Enabling Technology Readiness Assessments (TRAs) with Systems Engineering

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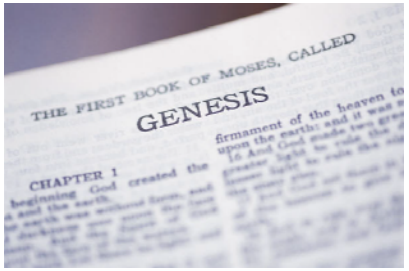
Outline

- **Introduction**
- **Technology Considerations in the SE Process During Systems Acquisition**
- **References and Resources**

How TRAs Got Started

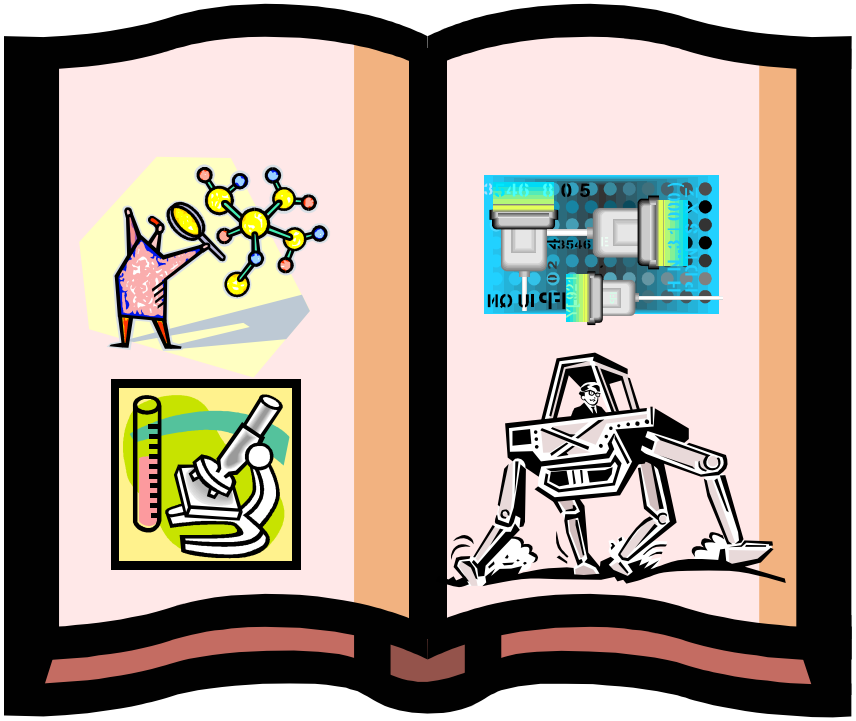


- **"Program managers' ability to reject immature technologies is hampered by (1) untradable requirements that force acceptance of technologies despite their immaturity and (2) reliance on tools that fail to alert the managers of the high risks that would prompt such a rejection."** ***GAO/NSIAD-99-162***
- **"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

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, or manufacturing technology; 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

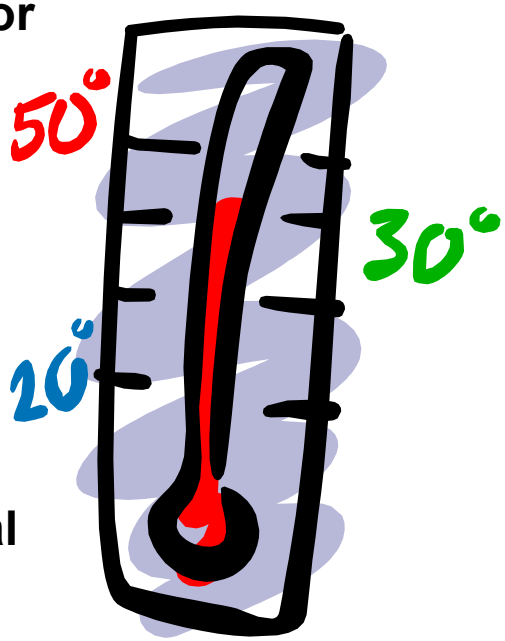
Hardware and Manufacturing TRLs

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



Why is a TRA Important?

- The Milestone Decision Authority 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

- Highlights critical technologies and other potential technology risk areas that require PM attention (and possibly additional resources) both at program initiation and before low rate initial production
- Congress receives a report on immature CTEs in programs

