Technology Maturity

"Introduction to the TRA/TMA Process"

Dr. Ed Copeland

5 April 2016

Technical Director

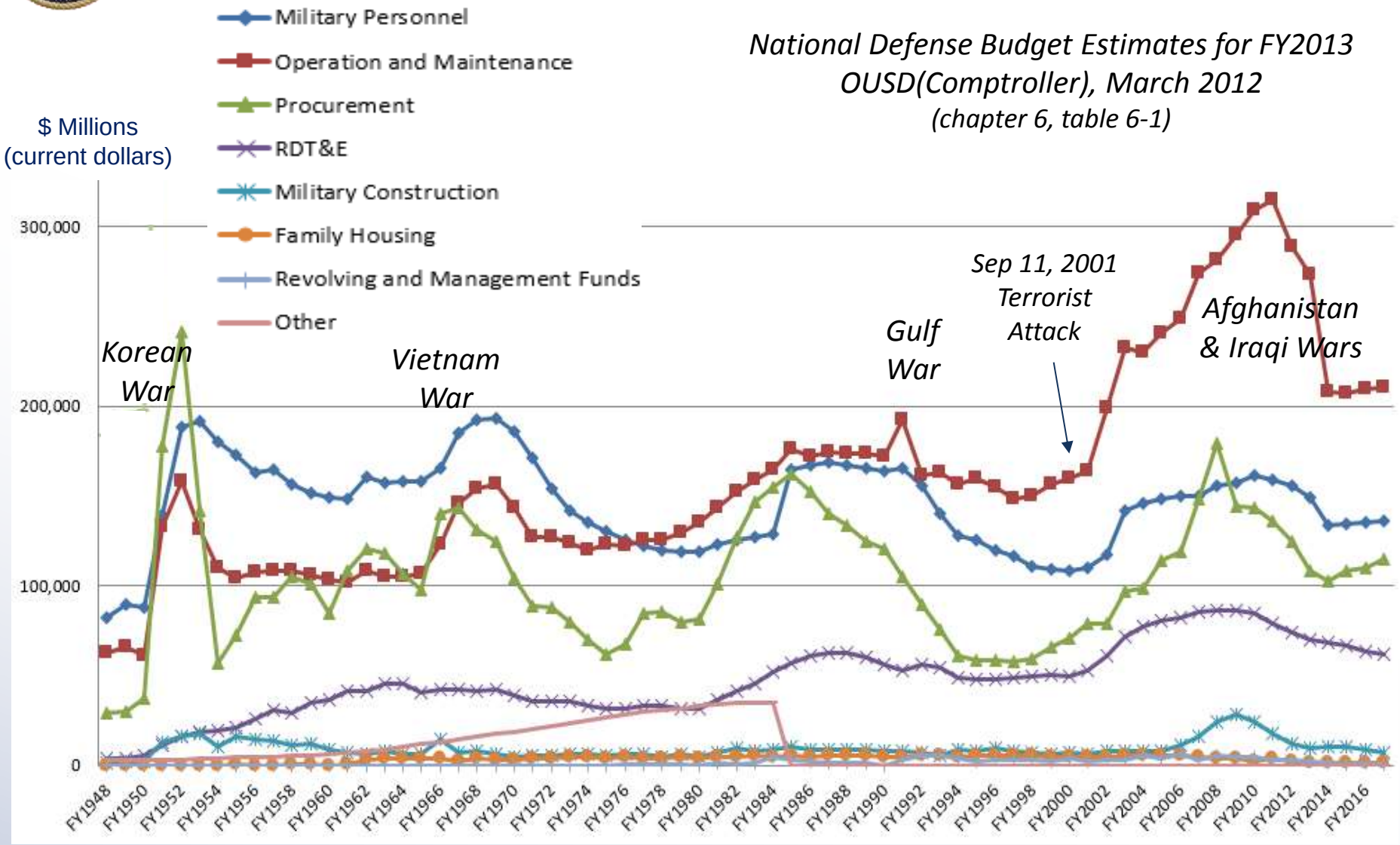
Avionics, Sensors, and E*Warfare Department (AIR-4.5)

Agenda

- Today's Environment
- TRA Background
- NAVAIR Independent Technical Review Office
- What is a TRA?
- TRA Requirements & USC 2366b
- DoD Acquisition Management System
- TRA General Process Flow
- Critical Technology Element (CTE)
- Independent Review Panel
- Technology Readiness Level (TRL)
- Technology Maturation Plan

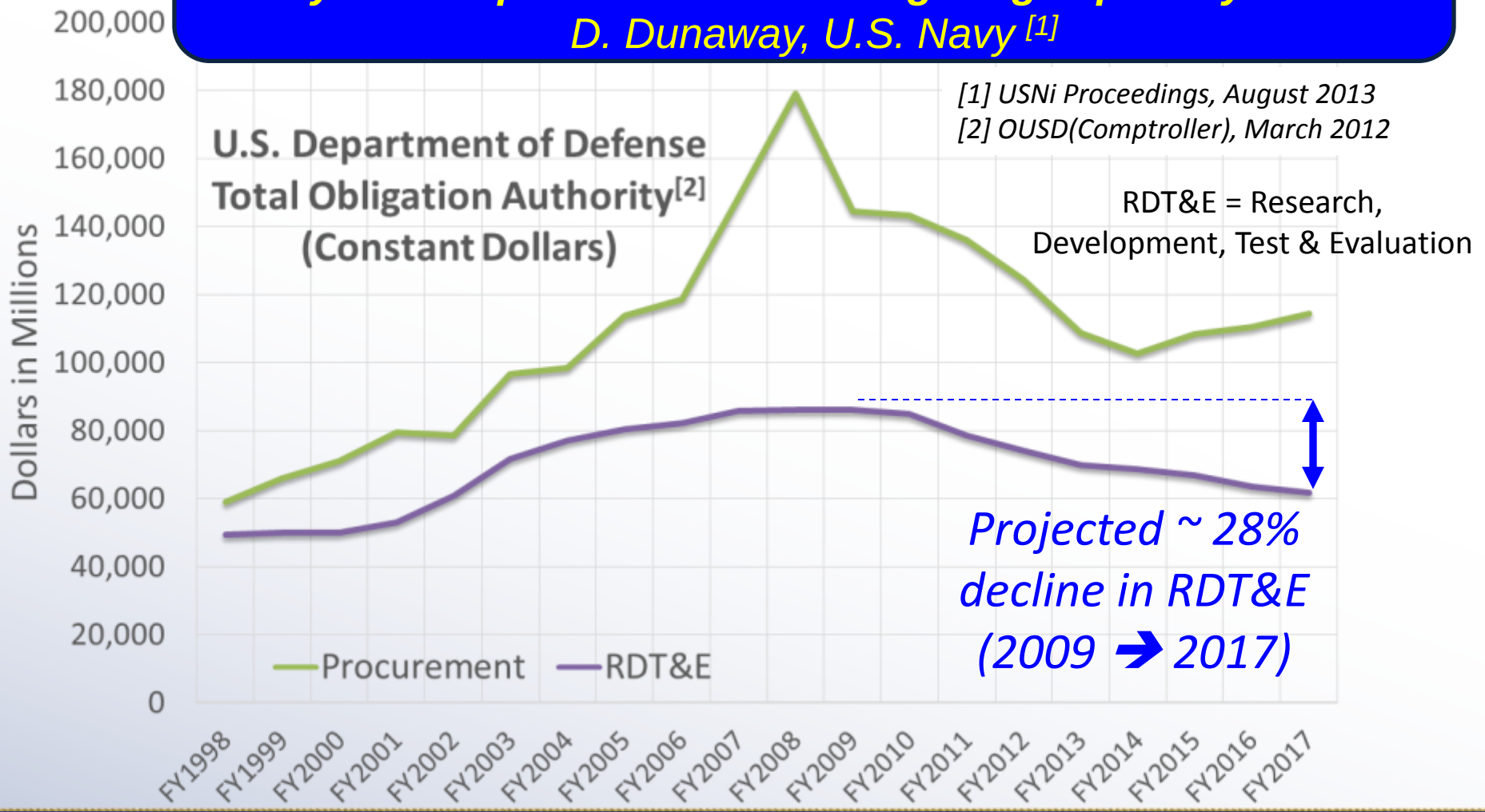
Historical DoD Total Obligation Authority

