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

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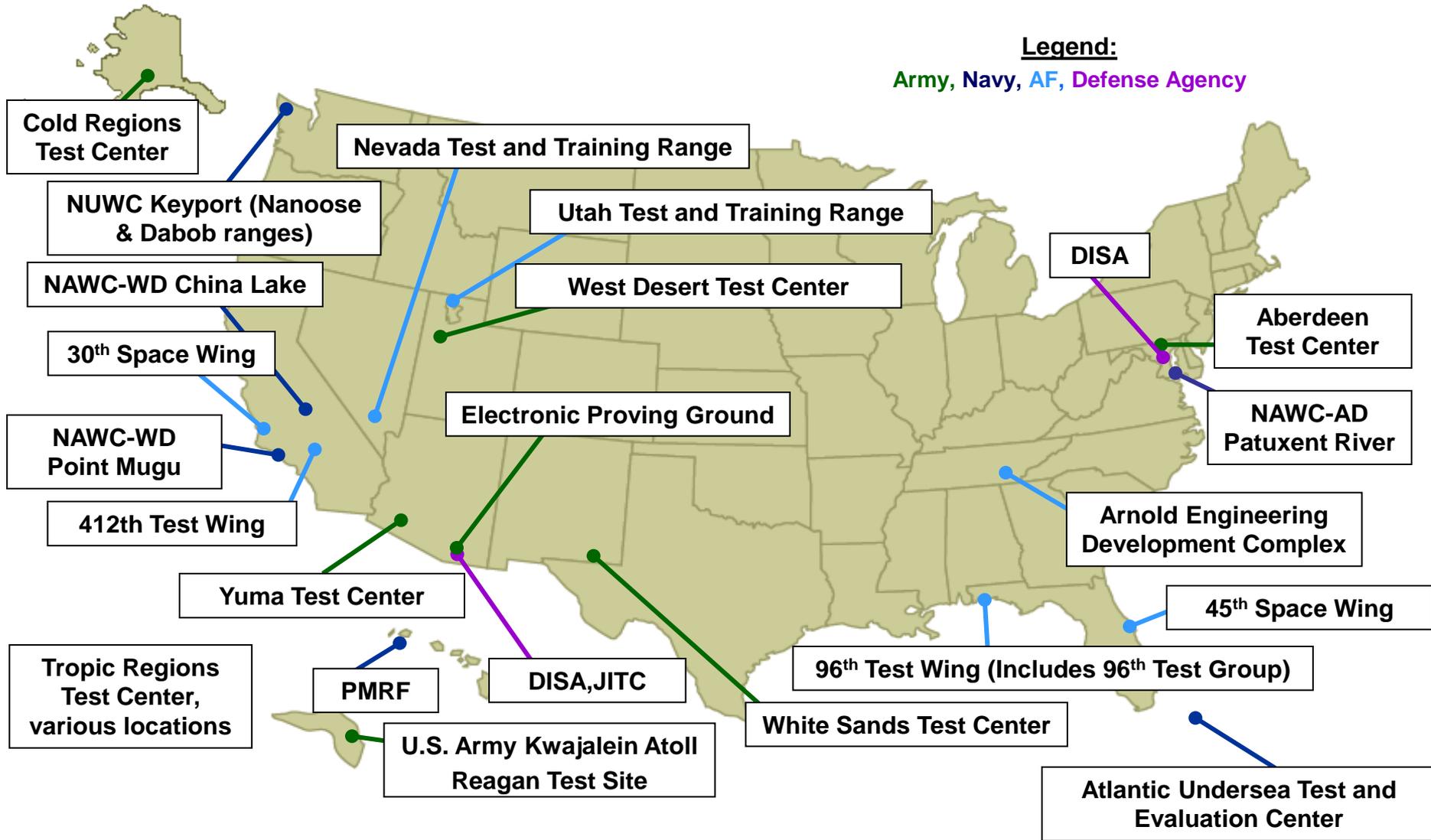**NDIA Ground Robotics Capabilities Conference**
Hyattsville, MD
13-14 August 2014