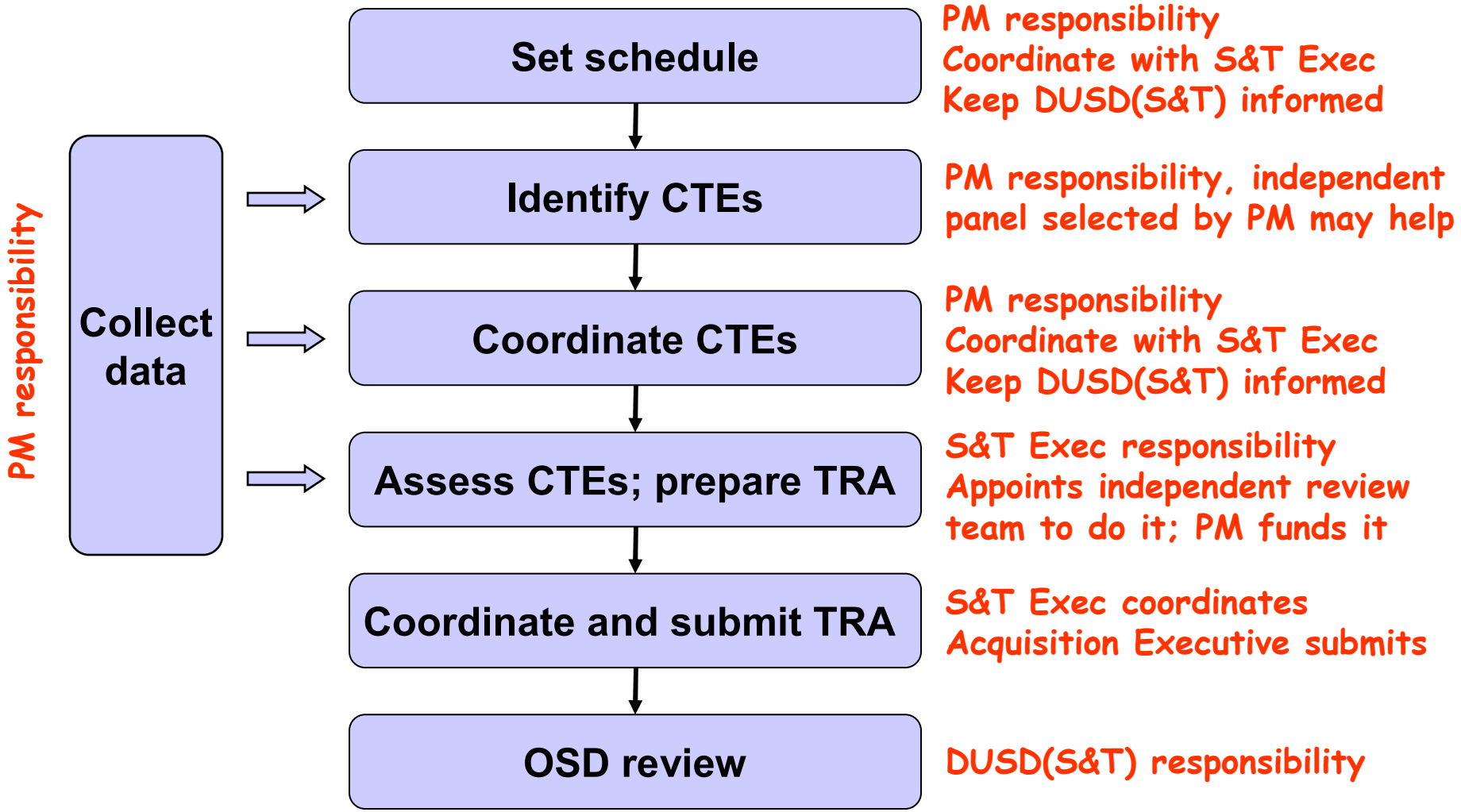
Quantifying the Effects of Immature Technologies

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

Process Overview



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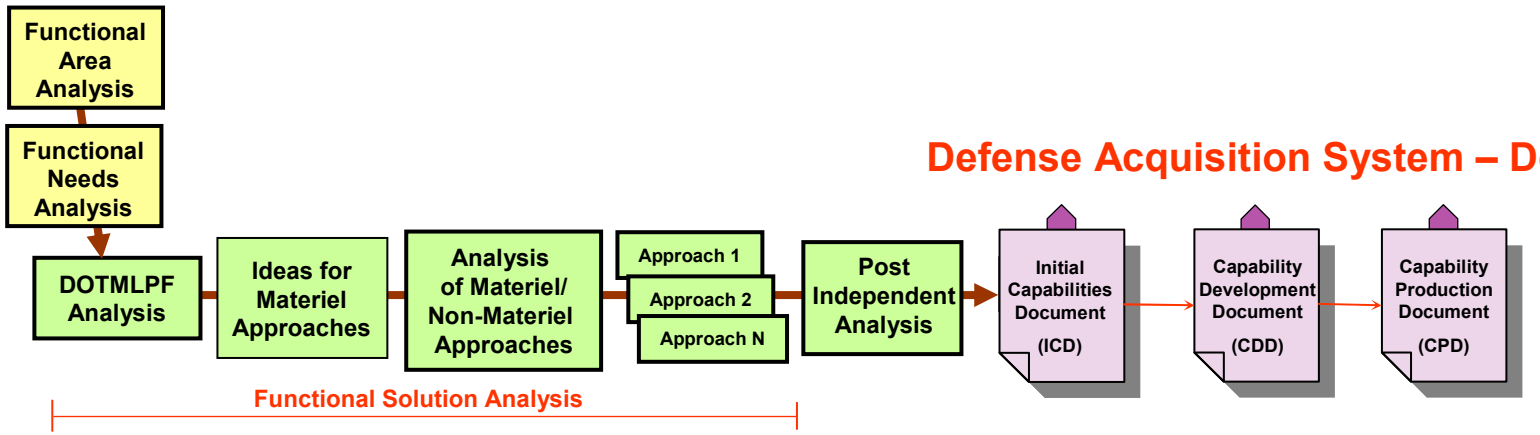
Joint Capabilities Integration and Development System (JCIDS)

Strategic Guidance --
National Security Strategy/National Defense Strategy/National Military Strategy

