# Using Technology Readiness Assessments (TRAs) to Assess the Maturity of Life-Cycle Related Technologies

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**Dr. Jay Mandelbaum**

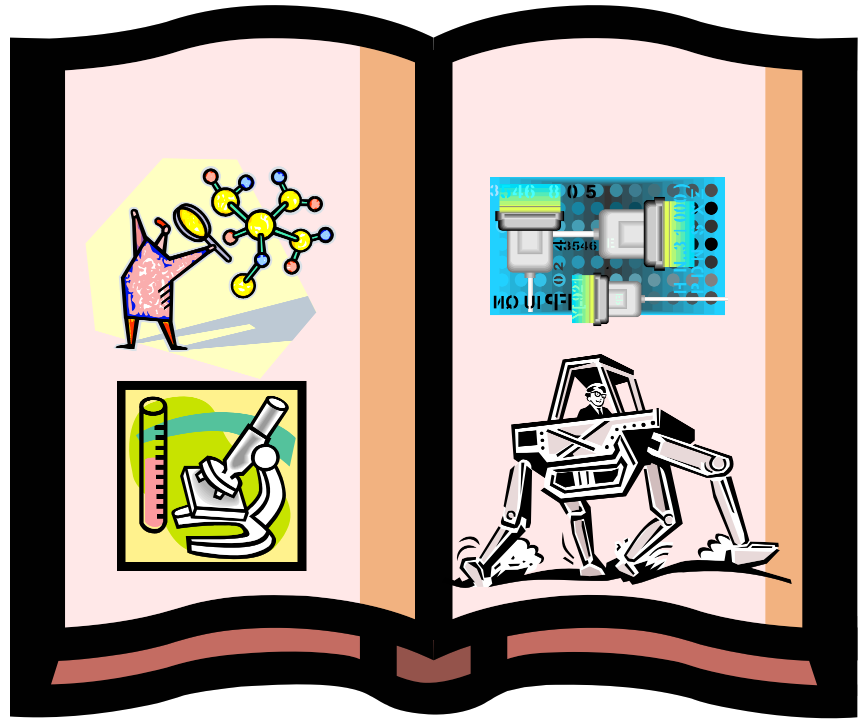
Institute for Defense Analyses
4850 Mark Center Drive • Alexandria, Virginia 22311-1882

# Outline

- **Introduction to Technology Readiness Assessments (TRAs)**
- **Life-cycle-related (LCR) Critical Technology Element (CTE) identification**
- **Life-cycle-related Critical Technology Element assessment**
- **References and resources**

# What is a TRA?

- **Systematic, metrics-based process that assesses the maturity of Critical Technology Elements (CTEs)**
  - **Uses Technology Readiness Levels (TRLs) as the metric**
- **Regulatory information requirement for *all* acquisition programs**
  - **Submitted to DUSD(S&T) for ACAT ID and IAM programs**



≠ Not a risk assessment

≠ Not a design review

≠ Does not address system integration

# Critical Technology Element (CTE) Defined

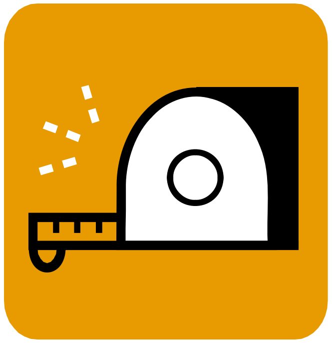
**A technology element is "critical" if the system being acquired depends on this technology element to meet operational requirements with acceptable development cost and schedule and with acceptable production and operation costs *and* if the technology element or its application is either new or novel.**

**Said another way, an element that is new or novel or being used in a new or novel way is critical if it is necessary to achieve the successful development of a system, its acquisition or its operational utility.**

**CTEs may be hardware, software, manufacturing, or life cycle related at the subsystem or component level**

# TRL Overview

- **Measures technology maturity**
- **Indicates what has been accomplished in the development of a technology**
  - **Theory, laboratory, field**
  - **Relevant environment, operational environment**
  - **Subscale, full scale**
  - **Breadboard, brassboard, prototype**
  - **Reduced performance, full performance**

