service (QoS) Algorithms and Object Model development (Jan 17)
- ✓ Completed LVC Link Manager (LLM) and Direct Injection Router applications (Jan 17)
- ✓ Finalized Emulated Air to Ground RF Network (Feb 17)

Deliverables (Mo/Yr):

- ✓ C4T Monthly Report LVCT (10/16, 11/16, 12/16, 01/17, 02/17, 03/17)
- ✓ LVCT Project Execution Plan (PEP) (02/17)
- ❑ Final Technical Report (07/17)
- ❑ All developed software (08/17)

Phase/Mos.	Mo/Yr	TRL	Status
Ph 1 / 16	Apr/16 - Aug/17	5	Current
Ph 2 / 16	Aug/17 - Dec/18	6	Future

Key Events (4/17 – 11/17):

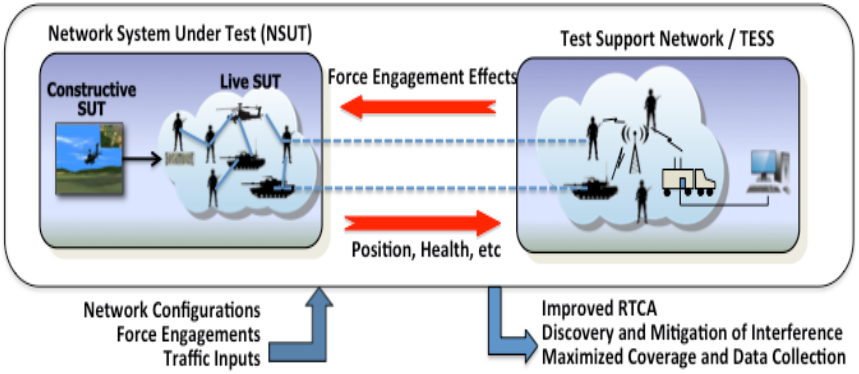
- ❑ Phase 2 Complete (Dec 18)

Integrated Planning of Tactical, Test Support, & Tactical Engagement Networks (IPT3N)

- **Simulations for test network planning require a careful representation of the test environment.**
  - When building a planner for structuring test networks at Ft. Hood's operational test facility care was given to representing;
    - Terrain/vegetation
    - Test network environmental signal attenuation
- **Simulations for test network planning require a careful representation of the expected test scenario.**
  - The test network laydown (tower placement) must consider dynamic movement of the tactical forces and hardware under test. (assuring connectivity through the entire test)
  - The planner must consider the expected load of test data (assuring adequate bandwidth during test)
- **Simulations for network planning must consider hardware robustness and spectral region availability.**
  - The Ft. Hood planner considered battery life supporting remote radios, key to test network
  - Planner also considered potential interference bands with Tactical Networks Under Test.

C4T Project: Integrated Planning of Tactical, Test Support, & Tactical Engagement Networks (IPT3N)

Scalable Network Technologies, Culver City, CA



Description: An integrated simulation-based test planning technology that provides a set of semi-automated tools to plan and optimize laydown of Test Support Networks (TSN), and improve coverage and accuracy of data collection from Networked System Under Test (NSUTs)

Enables: Mitigate potential interference between the NSUT and TSN, improved quality & volume of data collection for accurate Real Time Casualty Assessments (RTCA), reduced overall cost of planning (expeditionary) OTs, and shape battlefield effects so that OTs are more realistic

Current Status: Completed Phase 1 with capability demonstration to key external stakeholders (OTC and PM ITTS).

