U.S. Army Research, Development and Engineering Command

2014 NDIA Joint Armaments Forum
TUTORIAL

The ARDEC Technology Development Process

(Knowing What to Do and When to Do It)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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12 May 2014

Agenda

Overview of the ARDEC Technology Development Process:

- Background
- RDTE,A Funding Appropriation
- DoD Acquisition Framework
- Outline of the ATDP Framework, Phases and Gates
- Overview of the Major Tasks in Each Phase
- Gate Reviews
- Tools, Methods and Best Practices
- Summary

Background

ARDEC Lacked Defined Process for Technology Development

U.S. ARMY RDECOM

ARDEC Enterprise Process Framework

ARDEC Enabling Processes

Establish & Manage Customer Relationships	Manage & Improve Processes	Provide & Manage Human Capital	Provide & Manage Finances	Provide & Manage Knowledge, Equipment & Facilities	Acquire/Procure Required Resources

ARDEC Core Processes

Conduct Research & Technology Development	Execute & Support Product Development	Execute & Support Mfg/Production	Execute & Support Fieldings, Operations & Support	Conduct & Support System Demilitarization

ARDEC Governing Processes

Conduct Enterprise Planning & Management	Provide Environmental, Security & Safety Management

Enabling Processes *– processes that support one or more other processes, typically by supplying indirect inputs (e.g., hire to retire)*

Core Processes *– processes that convert inputs into outputs of greater value to external customers (e.g., transactional and developmental)*

Governing Processes *– processes that govern operation; how a company is directed and how objectives are achieved (e.g., strategic planning)*

ARDEC Implementation Goals

- Reduce Life Cycle Costs
- Shorten Development Cycle Time
- Transition More Robust Technologies and Products to PMs and Warfighters
- Improve the Probability of Success of the Project/Product/Technology
- Establish “How to” Methodology for Technology Development
- Improve Ability to Predict Time/Cost

The Evolving Result

- The ARDEC Technology Development Process (ATDP) is an Event-Driven, Phase-Gate Process.

- Within Each Phase, Key Tasks are Defined for Successful Project Execution and Tools, Methods, and Best Practices (TMBPs) are Identified to Support these Tasks.

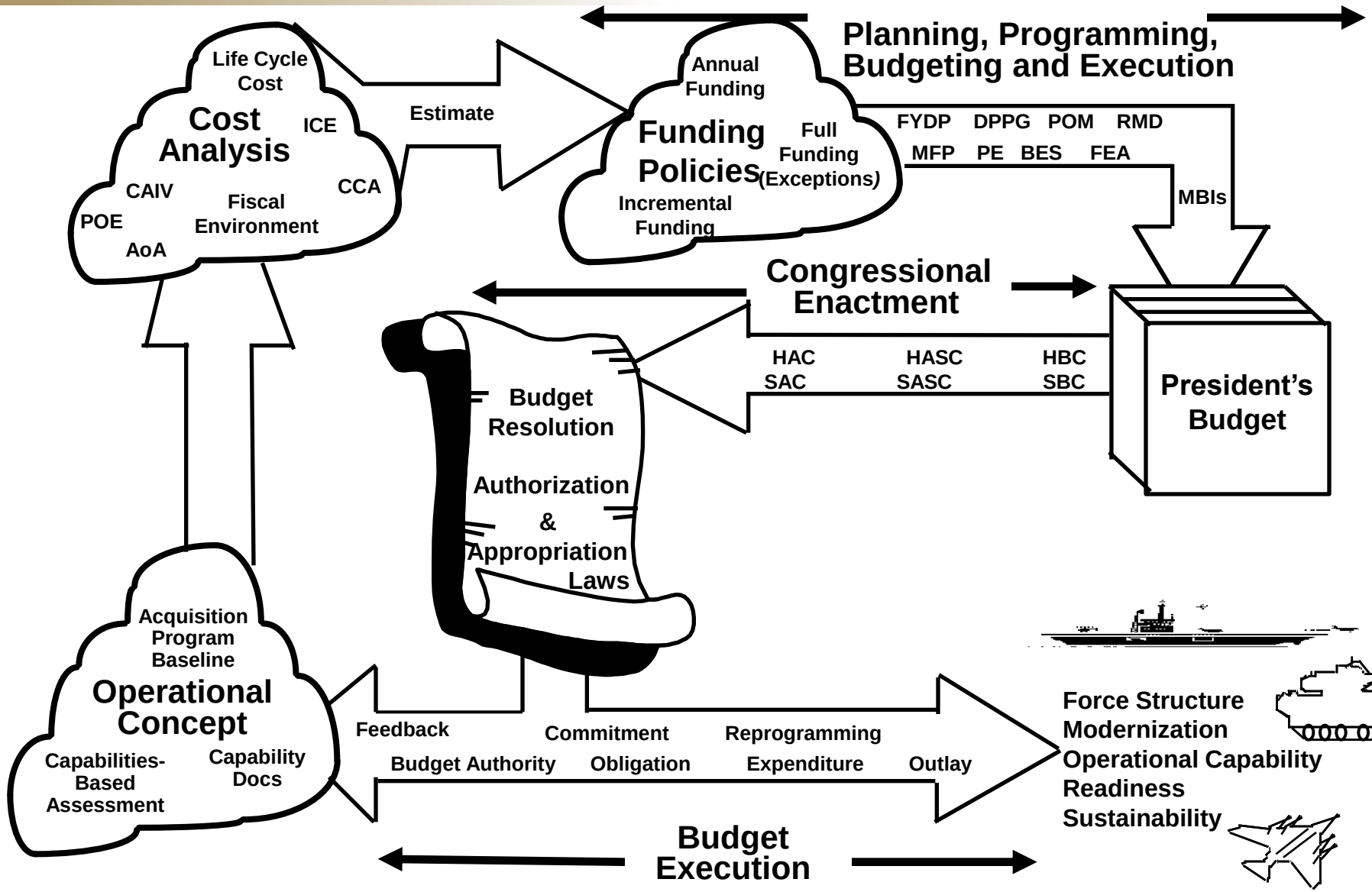
- The ATDP Integrates Project Management and All Engineering Disciplines and Provides an End-to-End Process to Help Project Teams Understand What To Do, When To Do It, and How To Do It.