National Defense Budget Estimates for FY2013
OUSD(Comptroller), March 2012
(chapter 6, table 6-1)



RDT&E Budget Continues Decline

"In the face of decreasing budgets, rapidly evolving threats, and a shift in national defense strategy … , ***it's imperative that every dollar spent increases warfighting capability***" *VADM D. Dunaway, U.S. Navy [1]*



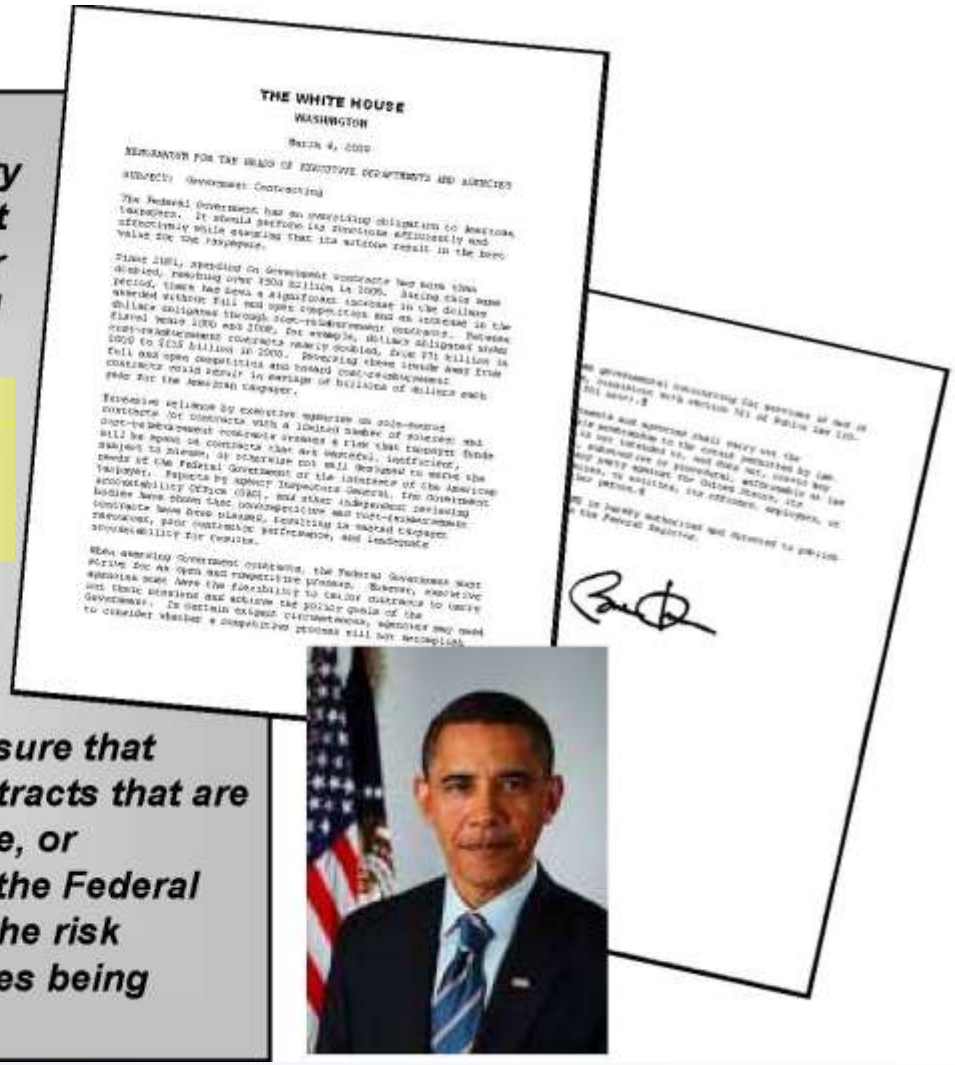
[1] USNi Proceedings, August 2013
[2] OUSD(Comptroller), March 2012

Presidential Direction

Technology Maturity is a Contributor To Risk

". . . it is essential that the Federal Government have the capacity to carry out robust and thorough management and oversight of its contracts in order to achieve programmatic goals, avoid significant overcharges, and curb wasteful spending. A GAO study last year of 95 major defense acquisitions projects found cost overruns of 26 percent, totaling $295 billion over the life of the projects. Improved contract oversight could reduce such sums significantly.

". . . the Federal Government shall ensure that taxpayer dollars are not spent on contracts that are wasteful, inefficient, subject to misuse, or otherwise not well designed to serve the Federal Government's needs and to manage the risk associated with the goods and services being procured. . . .



DAU, DTM 09-027 Implementation of the WSARA 2009, Brown, 2009

Secretary of Defense on Technology

DAU, DTM 09-027 Implementation of the WSARA 2009, Brown, 2009

"First, this department must consistently demonstrate the commitment and leadership to stop programs that significantly exceed their budget or which spend limited tax dollars to buy more capability than the nation needs…

Second, we must ensure that requirements are reasonable and technology is adequately mature to allow the department to successfully execute the programs…

Third, realistically estimate program costs, provide budget stability for the programs we initiate, adequately staff the government acquisition team, and provide disciplined and constant oversight.

We must constantly guard against so-called "requirements creep," validate the maturity of technology at milestones, fund programs to independent cost estimates, and demand stricter contract terms and conditions."