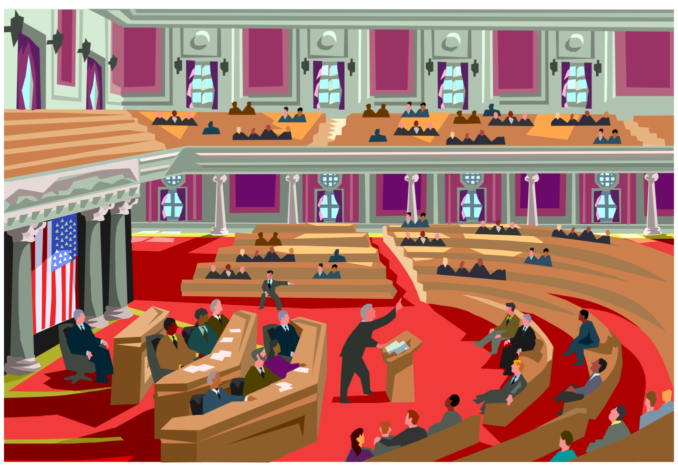


- **Does not indicate that the technology is right for the job or that application of the technology will result in successful development of the system**

# Why is a TRA Important? (1 of 2)

- **The Milestone Decision Authority (MDA) uses the information to support a decision to initiate a program**
  - **Trying to apply immature technologies has led to technical, schedule, and cost problems during systems acquisition**
  - **TRA established as a control to ensure that critical technologies are mature, based on what has been accomplished**

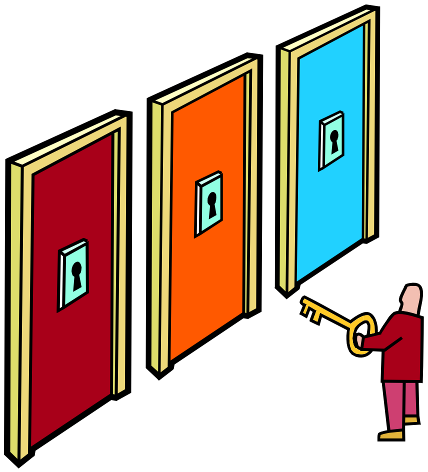

**TRA is the basis!**



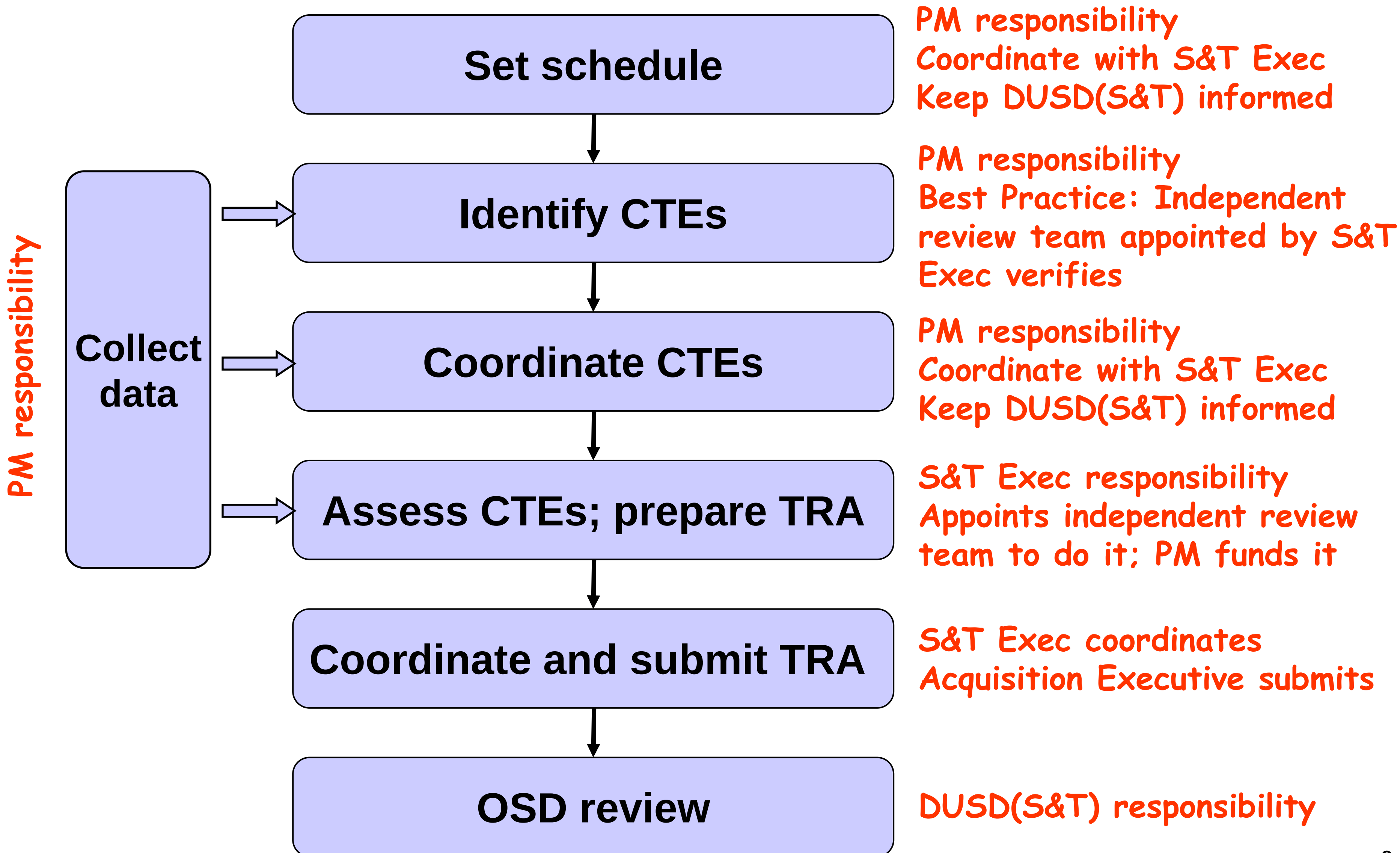
- **Congressional interest**
  - **MDA must certify to Congress that the technology in programs has been demonstrated in a relevant environment at program initiation**
  - **MDA must justify any waivers for national security to Congress**