- The ATDP Process Results in a Better Understanding of How a Technology Works and Defines the Range of its Design Capabilities or Limits, Beyond any Singular Demonstration of How That Technology Performs.

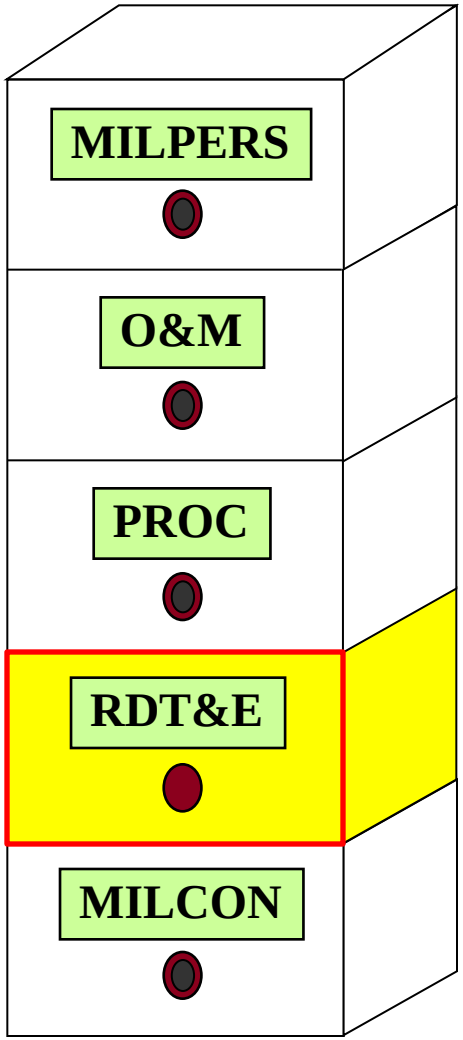
DoD Funding Essentials

U.S. ARMY RDECOM

From Requirement to Capability



Defense Appropriations ("Colors of Money")



Military Personnel (MILPERS)

Active & Reserve Forces

Operation & Maintenance (O&M)

Active & Reserve Forces
(civilian Salaries, supplies, spares, fuels, travel, etc…)
Environmental Restoration
Former Soviet Union Threat Reduction
Overseas Humanitarian, Disaster, & Civic Aid