Secretary of Defense Robert M. Gates (Dec 2006 – Jul 2011)

Sequestration Caps Imposed by 2011 Budget Control Act

"DoD would be forced to sharply reduce funding for procurement, RDT&E, and MILCON. … cuts of 15% to 20% might well be necessary"

Secretary of Defense Chuck Hagel (Feb 2013 to Feb 2015)

(Sec of Defense Ltr to Chairman & Ranking Member, Committee on Armed Services, July 2013)

TRA Background

- NASA first established the use of Technology Readiness Levels (TRLs) in the late 1980's
  - Applied to Program Reviews
  - Evolved from 7 levels to today's 9 levels
- DoD adopted the use of TRLs for new Major programs in 2001 per DUSD(S&T) Memorandum
  - Response to GAO recommendation to assess technology maturity prior to technology transition
  - Established 9 levels modeled from NASA index
  - Definitions are similar but different from NASA
- Today the importance of technology maturity is codified in DoD 5000 series acquisition documentation, DoD Defense Acquisition Guidebook, and ASD(RE) TRA Guidance

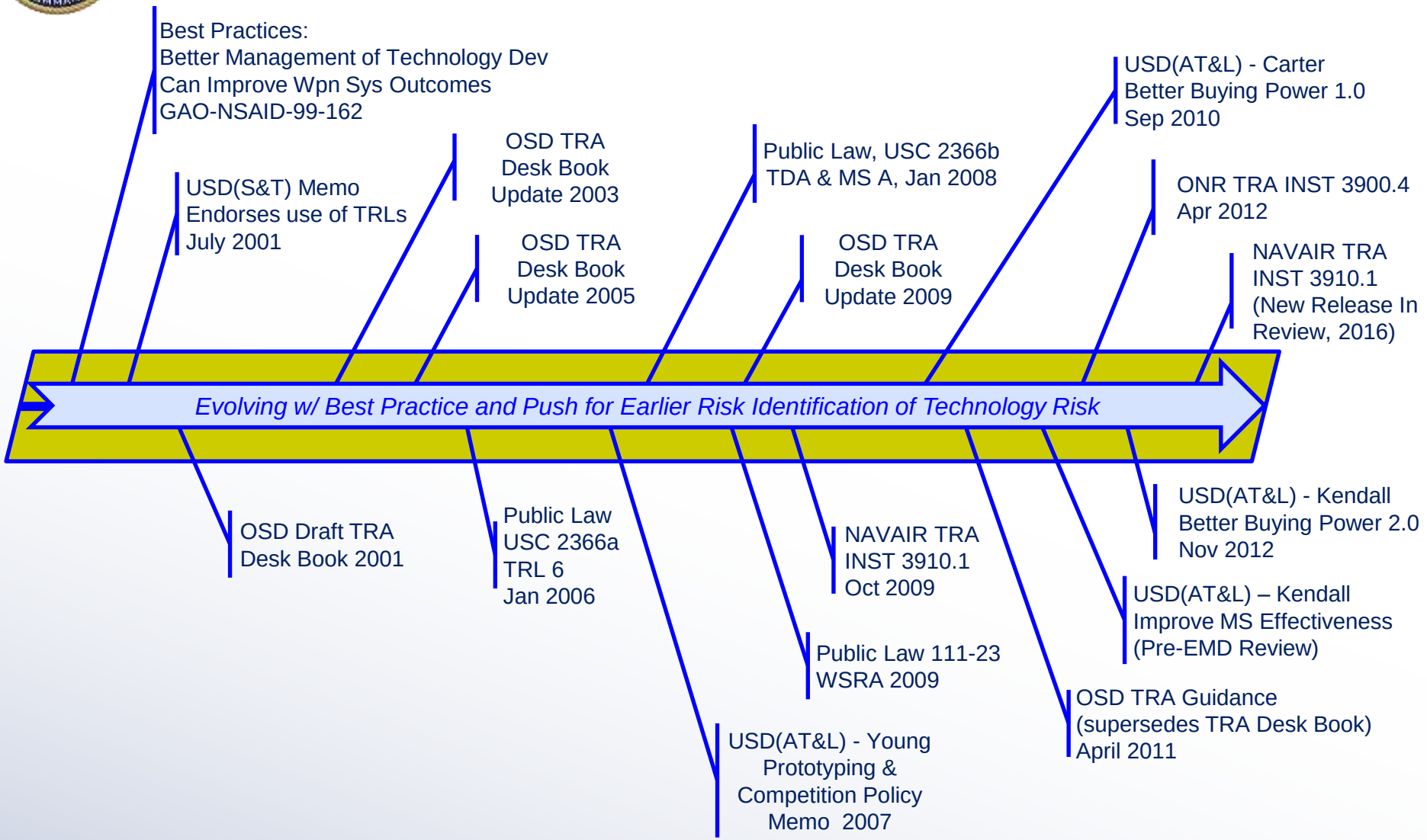
DoD to Use TRLs

- Within the Department of Defense (DoD), Technology maturity has become a major focus and criteria for allowing the insertion of new or novel technology into weapons systems acquisition programs
- As early as 1999, "GAO recommends that the Secretary of Defense adopt a disciplined and knowledge-based approach of assessing technology maturity, such as TRLs, DOD-wide, …"
- In response to GAO and Congressional pressures to act, DUSD (S&T/DDRE) issued in 2001 a memo that endorsed the use of TRLs and initiated the development of a Draft TRA Desk book
  - Leveraged NASA TRL model (first documented in 1989, Saden)
  - CAEs delegated responsibility to Service S&T executives
  - 2003, 2005, and 2009 Desk Book Revisions were issued as result of best practice ➔ *Replaced by 2011 DoD TRA Guidance*
  - Statutory Drivers, include: USC 2366b and WSARA 2009

GAO – Government Accountability Office
CAE – Component Acquisition Executive
WSARA – Weapon Systems Acquisition Reform Act
USC – United States Code

GAO/NSIAD-99-162

DoD Policy and Legislation Timeline



ITRO Mission Statement

To establish, promulgate, and implement NAVAIR Technology Readiness Assessment (TRA) and Technology Maturity Assessment (TMA) policy, procedures, and best practice for NAVAIR Acquisition Category (ACAT) I - IV programs consistent with ASN(RDA), ONR, OSD, and Congressional guidelines