The STEWARD of the DoD Test Infrastructure
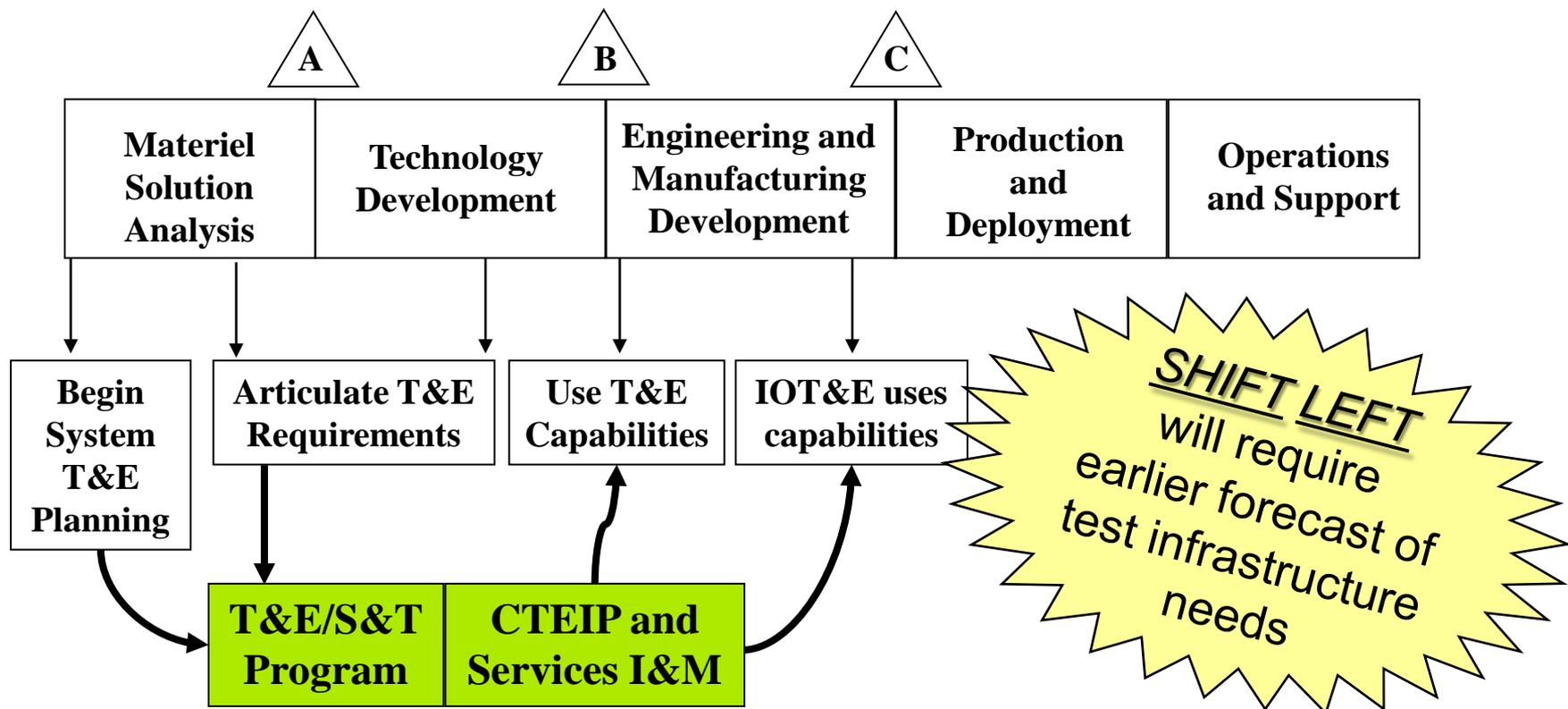## Major Range and Test Facility Base (MRTFB): The "Critical Core"
23 Sites: Army-8; Navy-6; Air Force-7; Defense Agency-2

Legend:
Army, Navy, AF, Defense Agency

- Cold Regions Test Center
- NUWC Keyport (Nanoose & Dabob ranges)
- NAWC-WD China Lake
- 30th Space Wing
- NAWC-WD Point Mugu
- 412th Test Wing
- Yuma Test Center
- Tropic Regions Test Center, various locations
- PMRF
- DISA, JITC
- U.S. Army Kwajalein Atoll Reagan Test Site
- Nevada Test and Training Range
- Utah Test and Training Range
- West Desert Test Center
- Electronic Proving Ground
- White Sands Test Center
- 96th Test Wing (Includes 96th Test Group)
- DISA
- Aberdeen Test Center
- NAWC-AD Patuxent River
- Arnold Engineering Development Complex
- 45th Space Wing
- Atlantic Undersea Test and Evaluation Center

T&E Capability Development Cycle

Challenge: T&E Capabilities must be available in time to provide useful insight to decision-makers and warfighters

A

B

C

Materiel Solution Analysis	Technology Development	Engineering and Manufacturing Development	Production and Deployment	Operations and Support

Begin System T&E Planning	Articulate T&E Requirements	Use T&E Capabilities	IOT&E uses capabilities

T&E/S&T Program	CTEIP and Services I&M

SHIFT LEFT will require earlier forecast of test infrastructure needs

Cycle for Test Capability Development Must Begin Early

TRMC Investment Programs Overview

Test *Technology* Development

T&E/S&T

- Established in FY2002
- Develops technologies required to test future warfighting capabilities
- BA 3 RDT&E funds
- ~$85M / year
- 8 Test Technology Areas
  - Electronic Warfare
  - Cyberspace
  - High Speed/Hypersonics
  - Autonomous Systems
  - Net-Centric Systems
  - Directed Energy
  - Advanced Instrumentation
  - Spectrum Efficiencies