Procurement

Aircraft
Missiles
Weapons
Weapons & Tracked Combat Vehicles
Ammunition
Other Procurement
Shipbuilding & Conversion
Marine Corps
Defense wide procurement
National Guard & Reserves

Research, Development, Test & Evaluation (RDT&E)

Basic Research (6.1)
Applied Research (6.2)
Advanced Technology Development (6.3)
Advanced Component Development & Prototypes (6.4)
System Development & Demo (6.5)
RDT&E Management Support (6.6)
Operational Systems Development (6.7)

Military Construction (MILCON)

Facilities
Family Housing
Base Realignment & Closure (BRAC)

Other

Defense Health Program
Chemical Agents & Munitions Destruction
Drug Interdiction & Counter-Drug Activities
Joint Improvised Explosive Device Defeat Fund
Rapid Acquisition Fund
Office of the Inspector General

ARDEC Direct RDTE,A Funds

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6.1 (**Basic Research**) Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind (e.g, SBIR, ILIR).

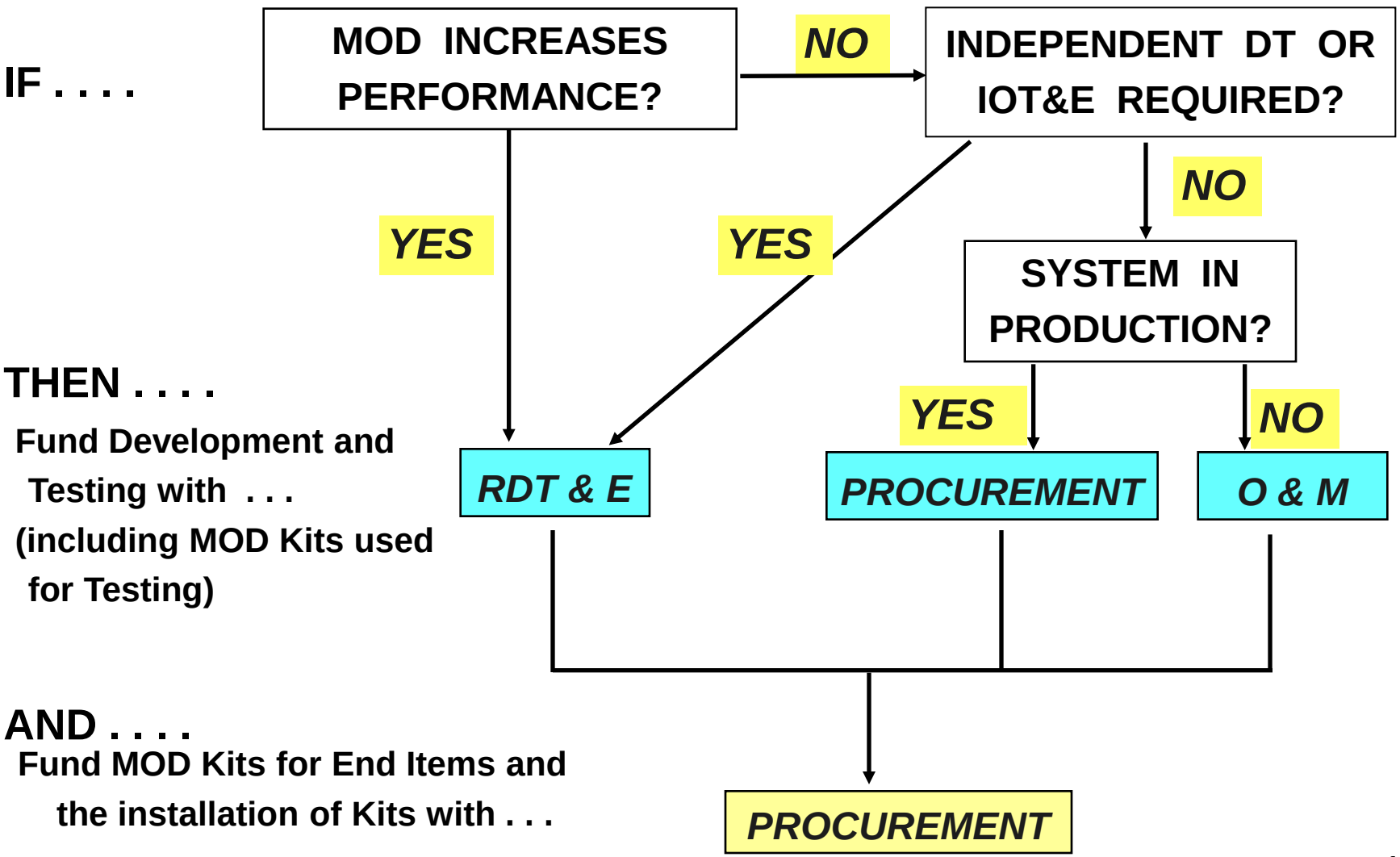
6.2 (**Applied Research**) Applied research is systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods.