# Why is a TRA Important? (2 of 2)

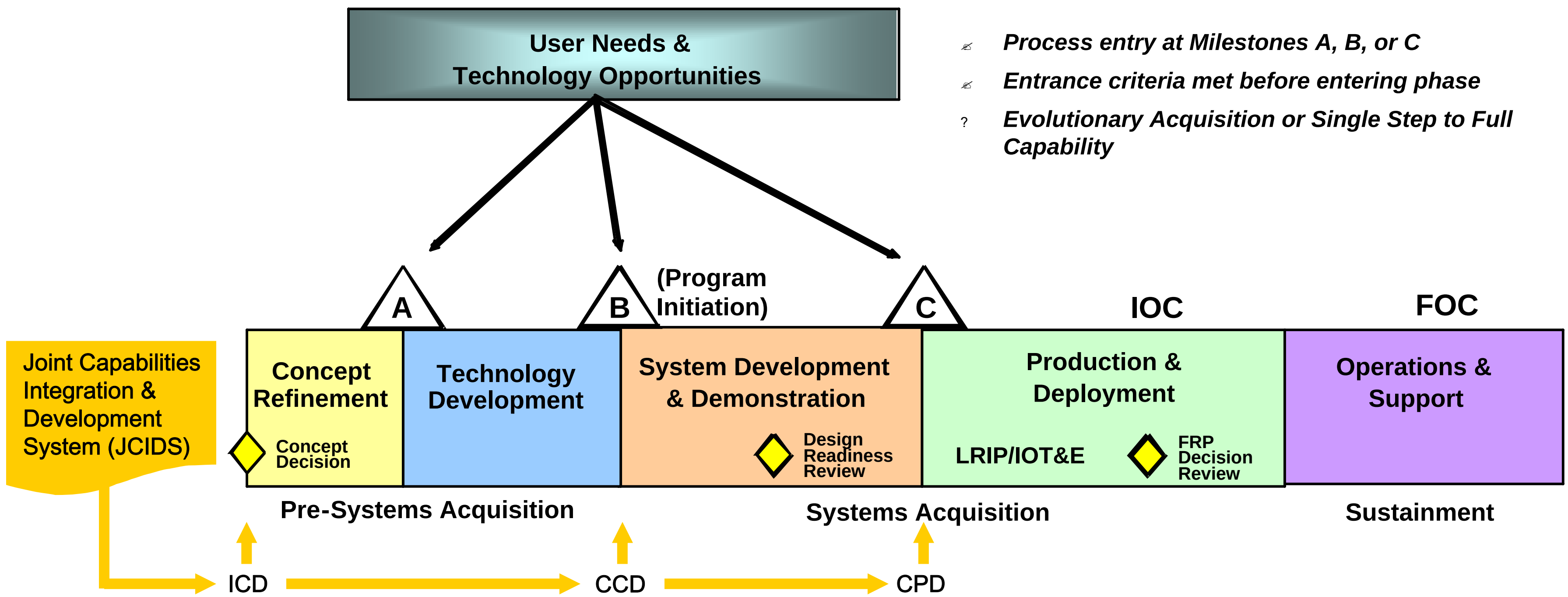
- **The PM uses the expertise of the assessment team and the rigor and discipline of the process to allow for:**
  - **Early, in depth review of the conceptual product baseline**
  - **Periodic in-depth reviews of maturation events documented as verification criteria in an associated CTE maturation plan**
  - **Highlighting *(and in some cases discovering)* critical technologies and other potential technology risk areas that require management attention (and possibly additional resources)**
- **The PM, PEO, and CAE use the results of the assessment to:**
  - **Optimize the acquisition strategy and thereby increase the probability of a successful outcome**
  - **Determine capabilities to be developed in the next increment**
  - **Focus technology investment**