Test *Capability* Development

CTEIP

- Established in FY1991
- Develops or improves test capabilities that have multi-Service utility
- BA 4 RDT&E funds
- ~$180M / year
- 43 current projects
  - 19 projects developing core Joint capabilities
  - 11 projects improving threat representations used in testing
  - 13 projects addressing near-term OT shortfalls

Distributed Test Integration

JMETC

- Established in FY2007
- Provides infrastructure for distributed Joint and Cyberspace testing
- BA 5 RDT&E funds
- ~$30M / year
- 78 current sites
  - Expanding to 93 sites
- Maintains
  - Network connections
  - Security agreements
  - Integration software
  - Interface definitions
  - Distributed test tools
  - Reuse repository

T&E/S&T Program
Overview

Mission: Develop Technologies Required to Test Future Warfighting Capabilities

- **Established in FY02**
  - **Joint DDR&E / DOT&E Initiative**
  - **Transitioned to TRMC in FY05**
- **RDT&E Budget Activity 3 funds**
- **Purpose**
  - **High Risk / High Payoff R&D for Testing**
  - **Foster technology transition to major DoD test ranges**
  - **Risk reduction for test capabilities developments**

82 Active Projects

- **Annual Broad Agency Announcements (BAAs)**
  - **Academia**
  - **Industry**
  - **Government Laboratories**
- **Tri-Service working groups**
  - **Validate requirements**
  - **Evaluate proposals**
  - **Facilitate technology transition**
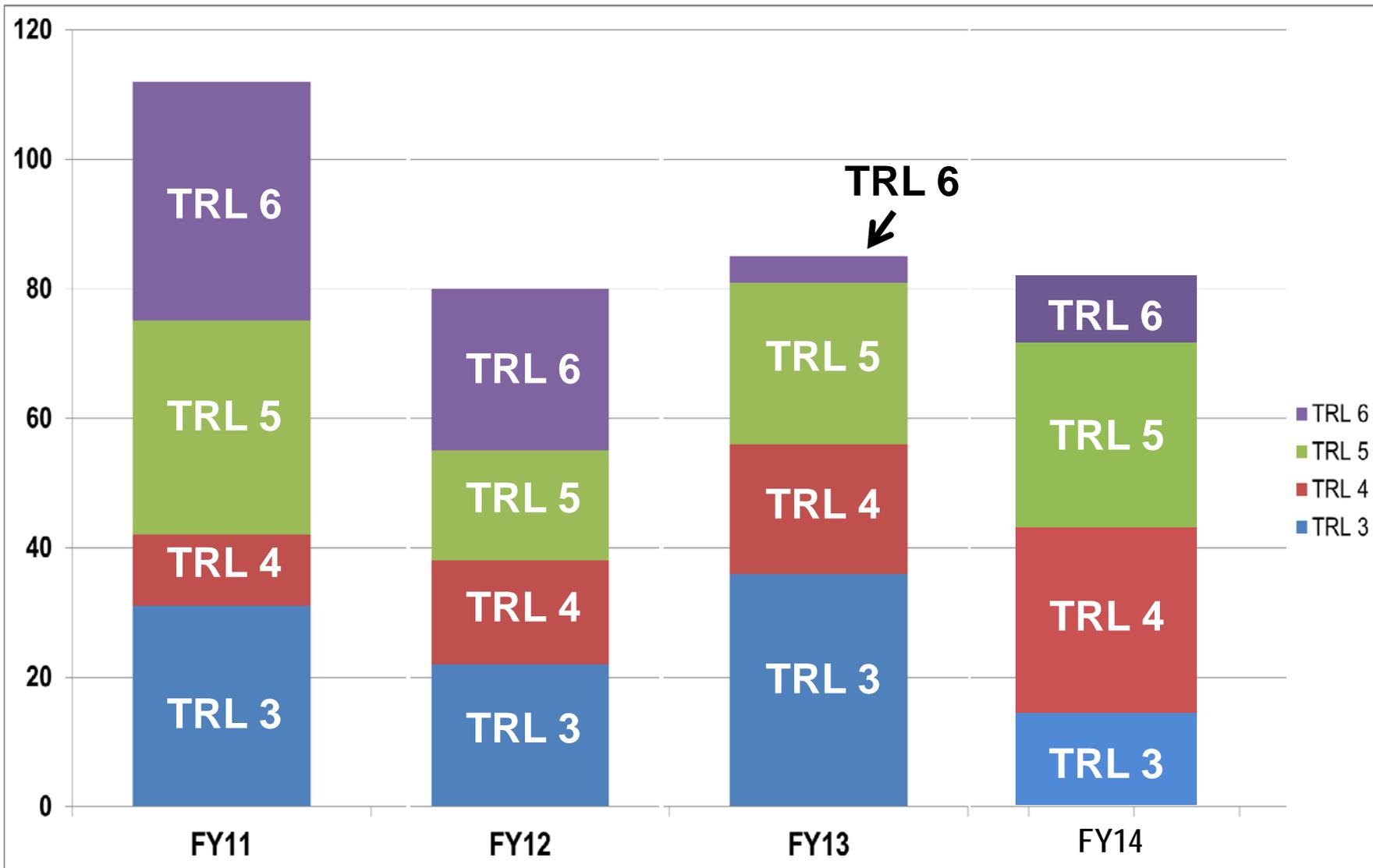- **Central Oversight – Distributed Execution**