NAVAIRINST 3910.1

NAVAIR (AIR-4.5E)TWH/Mentor for the TRA/TMA process

Ms. Jennifer Kirkwood

ITRO Lead & TRA Principle POC

(301) 342-9107

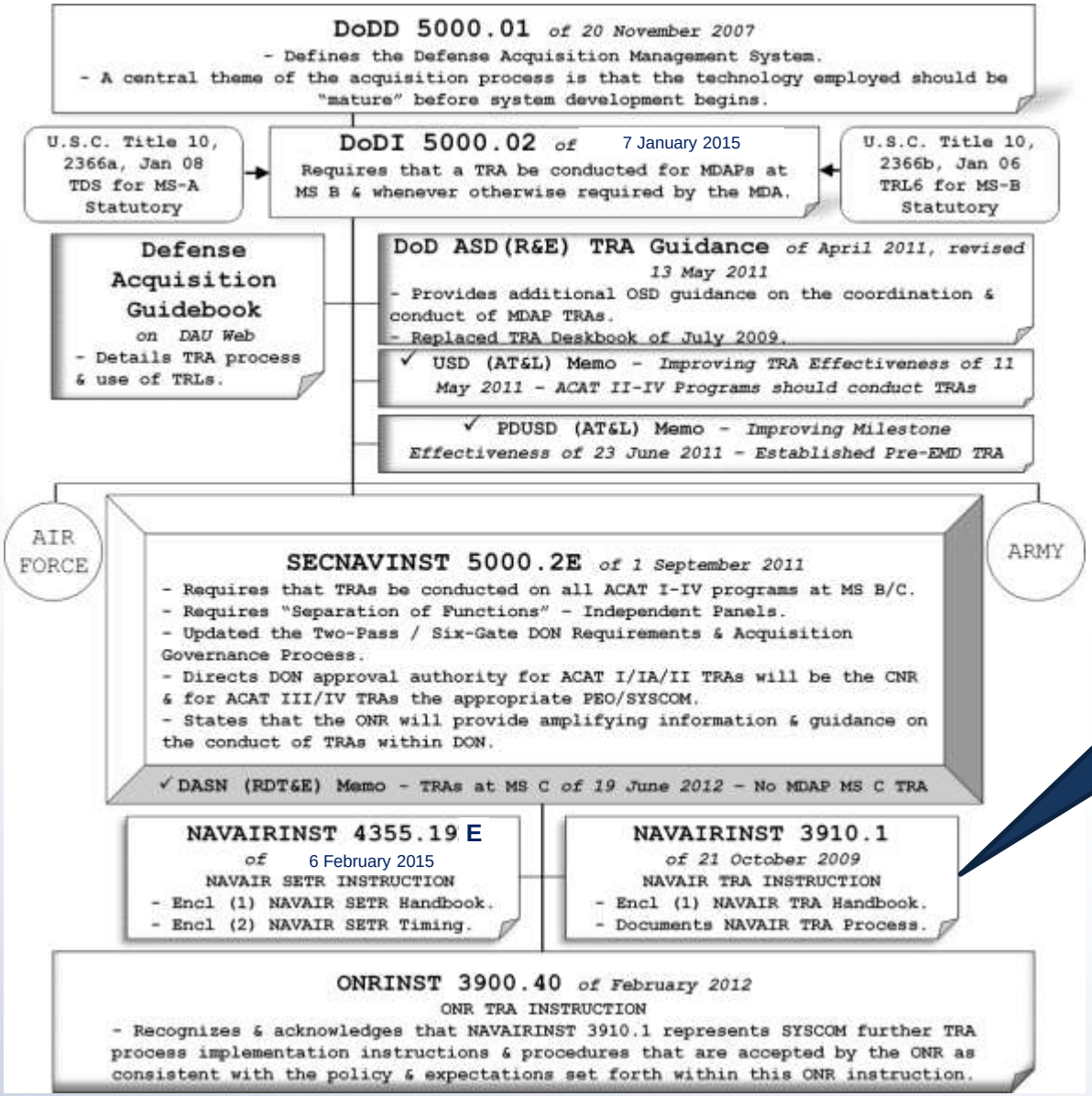
Independent Technical Review Office

~ 100 NAVAIR
TRAs / TMAs
Since 2002

TRA & TMA: “What is it?”

- Systematic metrics based process used to assess the maturity of Critical Technology Elements (CTEs)
  - Utilizes Technology Readiness Level’s (TRLs) as a metric to assess estimated CTE maturity
  - Helps “identify” areas for program technical risk management, but is **Not** a Risk Assessment
  - Assumes a threshold compliant design and assesses the technology maturity of the elements that make up the design foundation of which the design is dependent
  - Addresses Hardware and Software
  - Assessment Event “Draws a Line in the Sand” for determining technology maturity
    - No credit for future accomplishments when assigning TRLs

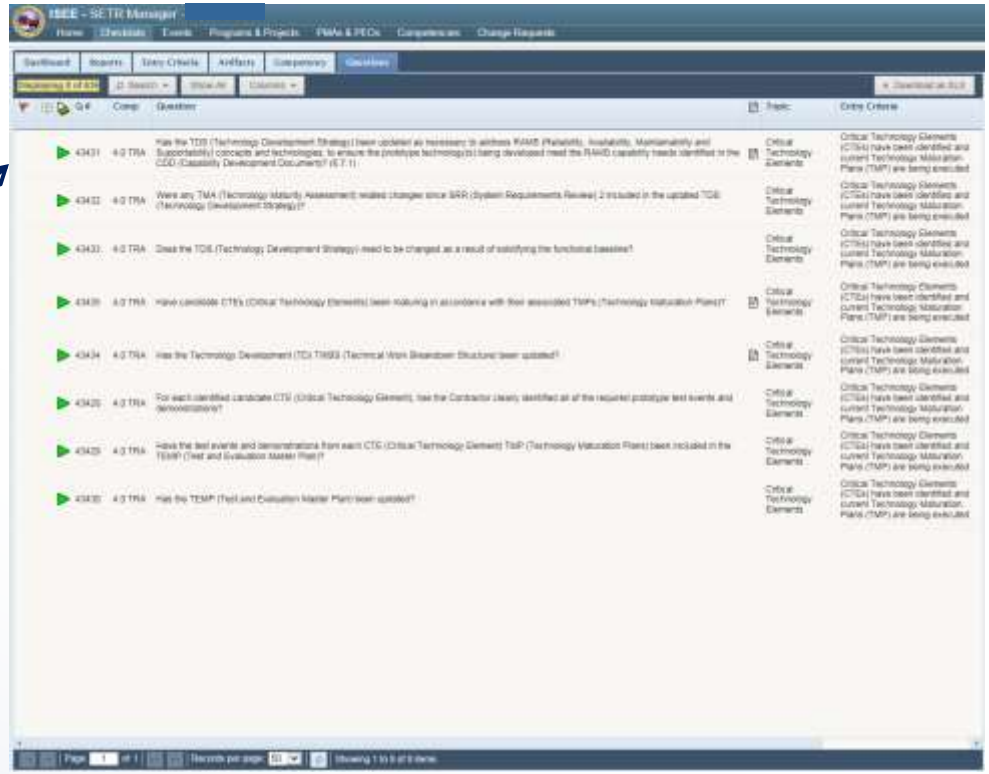
TRA Directives



- NAVAIRINST 3910.1 Update in Process
- NAVAIR TRA Handbook (2016)

TRA-Related SETR Checklists

- TMA/TRA questions exist for all SETR events
- Incorporated as part of the on-going SEDIC Menu-driven CHECKLIST update effort
- Identified under 4.0 TRA (Technology Readiness Assessment)
- ITRO reviews the tailoring-in and tailoring-out of questions for programs
- TMA/TRA checklist question updates are in process



TRL 6 Statutory Requirement

REQUIREMENT FOR CERTIFICATION BEFORE MAJOR DEFENSE ACQUISITION PROGRAM MAY PROCEED TO MILESTONE B.