Family of Joint Future Concepts
Concepts of Operations
Joint Tasks

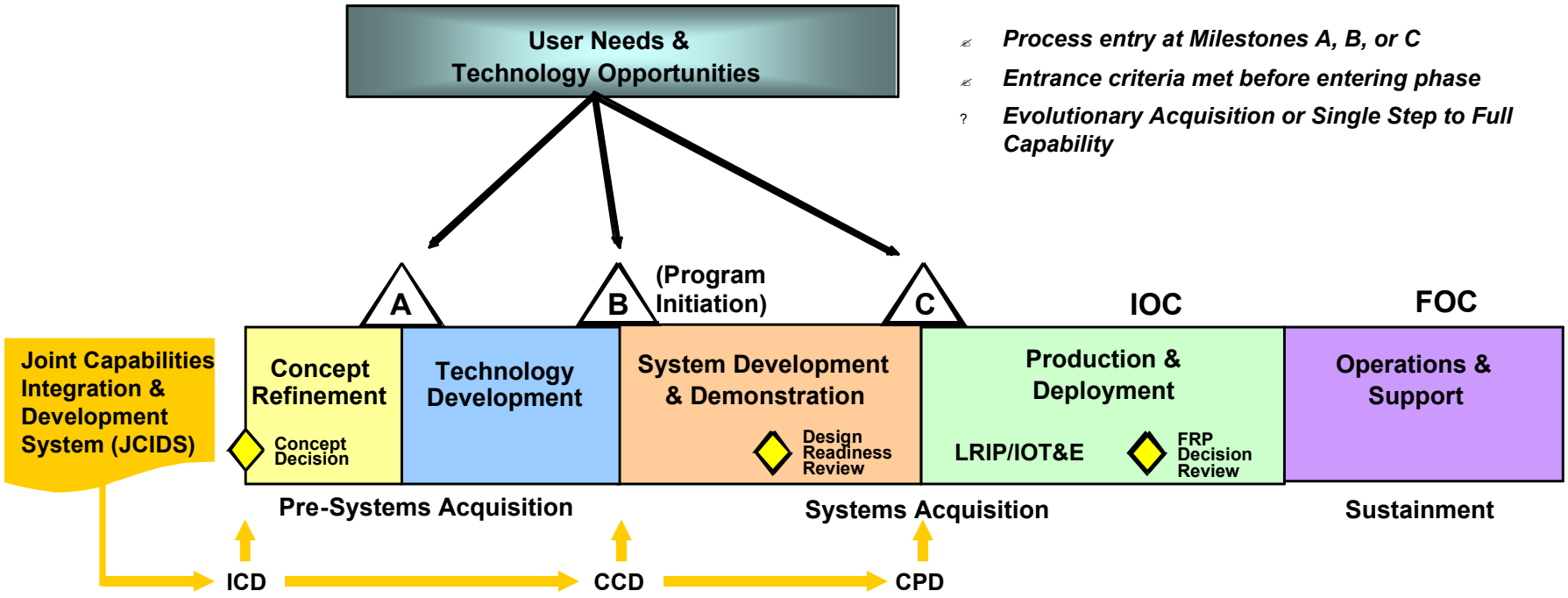
Integrated Architectures



Defense Acquisition System – DoD 5000

JCIDS governed by -- CJCSI 3170

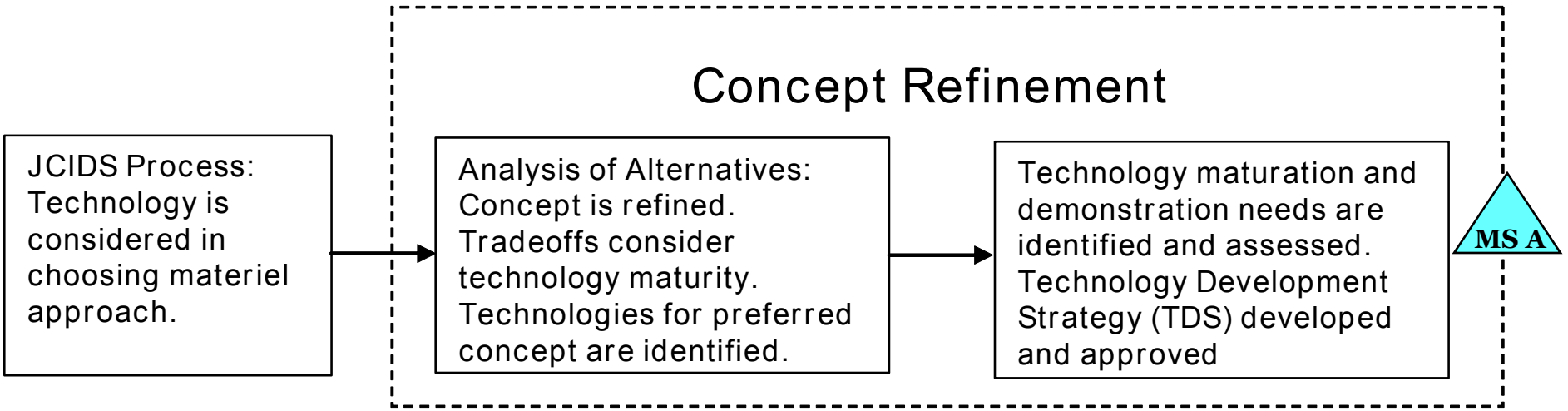
Overview of Technology Considerations During Systems Acquisition