Current Test Technology Areas

High Speed Systems	Unmanned & Autonomous Systems	Spectrum Efficiency	Advanced Instrumentation
14 Active Projects	4 Active Projects	13 Active Projects	11 Active Projects
Directed Energy	**Cyberspace**	**Electronic Warfare**	**Net-Centric Systems**
14 Active Projects	3 Active Projects	15 Active Projects	8 Active Projects

Shaping Technology into Tomorrow's T&E Capabilities

Project Portfolio Snapshot
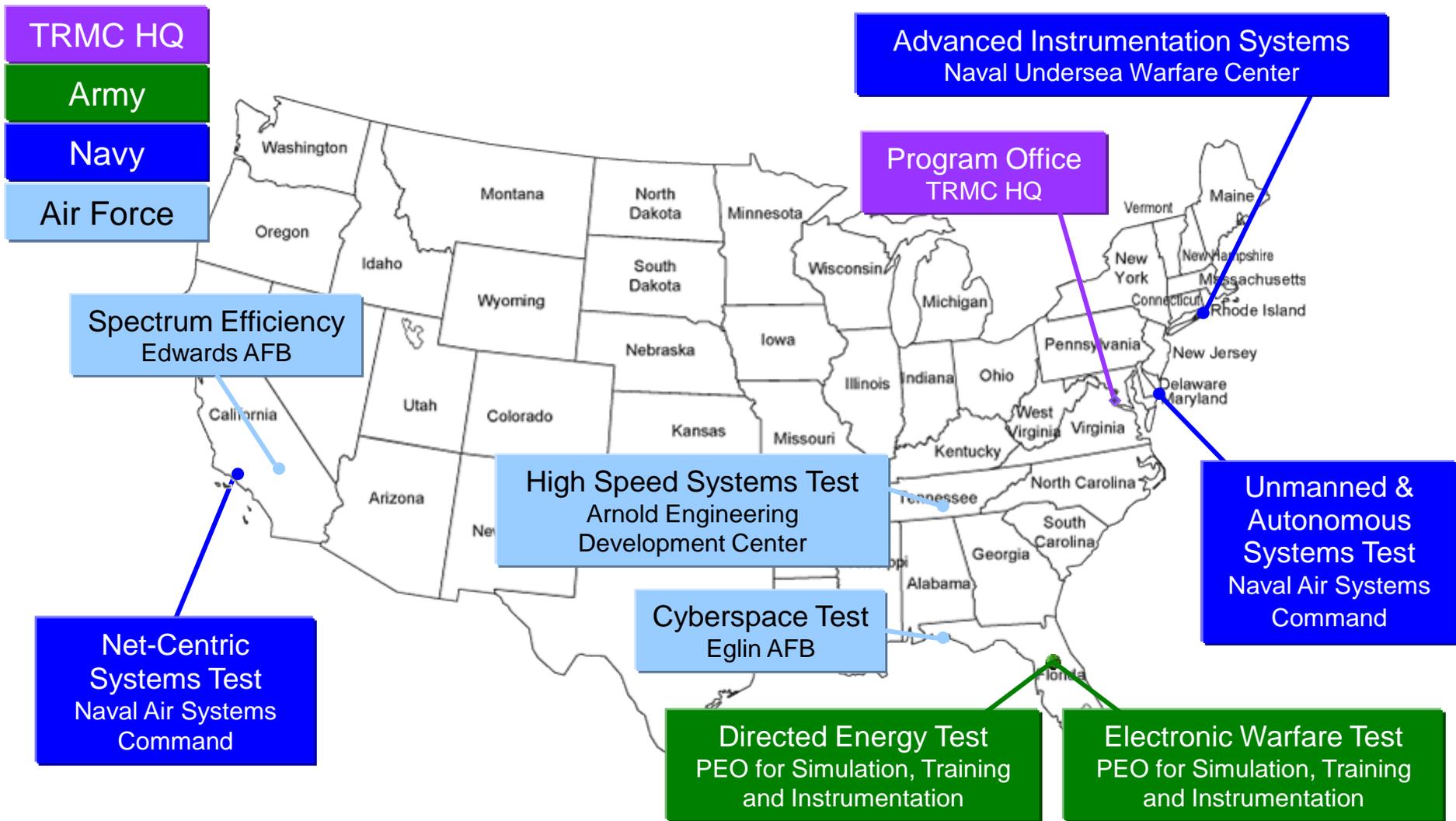## Technology Readiness Level by Fiscal Year