# Process Overview



# Overview of Technology Considerations During Systems Acquisition



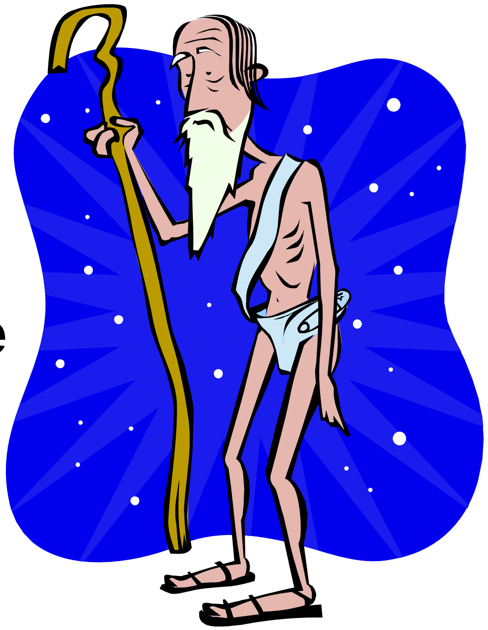

**TRAs required at MS B, MS C, and program initiation for ships (usually MS A).**

# Outline

- Introduction to Technology Readiness Assessments (TRAs)
- Life-cycle-related (LCR) Critical Technology Element (CTE) identification
- Life-cycle-related Critical Technology Element assessment
- References and resources

# What is a Life-Cycle-Related CTE

- **LCR technologies impact system supportability cost and/or time. They may:**
  - **Reduce the logistics footprint**
  - **Improve reliability/maintainability**
  - **Lower operating, support, or maintenance manpower requirements**
  - **Enhance training**
  - **Enhance human factors interactions**
  - **Increase operational availability or readiness**
  - **Improve the upgradability of the system**



# Examples of Life-Cycle-Related CTEs

- Corrosion resistant material
- Thermal protection materials
- Supportable low-observable materials
- Obsolescence mitigation technologies
- Technical data automation technologies
- Material handling technologies
- Simulators or training simulations
- Autonomic logistics sensors, data links, or messaging transmission
- Advanced technologies that affect human factors
- Analysis technologies, such as automated diagnostics and prognostics
- Methods/algorithms for sensing or trend analysis
- Technologies that enable open systems architecture

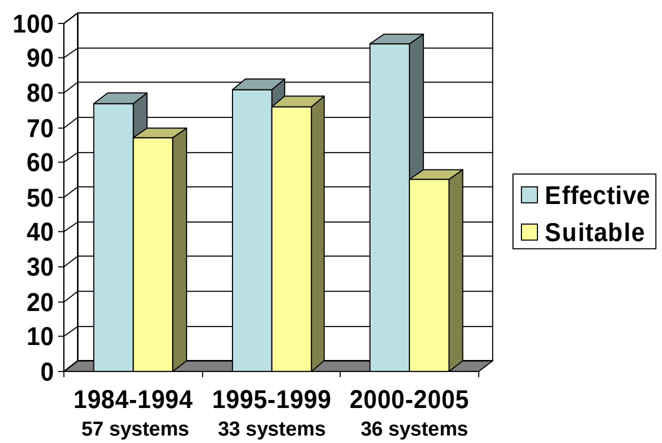
# Why Be Concerned About Life-Cycle-Related CTEs (1 of 2)