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

Pre MS A

Technology Considerations Pre Milestone A



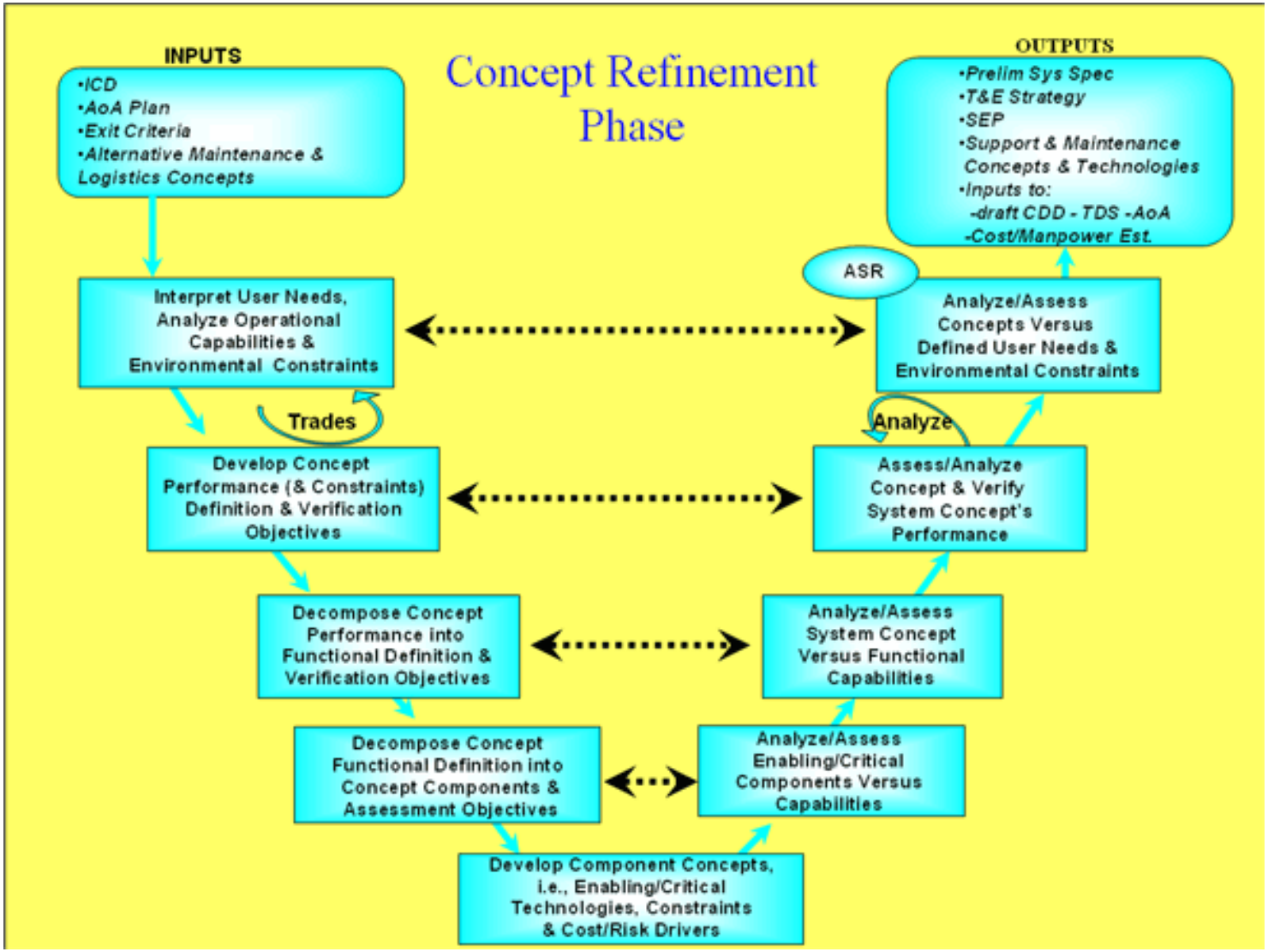
CTE identification begins in JCIDS process.
By MS A, CTE component should be demonstrated in a laboratory.

The Concept Refinement Phase

- **The purpose is to refine the initial concept and prepare a Technology Development Strategy (TDS)**
- **Guided by an Analyses of Alternatives (AoA) Plan for assessing the critical technologies associated with alternative system concepts, including technology maturity, technical risk, and if necessary, technology maturation and demonstration needs.**
- **Ends at Milestone A when Milestone Decision Authority approves:**
  - **Preferred system concept resulting from the AoA**
  - **Associated Technology Development Strategy**

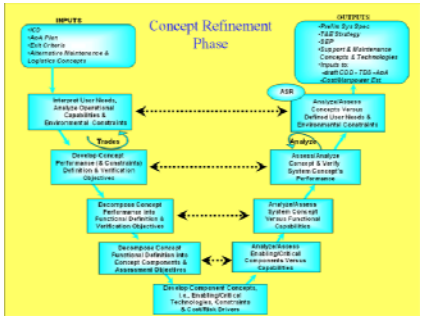
Pre MS A

Overview of Systems Engineering-Related Steps During Concept Refinement



Pre MS A

Overview of Systems Engineering-Related Steps During Concept Refinement (cont'd)

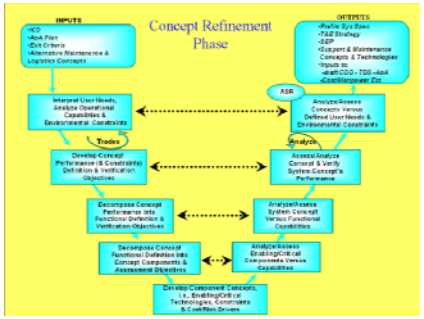


Systems engineering provides top level, iterative analytical processes for each alternative system concept that encompass:

- Requirements analysis, functional analysis and design
  - Occurs iteratively and recursively
  - Functional analysis links requirements and system design
- Trade offs among system operational requirements, operational utility, and cost, to arrive at best system solution within allowed constraints
- Resource allocation guiding design choices
- Verification at each step confirming that specified requirements have been fulfilled
- Validation at the end of the process confirming that the refined concept meets the needs of the user

Pre MS A

Purpose of Systems Engineering in Concept Refinement

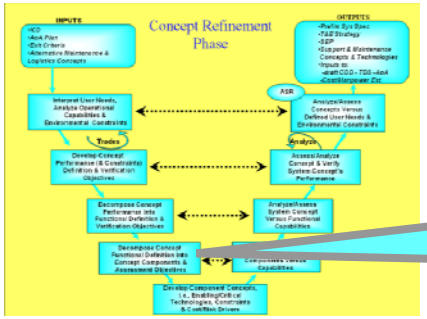


Systems engineering process can provide a technical evaluation of the operational effectiveness and estimated costs of the alternative system concepts that may provide a materiel solution to a needed mission capability