T&E/S&T Test Technology Area
Executing Agent Organizations

Legend:
- TRMC HQ
- Army
- Navy
- Air Force

Advanced Instrumentation Systems
Naval Undersea Warfare Center

Program Office
TRMC HQ

Spectrum Efficiency
Edwards AFB

High Speed Systems Test
Arnold Engineering Development Center

Unmanned & Autonomous Systems Test
Naval Air Systems Command

Net-Centric Systems Test
Naval Air Systems Command

Cyberspace Test
Eglin AFB

Directed Energy Test
PEO for Simulation, Training and Instrumentation

Electronic Warfare Test
PEO for Simulation, Training and Instrumentation

Central Oversight – Distributed Execution

Unmanned & Autonomous Systems Test
T&E/S&T Test Technology Area

- **Current Portfolio: 4 Projects**

- **FY14 Budget: $5.92M**

- **2 Test Technology Domains / 7 Current Topics**
  - **Autonomous System Test Planning: 3 Topics**
  - **Autonomous System Performance Assessment: 4 Topics**

- **Significant Technology Needs**
  - **Predicting Autonomous Behavior for Testing**
  - **Enhancing Safety of Autonomous Testing**
  - **Testing of Autonomy Functional Components**
  - **Measure Autonomous System Reliability and Performance**

UAST: Autonomous System Test Planning
Data Driven Tool (DDT)

Carnegie Mellon University NREC/ Pittsburgh

Real UAS   **Real** Sensor Data

Virtual UAS
(does not look so real)

Virtualized Sensor Data
(indistinguishable from real data)

Description: DDT is *developing a means to "virtualize" test sites into ultra high-fidelity, yet real-time simulators.*

Enables: *Verification, Assessment, <u>and</u> Evaluation of UAS in realistic, risk free, highly measureable, statistically significant manner.*

Current Status: *Phase 2 complete, Currently in Phase 3. Preparing to map a site in preparation of testing RPP 19 Pegasus system for final demo.*

Transition Partner (s) / Date (s): AMAS JCTD, Sept 2013, Sept 2014

FY14 Accomplishments
✓ Showed "boosting" achieves 10X (ground) and 100X (air) reduction in cost to virtualize sites.
✓ REV 2 ultra high fidelity mapping sensor with omnidirectional lidar, color, and IR modalities. Logging bandwidth is 1.3TByte /hr.
❑ Field exercise and final demo (Roadfollowing Autonomy SUT with Robotic Technology Consortium (RTC) RPP 19 Pegasus S/W).

Deliverables
❑ Savannah River Lidar simulator and AMAS vehicle slip models delivered to TARDEC.

Phase/mos.	Mo/Yr	TRL	Status
Ph 1	Sep/11-Sep/12	4	Complete
Ph 2/12	Sep/12-Sep/13	5	Complete
Ph 3/12	Sep/13-**Sep/14**	6	Current

Key Future Events:
- Technical Review June 2014
- Jun 2014: Field Exercise at TBD location.
- Final Demo Aug 2014

Safe Testing of Autonomy in Complex, Interactive Environments (TACE)

Johns Hopkins University Applied Physics Laboratory/MD

Description: *TACE is test infrastructure that combines synthetic and actual forces to produce a realistic, real-time, interactive autonomous vehicle test environment. TACE also provides safe testing assurances via on-board safety monitoring.*

Enables: *TACE assures safe testing and enables performance evaluation of autonomous vehicles.*

Current Status: *TACE demonstrated at Tech Readiness Level 4 on Feb 28th at the Aberdeen Test Center. Completing Phase 1 Final Report.*

Transition Partner (s) / Date (s): CTEIP/FY16; PM-UAS/FY18; PMA262/FY18; PMA263/FY18

FY 14 Major Accomplishment

- ✓ Demonstrate Safe Testing at TRL 4
- ✓ Demonstrate Interactive Environment at TRL 4

FY 15 Major Accomplishments

- ❑ Demonstrate Safe Testing at TRL 5
- ❑ Demonstrate Interactive Environment at TRL 5

Deliverables (Mo/Yr)

- ❑ Phase I Final Report Apr/14
- ❑ Phase II Final Report Apr/15
- ❑ TACE SW, Manuals and Final Report Apr/16

Phase/mos.	Mo/Yr	TRL	Status
Ph 1/12	Apr/13-Apr/14	4	Complete
Ph 2/12	Apr/14-Apr/15	5	Current
Ph 3/12	Apr/15-**Apr/16**	6	Planned

Key Future Events:

- • Kickoff May 14
- • Tech Review Jun 14
- • CDR Nov 14
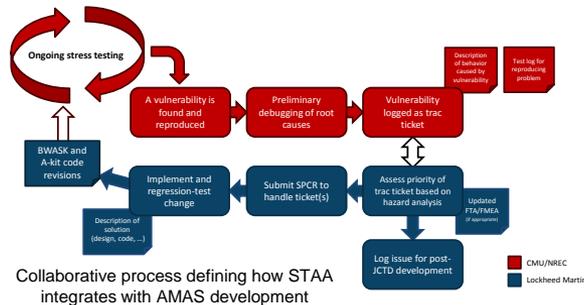- • Test Readiness Jan 15
- • Phase II Demo Mar 15