(a) CERTIFICATION REQUIREMENT.—Chapter 139 of title 10, United States Code (as amended by section 801 FY2006 NDAA; and section 805 FY2007 NDAA), is amended by inserting after section 2366 the following new section:

"§ 2366a. Major defense acquisition programs: certification required before Milestone B or Key Decision Point B approval

"(a) CERTIFICATION.—A major defense acquisition program may not receive Milestone B approval, or Key Decision Point B approval in the case of a space program, until the milestone decision authority certifies that—

"(2) the technology in the program has been demonstrated in a relevant environment;

Subsequently amended via FY2008 NDAA
Title 10 USC 2366b

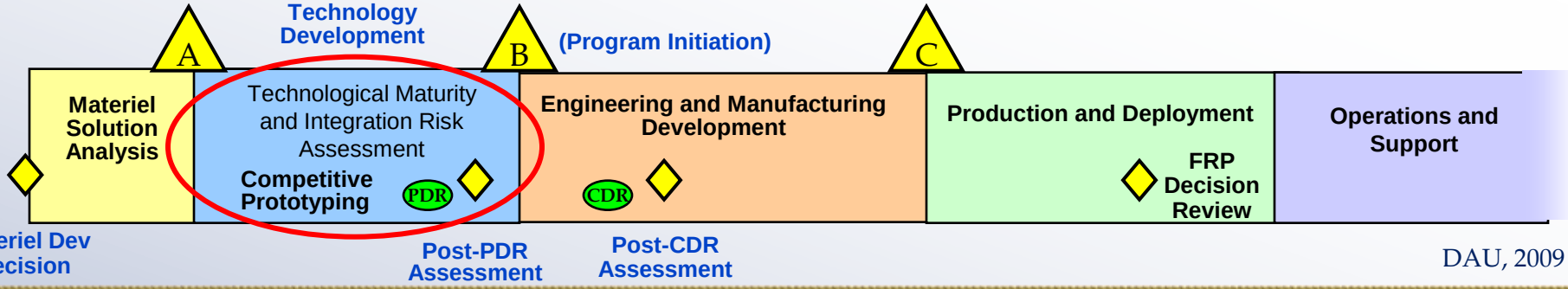
MDA must certify TRL 6 for all Critical Technology Elements (CTEs) prior to receiving Milestone B approval (i.e., enter the EMD Phase)

Evolution of DoD Acquisition Life Cycle

Defense Acquisition Management System, May 12, 2003

Defense Acquisition Management System, December 8, 2008

Defense Acquisition Management System, May 22, 2009



DAU, 2009

Weapon Systems Acquisition Reform Act

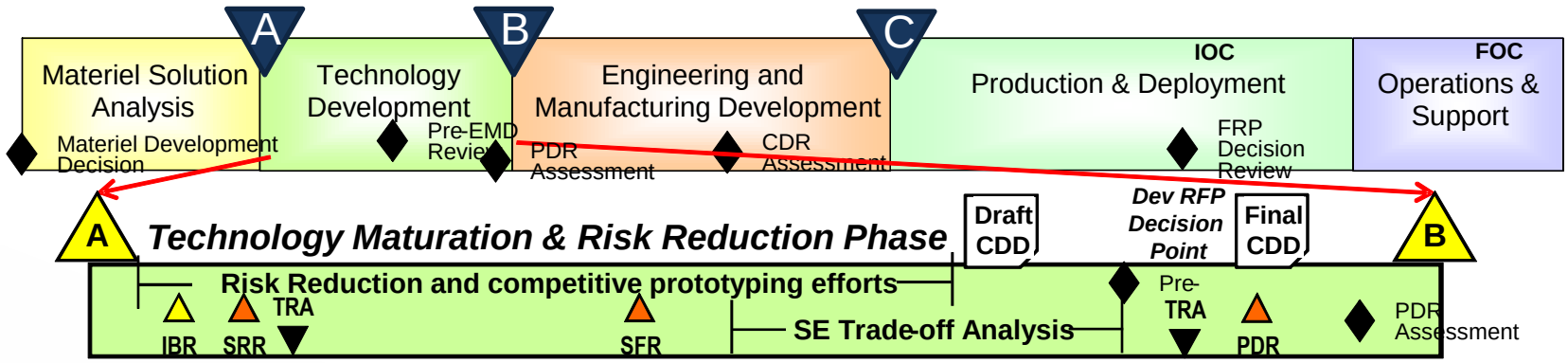
Public Law No. 111-23, 205(a)(3) Codified Title 10 U.S.C 2366b(a)(2)

"The key to successful acquisition programs is **getting things right from the start with sound systems engineering**, cost estimating, and developmental testing **early in the program cycle**. The bill that we are introducing today will require the Department of Defense to take the steps needed to put major defense acquisition programs on a sound footing from the outset. If these changes are successfully implemented, they should help our acquisition programs avoid future cost overruns, schedule delays, and performance problems."
–Senator Carl Levin, Chairman, Senate Armed Services Committee

"The Weapon System Acquisition Reform Act of 2009 is an important step in efforts to reform the defense acquisition process. This legislation is needed to focus acquisition and procurement on emphasizing systems engineering; **more effective upfront planning and management of technology risk**; and growing the acquisition workforce to meet program objectives."
–Senator John McCain, Ranking Member, Senate Armed Services Committee