- CTEs must be identified as part of the systems engineering process during the AoA
  - CTEs may be performance related or manufacturing related if production costs are too high
- CTE maturity must be a critical input to the decision on the preferred system concept
- The Technology Development Strategy encompasses the plans for maturing the CTEs associated with the preferred system concept

Pre MS A

System Engineering / TRA Interfaces During Concept Refinement (1 of 3)

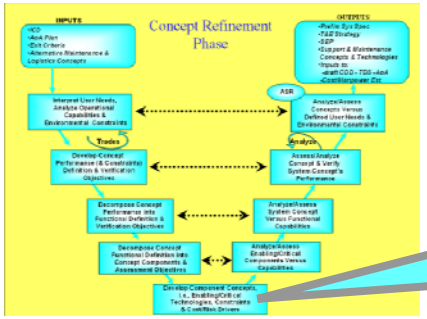


Decompose Concept Functional Definition into Concept Components & Assessment Objectives

- **Initiates the design process for each alternative system concept**
- **First cut at a top level physical architecture or work breakdown structure (system architecture for an IT system)**
- **Iteratively expands physical and functional architecture into greater levels of detail to get a better idea of the design (system and operational views for an IT system)**
- **Framework for beginning CTE identification**

Pre MS A

System Engineering / TRA Interfaces During Concept Refinement (2 of 3)

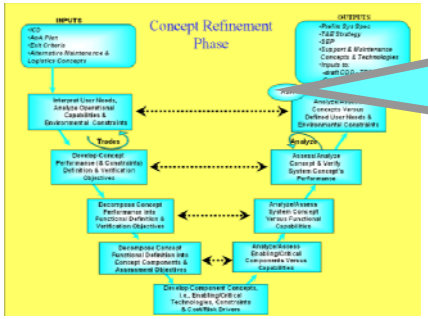


Develop Component Concepts, i.e., Enabling/Critical Technologies, Constraints & Cost/Risk Drivers

- **For each alternative concept, conduct paper studies and build breadboards to evaluate the maturity of the CTEs**
- **Studies and breadboards must be detailed enough to formulate the Technology Development Strategy**

Pre MS A

System Engineering / TRA Interfaces During Concept Refinement (3 of 3)

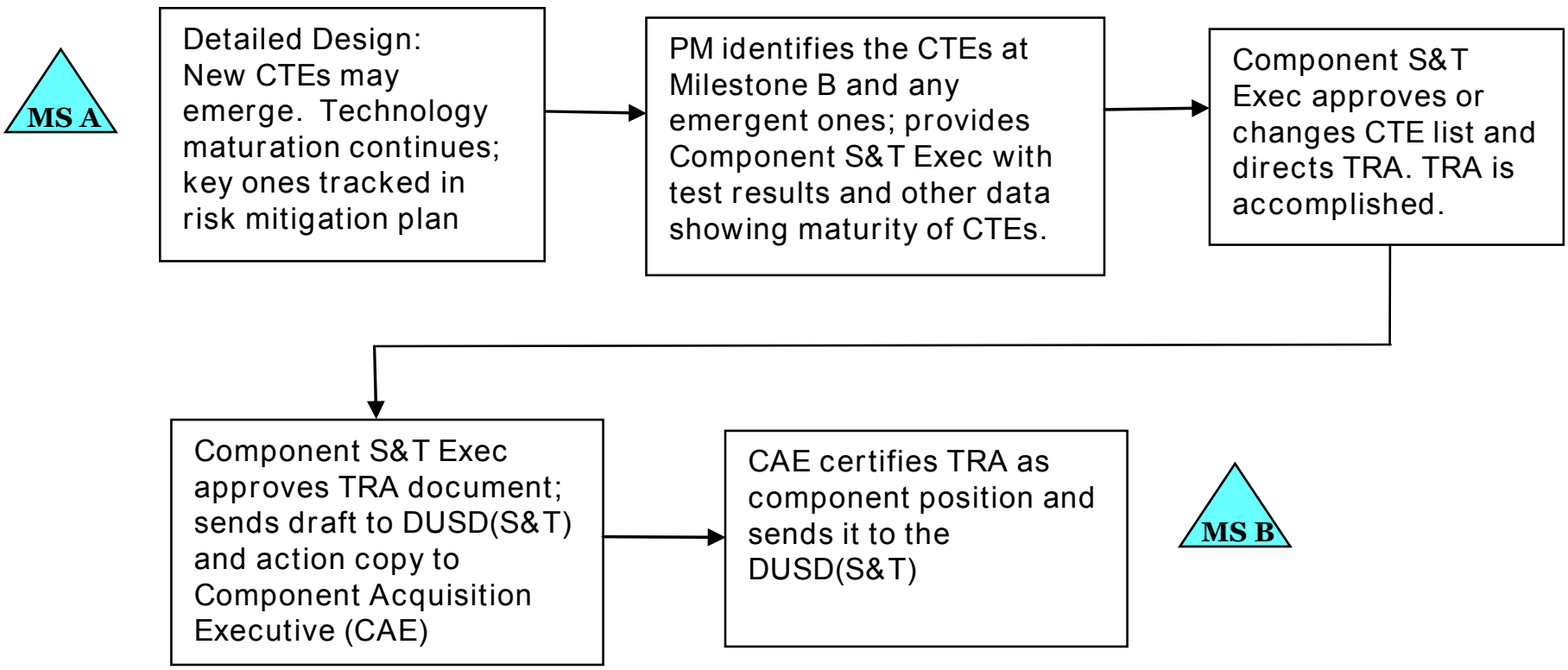


The Alternative System Review (ASR) is a multi-disciplined technical review to ensure that the resulting set of requirements meets the customers' needs and expectations and that the system can proceed into the TD phase. It's completion provides in part:

- **A recommendation on the preferred system concept(s) to take forward *(basis for the TRA)***
  - **A comprehensive rationale for the preferred solution, including the AoA that evaluated relative cost, schedule, performance (hardware, human, software), and technology risks**
- **Refined thresholds and objectives initially stated as broad measures of effectiveness *(first cut maturity goals for CTEs)***
- **Completed, comprehensive planning for the Technology Development phase (hardware, software and manufacturing), that addresses critical components to be developed and demonstrated, their cost, and critical path drivers *(CTE maturation plan)***
  - **A comprehensive risk assessment and risk reduction concept for the Technology Development phase**

Pre MS B

Technology Considerations During the Technology Development Phase



By MS B, CTE subsystem should be demonstrated in a relevant, preferably operational environment.