UAST: Autonomous System Performance Assessment
Stress Testing of Autonomy Architectures (STAA)

Carnegie Mellon University NREC/ Pittsburgh

Improving software robustness on several projects including AMAS JCTD and AACUS

By-Wire Testing

Autonomy Testing

Multi-Domain Testing

Ongoing stress testing

A vulnerability is found and reproduced → Preliminary debugging of root causes → Vulnerability logged as trac ticket

Description of behavior caused by vulnerability | Test log for reproducing problem

BWASK and A-kit code revisions → Implement and regression-test change → Submit SPCR to handle ticket(s) → Assess priority of trac ticket based on hazard analysis → Updated FTA/FMEA (if appropriate)

Description of solution (design, code, ...)

Log issue for post-JCTD development

■ CMU/NREC
■ Lockheed Martin

Collaborative process defining how STAA integrates with AMAS development

Description*: Built automated tools to test the robustness of black-box UASs to unexpected operating scenarios. Feeds inputs that trigger software bugs in other UASs, along with a mix of good/bad data. Automatically detects safety violations with run-time invariants. (Invariants and exceptions)*

Enables: *Efficient evaluation of safety-related robustness vulnerabilities in black-box UAS software, potentially early in development and without the need for costly field testing.*

Current Status: *TRL6 prototype nearly complete, used on AMAS JCTD and AACUS software, technology transitioning*

Transition Partner (s) / Date (s): U.S. Army Aberdeen Test Center and TARDEC (ongoing since Dec/12)

FY 14 Major Accomplishments

✓ Developed automated stress-testing tool and used it to find vulnerabilities in AMAS
✓ Integrated into AMAS development and T&E processes
✓ Found robustness vulnerabilities in AACUS UAV
❑ Finalizing TRL 6 tool, improving automation, incl. the ability to learn rules for invariant violations

Deliverables (Mo/Yr)
❑ TRL 6 functional tool prototype (Sept 2014)
❑ Final report (Sept 2014)