DAU, DTM 09-027 Implementation of the WSARA 2009, Brown, 2009

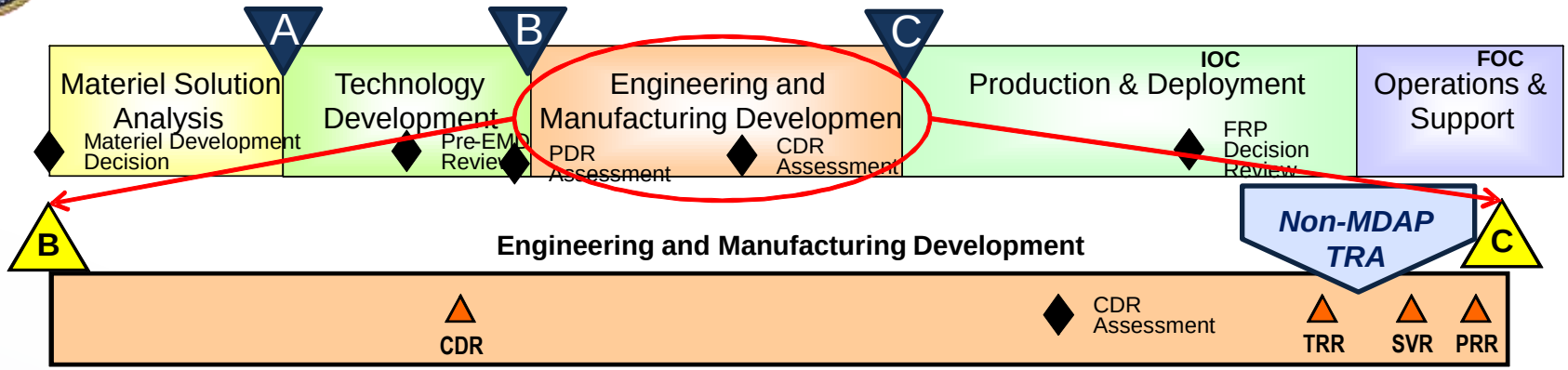
Tech Risk Reduction in TMRR Phase



- Technology Maturation & Risk Reduction
  - Conduct a TRA/TMA post MS-A contract award to establish/validate “candidate” CTEs and assess the risk of associated tech maturation plans
  - Consistent with AS/SEP, ensure competitive system prototype(s):
    - Provide true risk reduction through demonstrations of “candidate” CTEs in a relevant environment (i.e., TRL 6)
    - Inform SE tradeoff analysis and requirements refinement
    - Ensure technology risk reduction efforts considered in EMD proposals
  - Conduct Preliminary TRA for pre-EMD review
  - Conduct EMD TRA for Milestone B
  - Finalize CDD based on tech feasible and affordable system req’ts

IBR = Integrated Baseline Review
SE = Systems Engineering
SRR = System Requirements Review
CDD = Capabilities Design Document
SFR = System Functional Review
TRL = Tech Readiness Level

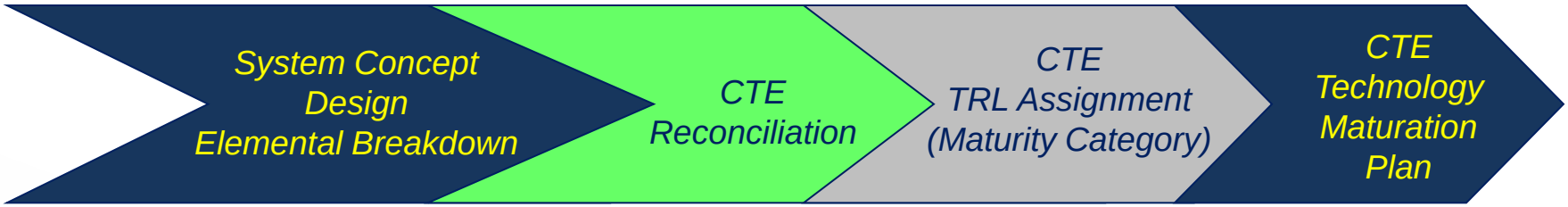
Technology Risk Reduction in EMD



- Engineering, Manufacturing, and Development (EMD) phase
  - Design maturity realized by Critical Design Review (CDR) allows for manufacturing quality engineering drawings
  - CPD informed by CDR and DT/OT results
  - CTE TMPs continue increasing technology maturity trend, such that TRL 7 (at min) can be achieved by Milestone C
  - MDAPs are not required to conduct a TRA for Milestone C, while non-MDAPs, CAEs are encouraged to do so
    - SECNAVINST 5000.2E requires Milestone C TRA for non-MDAPs unless waived by MDA

CPD = Capabilities Production Document DT = Developmental Test MDAP = Major Defense Acquisition Program
OT = Operational Test MDA = Milestone Decision Authority TMP = Technology Maturity Plan TRL = Tech Readiness Level
TRR = Test Readiness Review SVR = Specification Verification Review PRR = Production Readiness Review

TRA Process Flow



- Comprehensively decompose system components to address all critical technologies
- Assess and substantiate whether each critical technology is an immature technology (i.e., CTE) or not
  - Justification “why not” is as important as “why it is” a CTE
  - Pedigree/Heritage supporting CTE reconciliation must be understood
- Assess & assign an estimated TRL (ea. CTE) & Category
  - Only CTEs require a TRL
- Describe CTE(s) technology maturation roadmap(s) showing expected technology readiness progression
  - TRL progression is based on logical, relevant and successful demonstrations
  - Identification and insight into leveraged IRAD, S&T efforts, etc., is important to justify maturity and investment towards CTE maturation

Critical Technology Elements (CTEs)

- The adjective "critical" has several applications and context when referencing technology

  - Mission Critical Technology List
  - Critical Program Information
  - Critical for Mission Success
  - Critical Safety Items

  $\neq$ CTE

- The term Critical Technology Element (CTE) is used to uniquely identify immature technology

A technology element is considered "critical" if:

(1) the system being acquired depends on this technology element to meet operational requirements (within cost and schedule limits), and
(2) if the technology element or its application is either new or novel or in an area that poses major technological risk during detailed design or demonstration

Basic Criteria for Determining CTEs

- Is the technology Novel? If “Yes” then without question is a CTE
- Is the technology New? If “Yes” then the extent/context of “New” needs further investigation to determine whether a CTE
- If “Yes” to any of the following additional questions then further discussion is required to decide
  - Has the technology been modified?
  - Has the technology been repackaged such that a new and more stressful relevant environment is realized?
  - Is the technology expected to operate in an environment and/or achieve a performance expectation beyond it’s original design intention or demonstrated capability?
- Do not confuse CTEs with standard engineering development practice

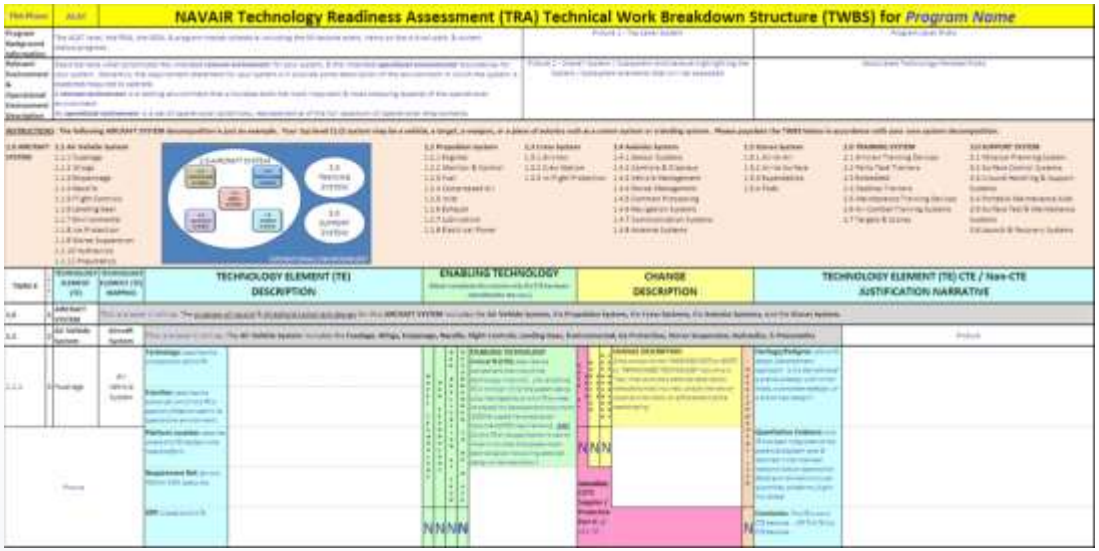
Is the physics or engineering understood in the industry and/or is it scalable from similar proven technology products?