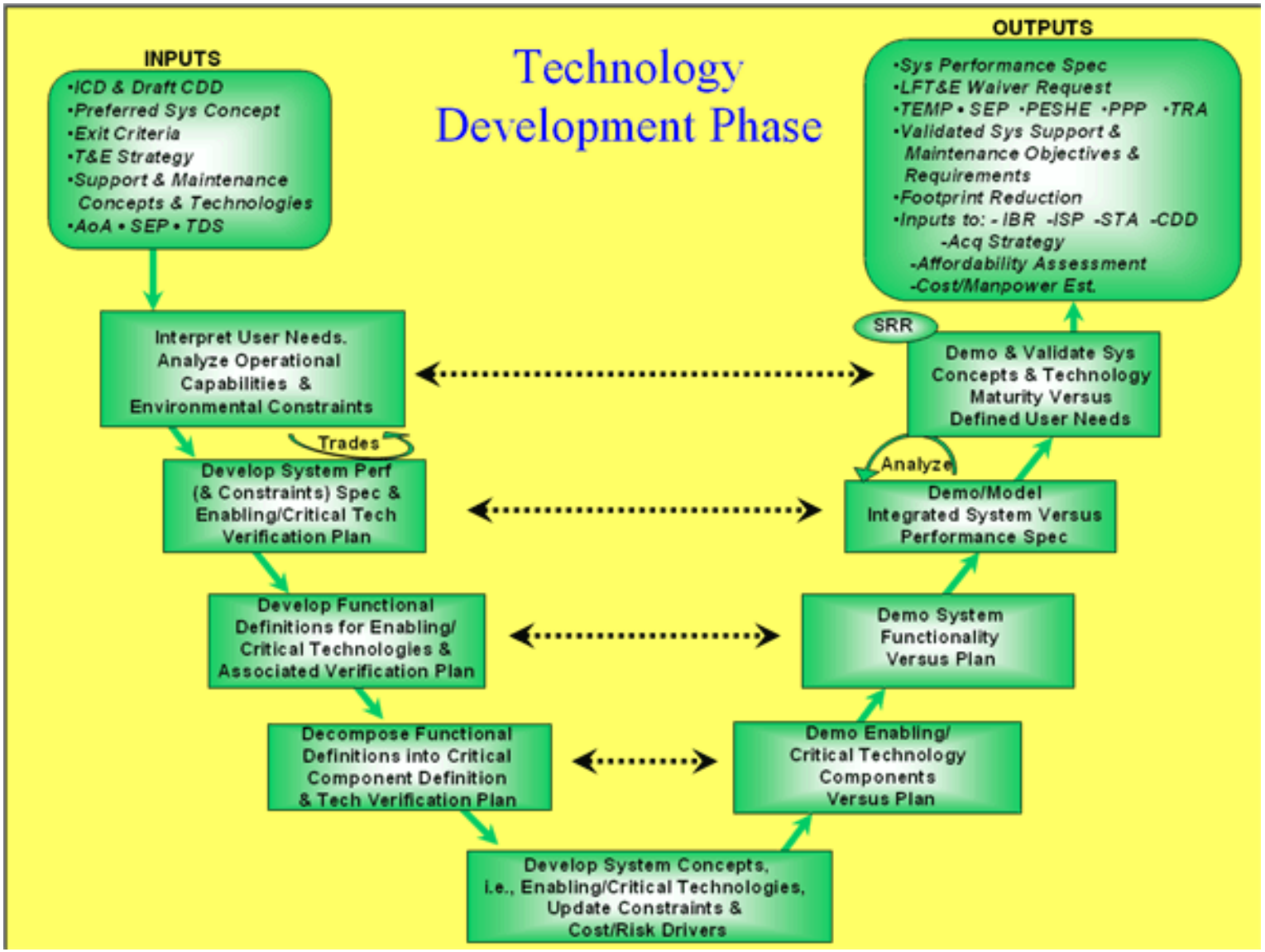
Pre MS B

The Technology Development Phase

- The purpose is to reduce technology risk and to determine the appropriate set of technologies to be integrated into a full system
- Guided by a Technology Development Strategy for maturing those technologies critical to achieving the required capabilities
- Ends, at Milestone B, when an affordable increment of militarily-useful capability has been identified, the technology for that increment has been demonstrated in a relevant environment, and a system can be developed for production within a short timeframe (normally less that five years)

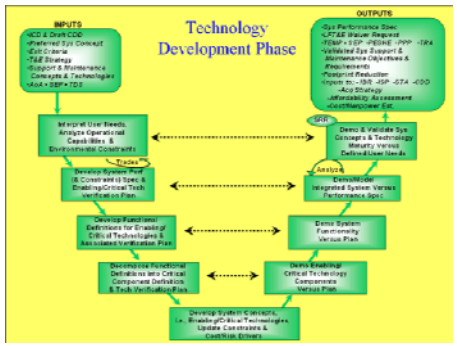
Pre MS B

Overview of Systems Engineering-Related Steps During Technology Development



Pre MS B

Overview of Systems Engineering-Related Steps During Technology Development (cont'd)