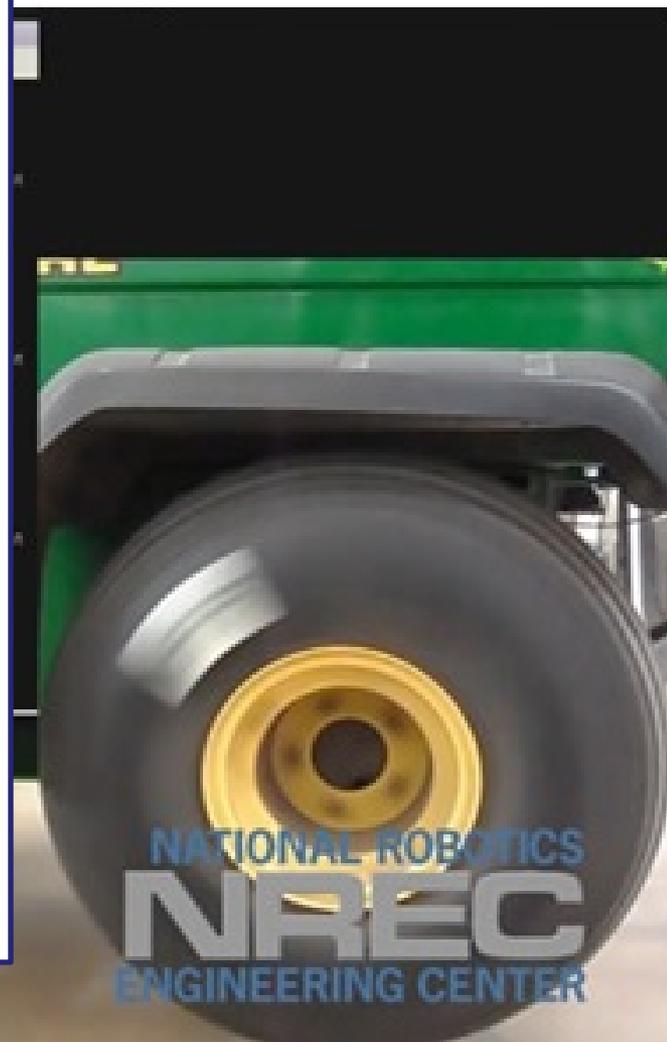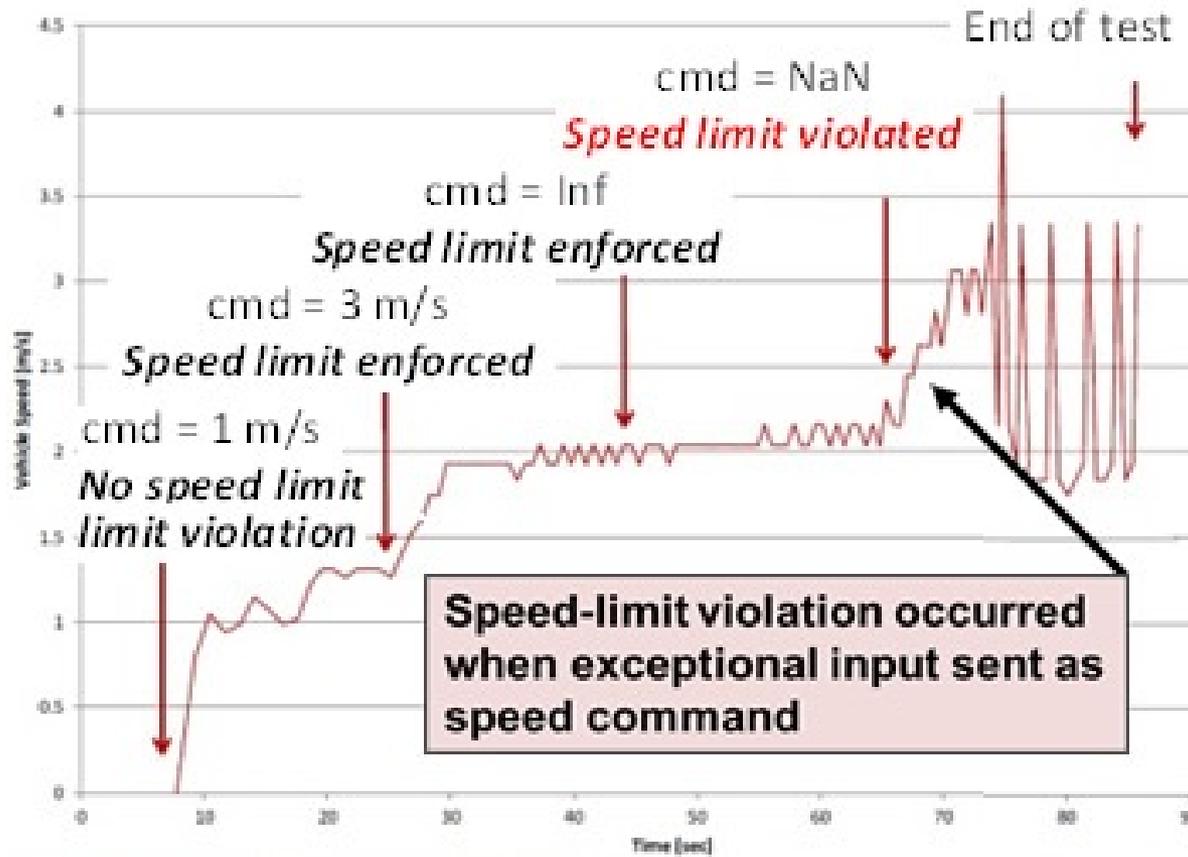| Phase/mos.	Mo/Yr	TRL	Status
Ph 1/12	Sep/11-Sep/12	4	Complete
Ph 2/28	Sep/12-**Jan/15**	5	Current
Ph 3/12	Sep/13-**Sep/14**	6	Current

Key Future Events:
• Technical Review June 2014
• AMAS B-kit testing complete: ~ Sep 14
• Final review meeting: ~ Aug 14

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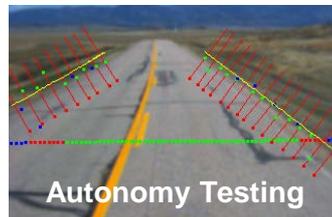# Stress Testing of Autonomy Architectures (STAA)

RECbot Speed Limit Tests

How STAA is Transitioning Technology to the AMAS JCTD
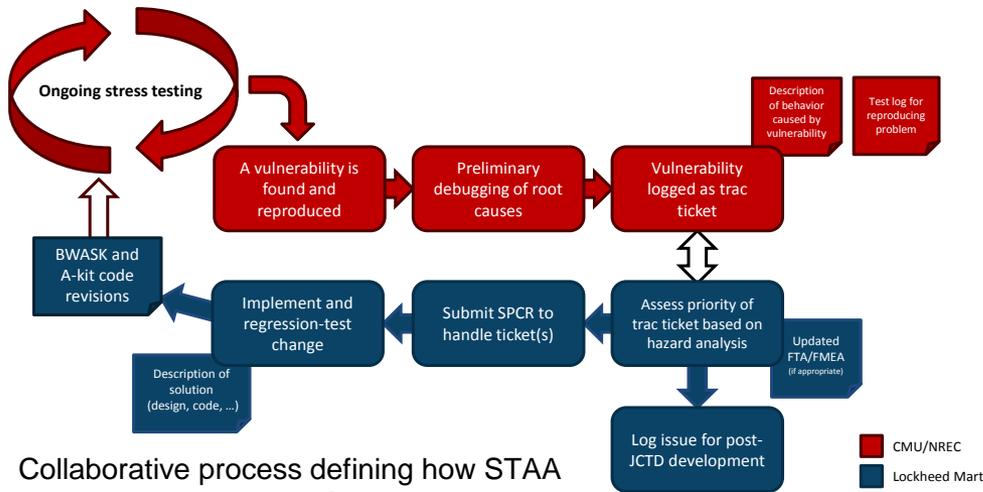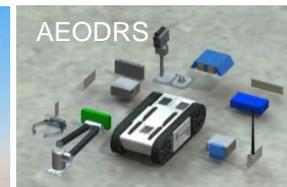
Role of STAA in AMAS Development