Transition Partner / Date: Operational Test Command (OTC), Fort Hood / 1QFY20

FY18 Accomplishments:

- ✓ Layout Optimization Design (Mar/18)
- ✓ Energy Optimization Design (Apr/18)
- ✓ TSN Optimization Detail Design (Apr/18)
- ❑ Critical Design Review for optimization algorithms for TSN (May/18)

Deliverables (Mo/Yr):

- ✓ Phase 1 Final Report and Prototype Software (Oct/17)
- ✓ Phase 2 Project Execution Plan (Dec/17)
- ✓ Phase 2 Architecture and Design Documents (Apr/18)
- ❑ Phase 2 Requirement Document (Jul/18)

Phase/Mos.	Mo/Yr	TRL	Status
Ph 1 / 13	Sep/16 – Oct/17	4	Complete
Ph 2 / 15	Oct/17 – Jan/19	5	Current
Ph 3 / 9	Jan/19 – Sep/19	6	Future

Key Events (4/18 – 10/18):

- ❑ Mid-Phase 2 Review (May/18)
- ❑ Phase 2 TAPETS Model, Simulation Resource Management, and Converter Development (Jul/18)
- ❑ Phase 2 Demonstration (Dec/18)

Verification and Validation of a Complex M&S Environment for T&E of a System Under Test (SUT)

- V&V of the Test Environment must establish the adequacy of the fidelity/time regime of individual simulations and the adequacy of the fidelity/time regime of the entire federated environment to stimulate the SUT.

- V&V of this M&S Test Environment must establish the environment's robust ability to stimulate the SUT across its full spectrum of performance requirements.

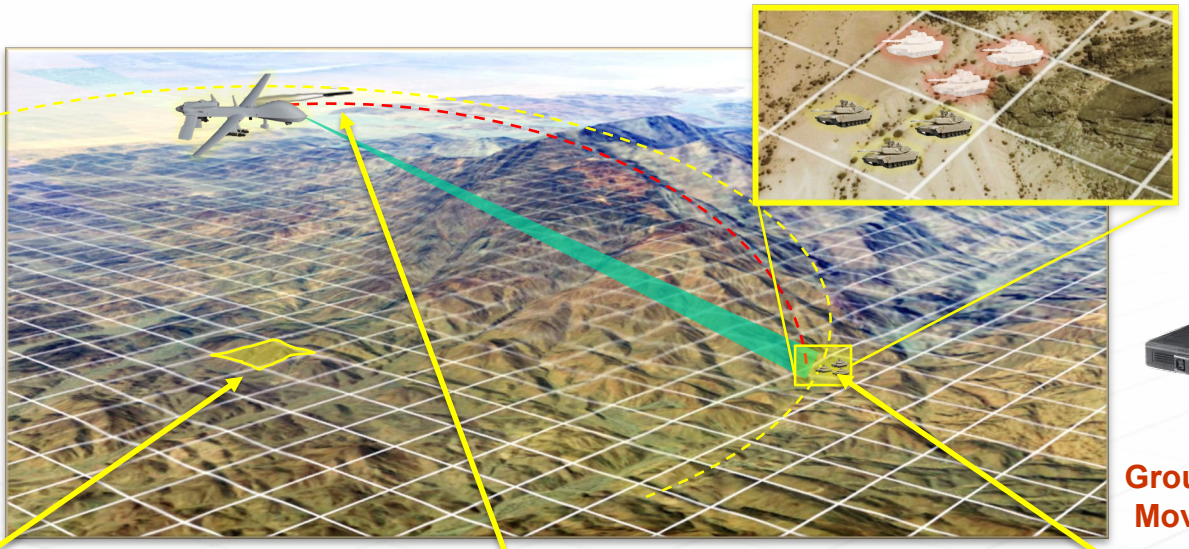
- The resulting Test Environment must create a "Data Chain With Causality (DCWC)" that can be tracked from changes in the M&S environment to changes in SUT performance. The DCWC must be Validated.