- **Definitional perspective**
  - **All costs encompassed in CTE definition**
- **Policy perspective**
  - **DoDI 5000.2 states that "The project shall exit Technology Development when an *affordable increment* of militarily-useful capability has been identified …"**
  - **CJCSI 3170.01E defines *increment* as "a militarily useful and *supportable* operational capability that can be effectively developed, produced or acquired, deployed, and sustained…"**
  - **Mobility and logistics footprint are military capabilities and reliability and maintainability are military performance parameters**

# Why Be Concerned About Life-Cycle-Related CTEs (2 of 2)

- **Experiential perspective**
  - **Increasing operating and support cost is decreasing acquisition capability; therefore greater emphasis is being placed on life cycle related issues including the technologies that affect them**
  - **Operating and support costs will continue to increase, thereby making life cycle related technologies even more critical**

**Percentage of Systems Passing Operational Test**




Source: 15 September 2005 David Duma presentation to the Defense Acquisition Performance assessment Project

# Enhancing the CTE Identification Process to Better Detect Life Cycle Related Technologies (1 of 3)

- **Modify determination of criticality**
  - **Does the technology directly impact an operational requirement?**
  - **Does the technology have a significant impact on an improved delivery schedule?**
  - **Does the technology have a significant impact on the *life cycle* affordability of the system?**

**A CTE may be critical from either a performance or a life cycle related perspective (or both)**

# Enhancing the CTE Identification Process to Better Detect Life Cycle Related Technologies (2 of 3)

- **Clarifying life cycle cost questions – procurement cost component**
  - **How much does it cost to buy the component or subsystem with this technology?**
  - **Will the cost be significantly higher without the technology?**

# Enhancing the CTE Identification Process to Better Detect Life Cycle Related Technologies (3 of 3)

- **Clarifying life cycle cost questions – O&S cost component**
  - **Does the technology significantly reduce the logistics footprint?**
  - **Does the technology significantly improve reliability/maintainability?**
  - **Does the technology significantly lower operational, support, or maintenance manpower requirements?**
  - **Does the technology significantly enhance training by some combination of lowering the resources needed or boosting its effectiveness?**
  - **Does the technology significantly increase operational availability or readiness?**
  - **Does the technology significantly improve the upgradability of the system?**

# Best Practices for Life-Cycle-Related CTE Identification

- Independent panel should evaluate "significance" as used in the questions for identifying CTEs
- Include experts on appropriate LCR areas on the independent TRA panel
- Once a CTE has been identified from a performance perspective, also evaluate if it is an LCR CTE as well
  – Must also apply "new or novel test

# An Example of a Technology Being Critical From Two Perspectives

**The AN/APG-79 Active Electronic Scanned Array (AESA) Radar**

- **The technology directly impacts an operational requirement**
  - **The radar beam can be steered close to the speed of light, thereby enabling superior performance including air-to-air tracking at very long detection ranges, almost simultaneous air-to-air and air-to-surface mode capability, and enhanced situational awareness**
- **The technology significantly impacts life cycle affordability**
  - **MTBCF is greater than 15,000 hours for the array and greater than 1,250 hours for the entire system**
- **Everything in the system is new**

**Sources:** ***June 28, 2005 Raytheon News Release, Raytheon's Revolutionary APG-79 AESA Radar is Awarded a $580 Million Multi-Year Procurement Contract by the Boeing Company http://www.prnewswire.com/cgi-bin/micro_stories.pl?ACCT=149999&TICK=RTN&STORY=/www/story/06-28-2005/0003985043&EDATE=Jun+28,+2005; November 20, 2002 Raytheon News Release, Raytheon Demonstrates First Next-Generation AESA Capability at APG-79 Event http://www.raytheon.com/newsroom/briefs/112002.htm; Raytheon AN/APG-79 AESA data sheet http://www.raytheon.com/products/stellent/groups/sas/documents/legacy_site/cms01_050831.pdf.*** 

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# Hardware and Manufacturing TRLs