By-Wire Testing

STAA is stress testing software components and systems with hardware in the loop

Autonomy Testing

Benefits to AMAS JCTD

- Critical functionality and robustness problems can be identified and fixed earlier in development
- Exploratory testing can find gaps in hazard analysis regarding important failure modes before they are encountered in the field

Other Transition Opportunities

LD-UUV

RCIS

ACTUV

HMDS

AACUS

AEODRS

Collaborative process flow

Ongoing stress testing

A vulnerability is found and reproduced → Preliminary debugging of root causes → Vulnerability logged as trac ticket

Description of behavior caused by vulnerability

Test log for reproducing problem

BWASK and A-kit code revisions ← Implement and regression-test change ← Submit SPCR to handle ticket(s) ← Assess priority of trac ticket based on hazard analysis

Description of solution (design, code, ...)

Updated FTA/FMEA (if appropriate)

Log issue for post-JCTD development

CMU/NREC

Lockheed Martin

Collaborative process defining how STAA integrates with AMAS development

Autonomous System Test Planning Domain

1. Enhance Safety of Autonomous Testing
– **Minimize risks of safety concerns in autonomous testing**

2. Predict Autonomous Behavior for Testing
– **Develop Virtual Proving Ground (VPG) for UAS to predict and ability to measure its behaviors in VPG**

3. Timely Design of Autonomous System Test Plans
– **Rapid and efficient generation of test plan**

Autonomous System Performance Assessment Domain

1. Testing of Autonomy Functional Components
- Develop generalized representations of fault rules and ability to test robustness of functional components

2. Measure Autonomous System Reliability and Performance
- Develop generalized representations of evaluation functions and ability to characterize performance envelope of autonomous systems

3. Measure Human-Autonomous System Interaction
- Test and evaluate external interaction of UAS

4. Assess Vulnerabilities of Autonomous Systems
- Test and evaluate external threat vulnerabilities of UAS

T&E/S&T Program
Broad Agency Announcements

- **Topics for Industry, Academia, and Government Laboratories to propose test technology solutions**
- **In-cycle Process**
  - **Declared schedule for white paper submissions (deadline)**
  - **Requires an allocation of available funding**
  - **Priority over out-cycle white papers (must be processed first)**
- **Out-of-cycle Process**
  - **White papers submitted anytime after "in-cycle" deadline**
  - **Offerors "highly encouraged" to contact Executing Agent before submitting white paper**
    - ➢ **Ensures interest**
    - ➢ **Can address whether a 'chance' exists for funding**
- **All BAAs include an "Other Test Technologies" topic to enable offerors to propose test technology developments that were not previously identified by the Government**

All T&E/S&T BAAs are always open for new white papers

T&E/S&T New Project In-Cycle Selection Schedule

Activity	T&E/S&T New Project Selection Schedule											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Draft BAA Topic Areas	◆ (Oct–Dec)											
Industry/Academia Days			◆ Open Forum Overview with Q&A Opportunities									
Refine BAA Topics			◆									
BAA Topics Finalized				◆								
BAA Topics Announced				◆ Call for White Papers								
White Paper Submissions					◆ White Papers due in March							
White Paper Reviews							◆					
Proposals Requested from Selected Offerors								◆				
Proposal Submissions									◆			
Proposal Review & Clarifications										◆		◆
Executing Agents Recommendations to PM										◆	◆	
PM New Start Decisions												◆
Contract Awards Initiated												◆

Program Manager Action | **Executing Agent Action** | **Contracting Officer Action** | **Offeror Action**

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The Proposal — Key Criteria

- **Meets a T&E need**

- **Requires S&T work**

- **High payoff**

- **Broad application**
  (more than one DoD test activity)

T&E/S&T Program
Summary

- **T&E/S&T Program initiated to address critical T&E needs tied to S&T drivers**
  - Advancing the state of the art in T&E technologies

- **The only DoD S&T program dedicated to T&E**

- **Annual Call to Industry, Academia, and Government Laboratories to address test capability needs**

- **Competitive technology developments to get the best technologies possible to the test community**

- **Focused on transition into needed test capabilities**

Looking Ahead, Responsive, and Agile

Questions?

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