Validation of an M&S Environment for T&E (Representations and V&V)

Simulated Test Environment of Battlefield Robustness

Sensor Platform/ Aircraft Movement Simulation
Update Rate (200 msec)

Terrain Generator
100 Meters Per Grid Tile



Rocket Sensor Guidance Software
System Under Test (SUT)

Rocket Fly Out Simulation
Update Rate (100 msec)
Non-Continuous

Ground Target/Vehicle Movement Simulation
Update Rate (1 sec)
Non-Continuous

Sensor Update Rate (50 msec); Guidance Update Rate (100 msec); Accuracy ≈ 6m (CEP)

Summary

- **Simulation Environments creating OT/DT situations for SUT testing are a reality. The requirements for creating these environments include;**
  - High fidelity, real time simulations to stimulate the SUT
  - Simulations with a robust range of capabilities (i.e. to generate a spectrum of outputs) to test overall SUT performance
  - Simulations that have an update rate cycle within the update cycle of the SUT.
- **Verification and Validation of M&S Environments for OT/DT are Complex. Requirements include;**
  - Validation of the individual simulations in the environment AND validation across the environment of all simulations impacting the SUT.
  - Verification and Validation and testing of the existence of the DCWC of impacts on the SUT.

– **BACKUPS**

C4T: Modeling & Simulation Topics (1)

T&E Need: Increase the Use of Modeling & Simulation for T&E

1. **Determine Required Fidelity**
   - Characterize the level of fidelity/timing required for a group of simulations in planning the distributed test infrastructure
   - Represent multi-sensor emulation (either singular or fused) when testing in Degraded Visual Environments (e.g. dust, smoke, fog, weather)
   - Real-time simulation and analysis of the environment, to fuse test data from multiple instrumentation sources
2. **Verification & Validation Across Battlespace Environments**
   - Automate M&S Verification & Validation (V&V) for use in the test environment to stimulate the SUT
     - Ability of the group of simulations to provide a full fidelity of the stimulation to the SUT
     - Synthetic Battlespace Test Environment Robustness and Adequacy
     - Unbiased Test Metrics Adequacy
   - Dynamic Correction of Fidelity Mismatches During Test

C4T: Modeling & Simulation Topics (2)

T&E Need: Increase the Use of Modeling & Simulation for T&E

3. Battlespace Environments Aggregation

- Develop analytical aggregation techniques for scaling test environment while maintaining fidelity
  - Large target scale aggregation/de-aggregation techniques
  - Algorithms to support mission thread interactions between aggregated and de-aggregated entities and the SUT
- Algorithms to combine data from aggregated/de-aggregated entities into meaningful test metrics

4. Improve Simulation Run-time Performance

- Test metrics that characterize the simulation fidelity necessary to stimulate the SUT
- Measures of the impact of reduced simulation fidelity on the validity of system test results

C4T: Modeling & Simulation Topics (3)

T&E Need: Increase the Use of Modeling & Simulation for T&E

5. Representation of Systems, Communications, and Environments

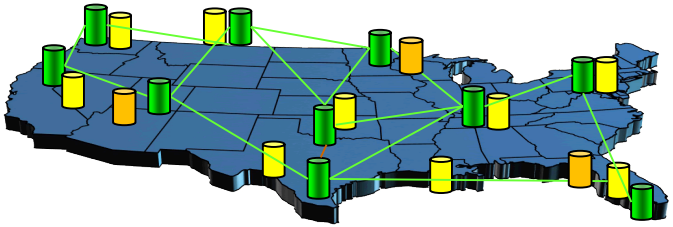
- Representation of the system and/or platform performance, communications, and operational environments
- Representation of complex C4I and Software Intensive Systems operating in a realistic tactical environment
  - Persistent and repeatable capability to test mission effectiveness in a combat-loaded dense battlefield environment

C4T: Modeling and Simulation

Test Use Case 11: M&S for T&E of Systems in Complex Environments (Run-Time Performance)

High Fidelity Simulated Environments & Systems

Distributed M&S Infrastructure for T&E



T&E Instrumentation

Warfighter Systems

Virtual and Constructive M&S

Live Environments & Systems

Improve Simulation Run-time Performance

Improve Simulation Run-Time Performance

- Test metrics that characterize the simulation fidelity necessary to stimulate the SUT
- Measure the impact of reduced simulation fidelity on the validity of system test results