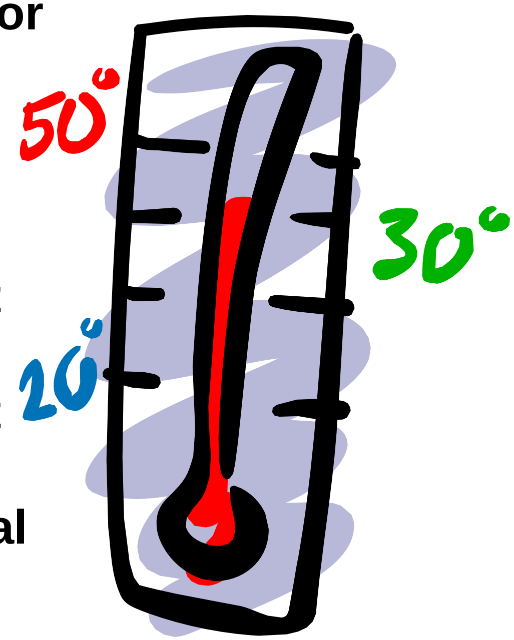
Increasing maturity

1. **Basic principles observed and reported**
2. **Technology concept and/or application formulated**
3. **Analytical and experimental critical function and/or characteristic proof of concept**
4. **Component and/or breadboard validation in a laboratory environment**
5. **Component and/or breadboard validation in a relevant environment**
6. **System/subsystem model or prototype demonstration in a relevant environment**
7. **System prototype demonstration in an operational environment**
8. **Actual system completed and qualified through test and demonstration**
9. **Actual system proven through successful mission operations**

# Software TRLs

Increasing maturity

1. Basic principles observed and reported.
2. Technology concept and/or application formulated.
3. Analytical and experimental critical function and/or characteristic proof of concept
4. Module and/or subsystem validation in a laboratory environment, i.e. software prototype development environment
5. Module and/or subsystem validation in a relevant environment
6. Module and/or subsystem validation in a relevant end-to-end environment
7. System prototype demonstration in an operational high fidelity environment
8. Actual system completed and mission qualified through test and demonstration in an operational environment
9. Actual system proven through successful mission proven operational capabilities



# Assessments Supported by Additional Information
# Example: TRL 6 Hardware Criteria

- **Definition:** **System/subsystem model or prototype demonstration in a relevant environment.**
- **Description:** **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 laboratory environment or in a simulated operational environment.**

- **Supporting Information:** **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 actions to resolve problems before moving to the next level?**

# Modifying the CTE Assessment Process for Life-Cycle-Related Technologies (1 of 5)

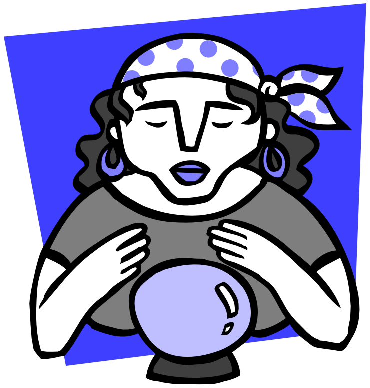
- **The definitions and descriptions corresponding to the various TRLs apply to LCR technologies**
- **Supporting information sufficient when:**
  - **Long-term effects do not have to be calculated**
    - **TRL 3 (analytical and experimental critical function and/or characteristic proof of concept) or lower**
  - **Long-term effects of the LCR CTE can be calculated analytically and the risk of error is minimal**


LAB PROTOTYPE SWL

    - **Shipboard weapons loader (SWL) provides a capability for a single operator to upload and download munitions while reducing operator workload and life-cycle cost**
    - **SWL demonstrations can confirm ship manpower reductions across the entire life cycle through a comparison with current crew requirements**

# Modifying the CTE Assessment Process for Life Cycle Related Technologies (2 of 5)

- **Under certain circumstances, the supporting information should be augmented or tailored for the specific situation**
  - **When long-term effects cannot be accurately calculated analytically and the risk of a miscalculation is large**
  - **When amplification of the Deskbook supporting information will be helpful in assigning the proper TRL**