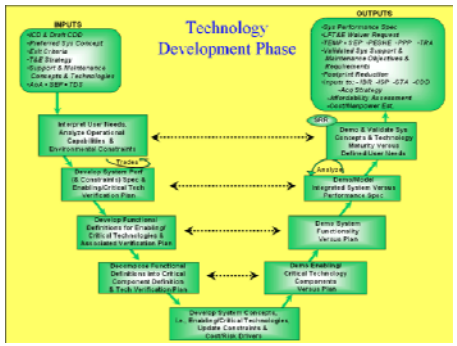


Systems engineering provides comprehensive, iterative processes to accomplish the following activities for critical subsystems:

- Conduct trade studies and convert required capabilities into performance specifications
- Translate user-defined performance parameters into configured critical subsystems
- Characterize and manage technical and production risk
- Transition technology from the technology base into program specific efforts
- Verify that preliminary designs meet operational needs

Pre MS B

Purpose of Systems Engineering in Technology Development

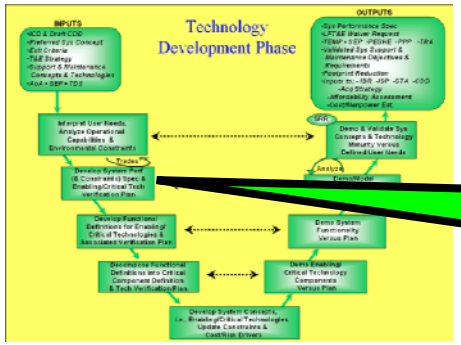


Systems engineering process used to develop the suite of technologies for the preferred system solution

- **CTEs will be matured from (at worst) having a component and/or breadboard validation in a laboratory environment to system/subsystem model of prototype demonstration in a relevant environment**
  - **Applies to critical hardware, software and manufacturing technologies**
- **While most of the CTEs will have been identified during Concept Refinement for the Technology Development Strategy, additional CTEs may be uncovered in the maturation process**

Pre MS B

System Engineering / TRA Interfaces During Technology Development (1 of 5)

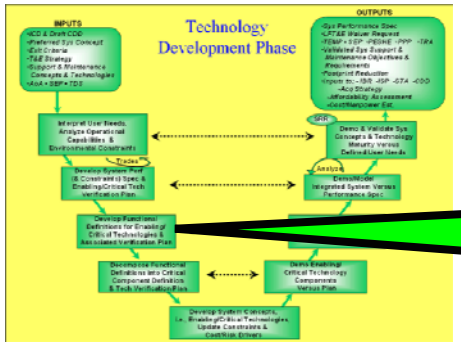


Develop System Perf (& Constraints) Spec & Enabling/Critical Tech Verification Plan

- **Begins where Concept Refinement finished**
- **Processes apply to each technology development effort – in effect, a "V" for each critical subsystem**
- **Establishes the top level critical subsystem requirements**

Pre MS B

System Engineering / TRA Interfaces During Technology Development (2 of 5)

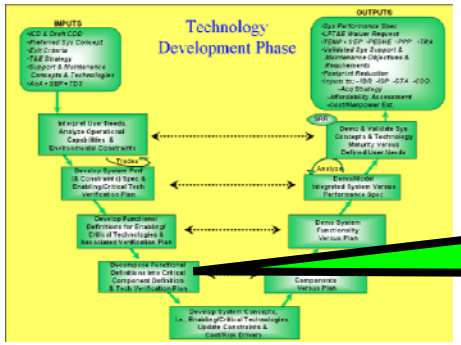


Develop Functional Definitions for Enabling/ Critical Technologies & Associated Verification Plan

- **Functional decomposition in greater detail (operational view for an IT system)**
- **Trade space and risk should be re-analyzed and assessed against available technologies**
- **Enabling and/or critical technologies finalized**
- **Technology functional performance specified *(final CTE maturity goals)***

Pre MS B

System Engineering / TRA Interfaces During Technology Development (3 of 5)

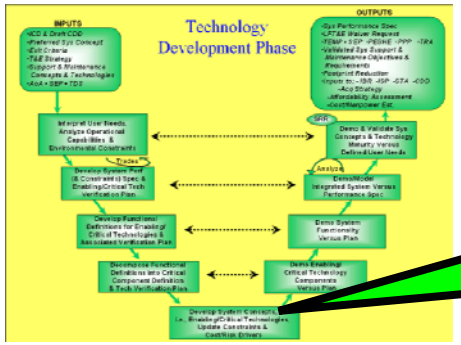


Decompose Functional Definitions into Critical Component Definition & Tech Verification Plan

- **Adds greater levels of detail to the physical architecture (system view for an IT system)**
- **Defines components that will provide the required functionality – these are the CTEs**
  - **New CTEs may emerge**
- **Additional tradeoffs occur to stay within program constraints or identify mature technology alternatives**

Pre MS B

System Engineering / TRA Interfaces During Technology Development (4 of 5)

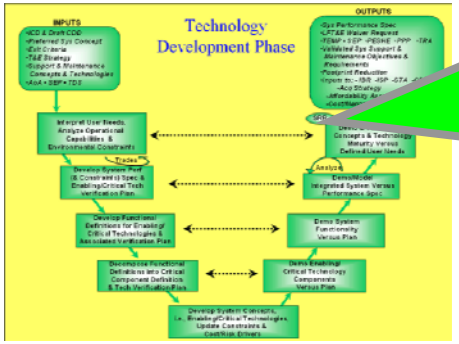


Develop System Concepts,
i.e., Enabling/Critical Technologies,
Update Constraints &
Cost/Risk Drivers

- **All basic design requirements have been analyzed, defined and reconciled with constraints**
- **Components (CTEs) are synthesized to allow verification of the components against requirements**
- **Prepare for tests to demonstrate CTEs in a relevant environment**