Additional CTE Considerations

- CTE drivers could also be:
  - Affordability, Lethality, Supportability, and/or Manufacturability Goals
  - Enabling technologies which allow for performance margin or cost reduction initiatives (CAIV'able requirements?)
- All CTEs are traceable to a threshold req't
- CTEs may or may not be KPP related
- CTEs should have mature fallback alternatives
- CTEs can be associated with either a low or high risk design approach
- CTEs may be COTS or NDI

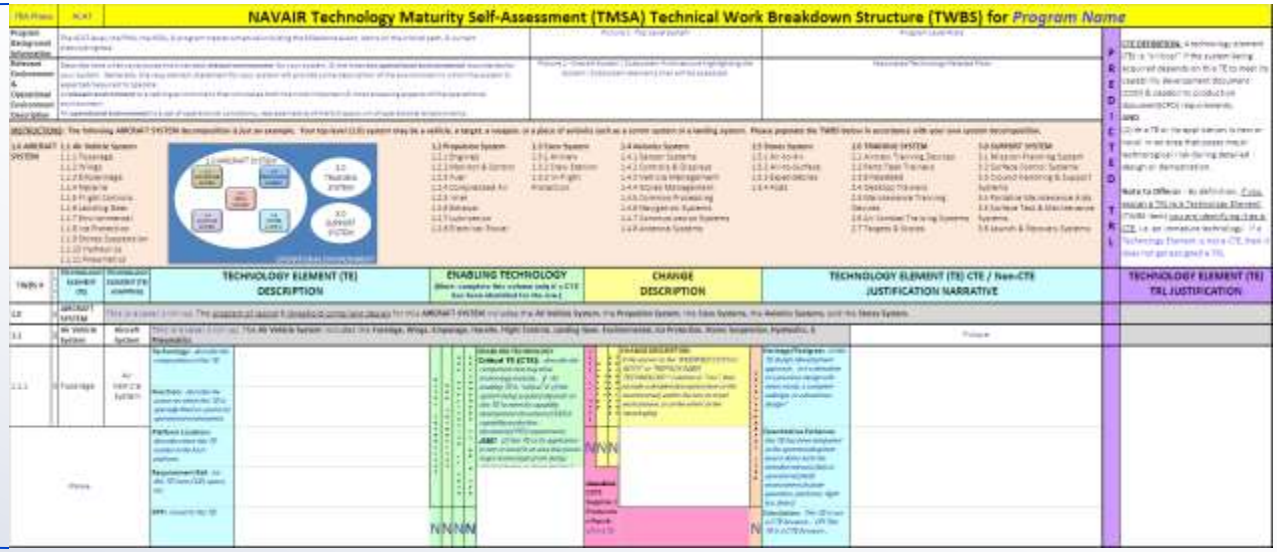
→ The NAVAIR TRA process implements a rigorous and comprehensive review of the entire decomposed product design to reconcile the existence (or not) of CTEs

TRA TWBS & TMSA Templates



TRA TWBS tool used w/ PM and/or Contractor to reconcile CTEs when not in competitive Source Selection

TMSA tool used to reconcile CTEs when in competitive Source Selection *(Self-Assessment used to capture data)*



Reconciliation of CTEs

Panel Membership Dependent on Technologies Involved

CTE Technical Work Breakdown Structure (WBS) Systematic Review

Manufacturing Sensors Missile Warning Communications

Architecture Processing Software Survivability DIRCM

Weapons / Stores R&M Aircrew Systems EO/IR

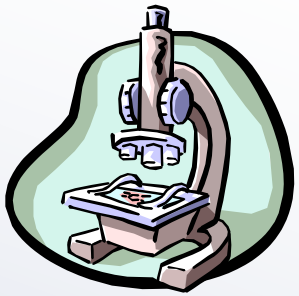
Antennas Structures Propulsion Electrical Systems

Materials Flight Vehicle Performance

Security Information Systems Navigation

Safety Logistics Training

Aeromechanics * * *



Reconciliation Event

Final Panel Membership Based on Resulting CTEs

Comprehensive Review

TRA Plate

Focused Panel Membership

Scoring Event

TRA/TMA “Watch Items”

- A "Watch Item" represents a technology area that the Independent Review Panel (IRP) could not assess without
  - Additional PM action, or
  - Depending upon the actual design implementation, could potentially lead to additional CTE(s) as the design evolves during EMD

- Technologies added to the "Watch Item" list could fall any one of the three following categories:

  1) PM acknowledged non-threshold compliant design which therefore precluded the IRP from assessing an acceptable technology approach to achieve CDD/CPD or ORD compliance, and/or;
  2) GFE representing a potential external technology maturity insertion risk, and/or;
  3) Technology risk implemented within the baseline design to afford greater robustness or performance enhancement but do not trace to the CDD/CPD or ORD, and/or;
  4) Technology integration approach today provides no reason for concern but potential exists as the baseline design implementation evolves for additional complexity and dependence upon novel application techniques