# Modifying the CTE Assessment Process for Life Cycle Related Technologies (3 of 5)

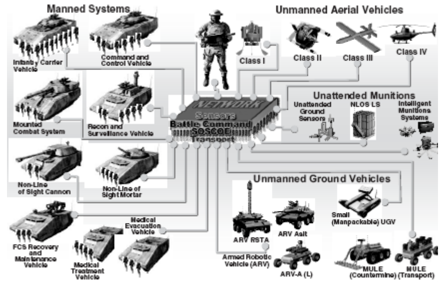
- **Technologies that improve reliability/maintainability and correspondingly reduce the logistics footprint and operating, support, or maintenance manpower requirements**
  - **Additional supporting information should focus on the performance of the end item**
    - **The C-5 Reliability Enhancement and Re-Engining Program (RERP) is a comprehensive effort to improve reliability, maintainability, and availability**
    - **Long-term commercial experience used to assess TRL 7 for new propulsion system**

# Modifying the CTE Assessment Process for Life Cycle Related Technologies (4 of 5)

- **Technologies used to protect against the environment (may also protect the environment)**
  - **Additional supporting information should focus on the performance of the material being tested**
    - **Using advanced high solid-edge retentive tank coatings instead of solvent-based paints; representation of tanks represents the highest annual maintenance cost**
    - **TRL 7 based on long-term commercial data on service life; reduced inspection, cleaning, preparation, and painting; and labor to apply the new coatings**

# Modifying the CTE Assessment Process for Life Cycle Related Technologies (5 of 5)

- **On-board and off-board technologies for analysis, status, or diagnosis of failure**
  - **Additional supporting information should focus on accuracy**
    - **The extensive use of predictive maintenance, conducted by networked on-board diagnostics and prognostics that pulse the system when issues arise (or are expected), is an important component of the Future Combat Systems (FCS)**
    - **When failures are random, physics-of-failure models do not exist; a statistical approach to prediction must be taken, but, data must be generated to support TRL greater than 4**



# Additional Life-Cycle-Related Supporting Information Has Been Developed

| Hardware TRL 6 Definition | Hardware TRL 6 Description | Hardware TRL 6 Supporting Information |
|---|---|---|
| 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 laboratory environment or in a simulated operational environment. | 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 actions to resolve problems before moving to the next level? |

***Additional hardware supporting information for technologies to improve reliability/maintainability***

Analytical efforts at the subsystem level that estimate reliability (or reliability improvement if comparing to something already in existence). Efforts may encompass both an FMEA and failure-rate calculations for each of the subsystem failure mechanisms. Alternative corrective and/or preventive actions that could mitigate the most significant failure mechanisms should be identified. Maintainability analyses conducted to determine reliability-centered (failure-based) maintenance and condition-based maintenance strategies as well as a level of repair determination. Estimated support man-hours and spare parts' needs meet expectations/requirements. Form-fit-function performance ensured.

***Additional hardware supporting information for technologies used to protect against the environment***

Material tested in a laboratory environment to provide assurance of its performance throughout its intended life cycle. Deliberately stressful/relevant environments are used to determine whether any degradation in performance occurs against known standards. Material interaction testing is conducted to ensure that no adverse chemical or other reactions occur in either the components being protected or other adjacent parts of the system.

| Software TRL 6 Definition | Software TRL 6 Description | Software TRL 6 Supporting Information |
|---|---|---|
| Module and/or sub-system validation in a relevant end-to-end environment. | Level at which the engineering feasibility of a software technology is demonstrated. This level extends to laboratory prototype implementations on full-scale realistic problems in which the software technology is partially integrated with existing hardware/software systems. | Results from laboratory testing of a prototype package that is near the desired configuration in terms of performance, including physical, logical, data, and security interfaces. Comparisons between tested environment and operational environment analytically understood. Analysis and test measurements quantifying contribution to system-wide requirements such as throughput, scalability, and reliability. Analysis of human-computer (user environment) begun. |

***Additional software supporting information for analysis technologies***

Verify that faults can be detected/predicted using known faults in a simulated real environment such as a test cell or test platform not in use. Both Type I errors (actual faults not detected) and Type II errors (false positives) are within acceptable limits.