Pre MS B

System Engineering / TRA Interfaces During Technology Development (5 of 5)

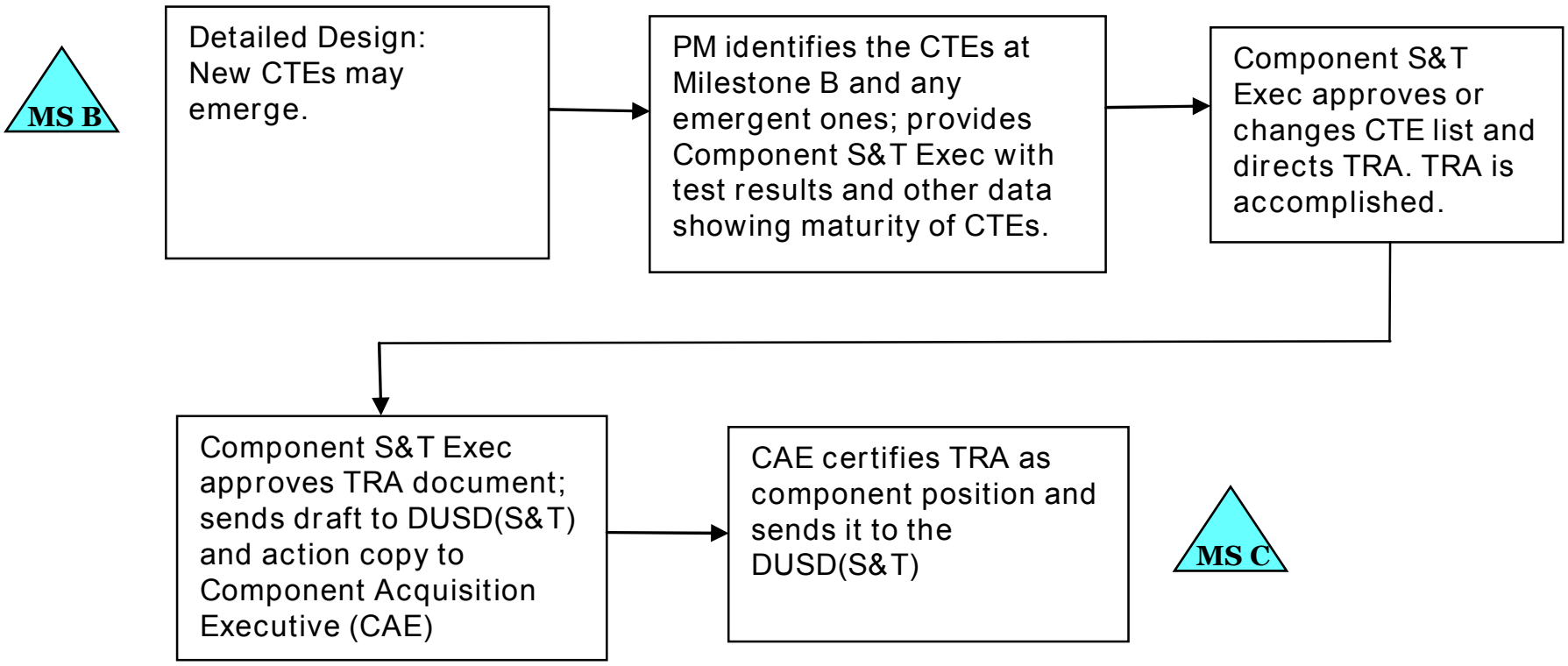


The System Requirements Review (SRR) is a multi-disciplined technical review to ensure that the system can proceed into the SDD phase, and that all system requirements and performance requirements are defined and are consistent with cost, schedule, risk, and other system constraints. It's completion provides in part:

- **An approved preliminary system performance specification**
- **A preliminary allocation of system requirements to hardware, human, and software subsystems**
- **A determination that the available technology, and program resources (funding, schedule, staffing, and processes) form a satisfactory basis for proceeding into the SDD phase**
- **A comprehensive risk assessment for System Development and Demonstration *(TRA is input to this assessment)***

Pre MS C

Technology Considerations During the System Development and Demonstration Phase



By MS C, system prototype should be demonstrated in an operational environment.

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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/weapons.htm**
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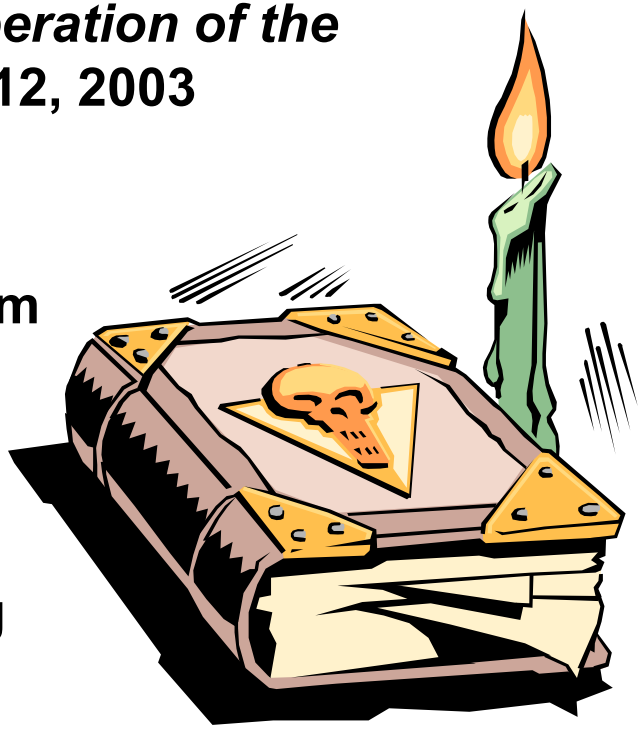

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