NAVAIR Best Practice

Panel Member Characteristics

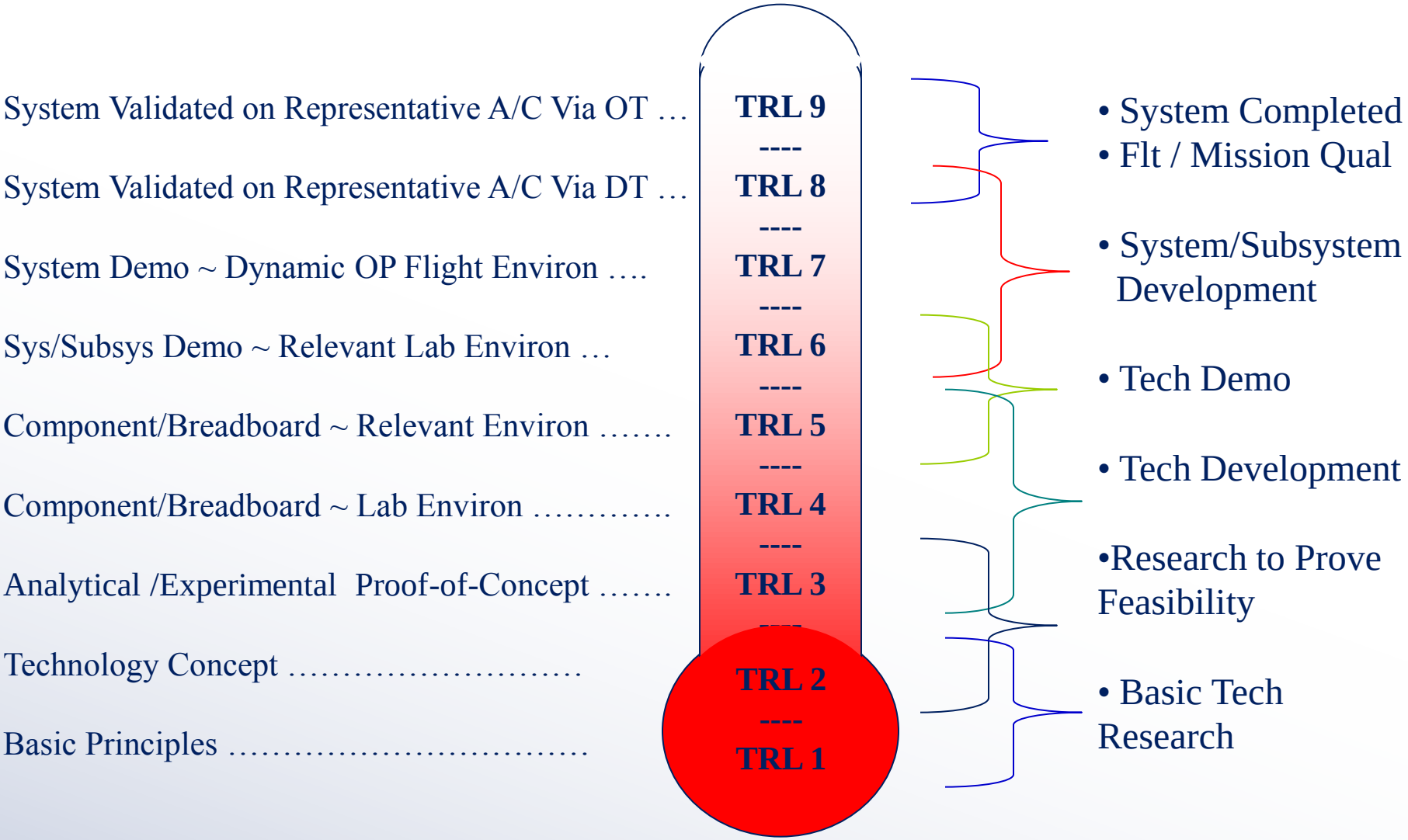
- Independent and therefore, not a member of the program IPT or any specialized interest group
- Recognized expert with proven experience (meets chair & ONR TRAC expectations)
- Grey Head that has authority to speak for Dept/Command concerning respective technology
- No personal gain for program success or failure
  - Not a “Pet Rock” technology
- Has current and appropriate clearance level
- Will proactively work to de-conflict schedule as program plans change
  - Maintain consistent IRP throughout duration of TRA Process, where possible

TRA Panel Member Considerations

- NAVAIR Competency Aligned Organization (CAO)
  - Research & Engineering (AIR-4.0), Test & Evaluation (AIR-5.0), and Logistics (AIR-6.0)
    - Senior Subject Matter Experts
    - NAVAIR / Navy / DoD National Experts
- NAVAIR Fellows Recognition 

  - Esteemed Fellow: Top 0.25% Engineers/Scientists Within Naval Aviation
  - Fellow: Top 0.75% Engineers/Scientists Within Naval Aviation
  - Associate Fellow: Within Top 3% Engineers/Scientists of Department
- Office of Naval Research (ONR)
- Johns Hopkins Applied Research Laboratory (JHU APL)
- FFRDC (e.g., MITRE), Industry, and Academia
- Other DoD Services, NASA, and Agencies

DoD TRL Characteristics *(Snapshot)*



DoD Technology Readiness Levels

TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied	Published research that identifies the principles that underlie this technology. References to who, where, when.
2	Technology co cept and/or ap cation formulat		d
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
4	Component and/or breadboard validation in a laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and results from testing laboratory-scale breadboard(s). References to who did this work and when. Provide an estimate of how breadboard hardware and test results differ from the expected system goals.
5	Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.	Results from testing laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match the expected system goals?
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or

System prototype demonstration in an operational environment.
(Milestone C Target)

TRL	Definition	Description	Supporting Information
		laboratory environment or in a simulated operational environment.	actions to resolve problems before moving to the next level?
7	System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.	OT&E reports.

(OSD TRA Guidance 2011)

System/subsystem model or prototype demonstration in a relevant environment.
(Milestone B Statutory Req't)

System Prototype Demonstrations
"Relevant Environment → TRL 6"


Source: U.S. Army.


Source: U.S. Air Force.


Source: U.S. Navy.


Source: U.S. Air Force.


Source: U.S. Navy.


Source: U.S. Army.


Source: U.S. Navy.


Source: U.S. Navy.

Relevant environment varies dependent upon system performance requirements and worse case (threshold) mission relatable scenarios

Physical, logical, data, security & user environments


Source: U.S. Air Force.

TRL = Technology Readiness Level

- System prototype demo must address worse case mission relevant environment to minimize technology risk to EMD

IRP Scoring of CTEs
(Data Types Required)

- Demonstration accomplishments that reflect “CTE Maturation Progress”
  - State quantitative facts in order to temper and legitimize significance of the technology maturation accomplishments
  - Describe the measurement environments and methodology used
  - Identify:
    - Laboratory Hrs
    - M&S Hrs
    - Flying Test Bed Hrs
    - Flight Test Hrs (Actual platform, EDM, or representative platform)
    - Physics Based Models and certification status
  - Put all demonstration evidence in Perspective (Build #, Prototype State, etc.)
  - Relevant/Operational environment relationship to Actual Relevant Environment
- Tangible evidence of CTE Maturation accomplishments (e.g., hardware, pictures, displays, technical papers, reports, etc.)
  - Clearly state what is and is not represented by the evidence
- Relevant CTE Maturation leveraged from other programs
  - Clearly state any differences between this program and legacy leveraged
- Significant maturation events that fall short or have not been accomplished

Technology Maturation Plan (TMP)

- TMPs are written for each candidate CTE
- TMPs should include: the demonstration planned (or completed), objective, venues, dates of occurrence, method & scope of tests, and anticipated TRL graduation dates (based on statistically sound repeatable demo successes)
- TMP should describe the system representative prototype(s) and demonstration relevant environment

Thank You !

Any Additional Questions