# Best Practices for Life-Cycle-Related CTE Assessment

- **Include experts on appropriate LCR areas on the independent TRA panel, preferably the same ones used in the CTE identification process**
- **If the LCR CTE is also critical from a performance perspective, also determine a performance-related TRL**
  - **TRAs evaluate readiness to transition to the next phase of development**
  - **Therefore *all* aspects of their maturity should be assessed**

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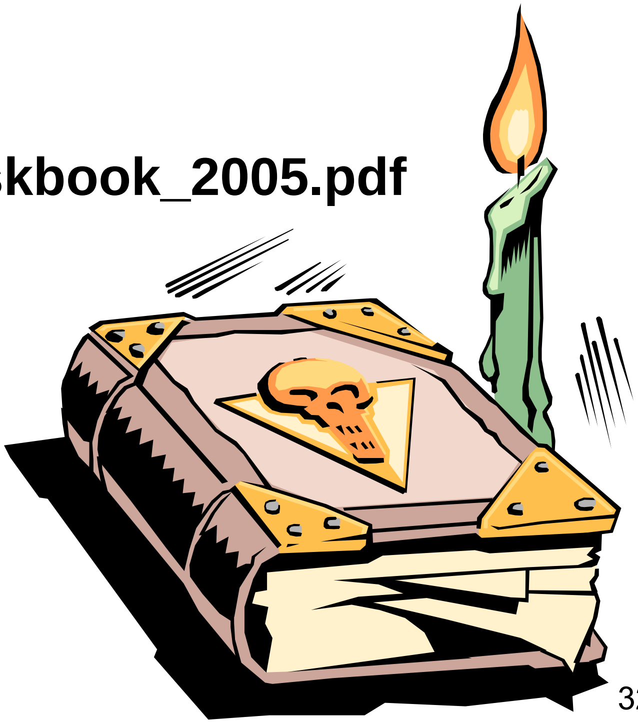
# References and Resources

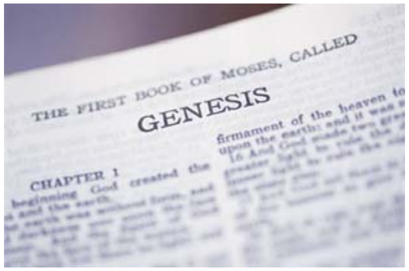
- **Defense Acquisition Resource Center http://akss.dau.mil/darc/darc.html**
  - **DoD Directive 5000.1 (DoDD 5000.1), *The Defense Acquisition System*, dated May 12, 2003**
  - **DoD Instruction 5000.2 (DoDI 5000.2), *Operation of the Defense Acquisition System*, dated May 12, 2003**
  - ***Defense Acquisition Guidebook***
- ***TRA Deskbook***

  **http://www.defenselink.mil/ddre/doc/tra_deskbook_2005.pdf**
- **DDR&E**
  - **Mr. Jack Taylor jack.taylor@osd.mil**
- **Institute for Defense Analyses**
  - **Dr. David Sparrow dsparrow@ida.org**
  - **Dr. Jay Mandelbaum jmandelb@ida.org**



# BACKUP

# How TRAs Got Started




- **"Program managers' ability to reject immature technologies is hampered by (1) untradable requirements that force acceptance of technologies despite their immaturity and (2) reliance on tools that fail to alert the managers of the high risks that would prompt such a rejection."** ***GAO/NSIAD-99-162***
- **"Identify each case in which a major defense acquisition program entered system development and demonstration … into which key technology has been incorporated that does not meet the technology maturity requirement … and provide a justification for why such key technology was incorporated and identify any determination of technological maturity with which the Deputy Under Secretary of Defense for Science and Technology did not concur and explain how the issue has been resolved."** ***National Defense Authorization Act for Fiscal Year 2002***
- **"The management and mitigation of technology risk, which allows less costly and less time-consuming systems development, is a crucial part of overall program management and is especially relevant to meeting cost and schedule goals. Objective assessment of technology maturity and risk shall be a routine aspect of DoD acquisition."** ***DoDI 5000.2, paragraph 3.7.2.2***

**Stop launching programs before technologies are mature**

# Quantifying the Effects of Immature Technologies

**According to a GAO review of 54 DoD programs:**

- **Only 15% of programs began SDD with mature technology (TRL 7)**
  - **Programs that started with mature technologies averaged 9% cost growth and a 7 month schedule delay**
  - **Programs that did not have mature technologies averaged 41% cost growth and a 13 month schedule delay**
- **At critical design review, 42% of programs demonstrated design stability (90% drawings releasable)**
  - **Design stability not achievable with immature technologies**
  - **Programs with stable designs at CDR averaged 6% cost growth**
  - **Programs without stable designs at CDR averaged 46% cost growth and a 29 month schedule delay**

Source: Defense Acquisitions: Assessments of Selected Major Weapon Programs, GAO-05-301, March 2005