6.3 (**Advanced Technology Development**) Development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment. ATD includes concept and technology demonstrations of components and subsystems or system models. The results of this type of effort are proof of technological feasibility and assessment of subsystem and component operability and producibility rather than the development of hardware for service use.

6.7 (**Operational System Development**) Development efforts to upgrade systems that have been fielded or have received approval for full rate production and anticipate production funding in the current or subsequent fiscal year (e.g., ManTech) .

Product Improvement Funding

Decision Tree



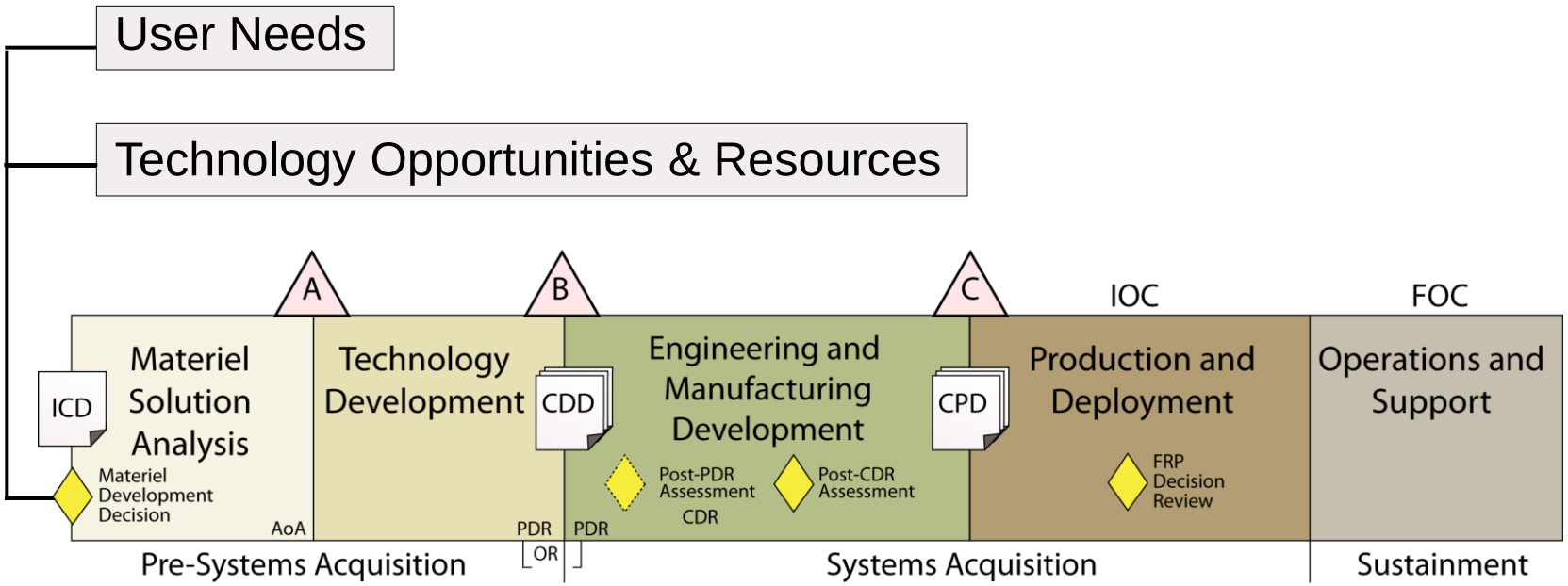
The DoD Acquisition Model

Acquisition vs. Procurement

- **Acquisition** includes design, engineering, test and evaluation, production, and operations and support of defense systems. The term **"Defense Acquisition"** generally applies only to weapons and related items, such as military cargo trucks and information technology systems, processes, procedures, services, and end products.

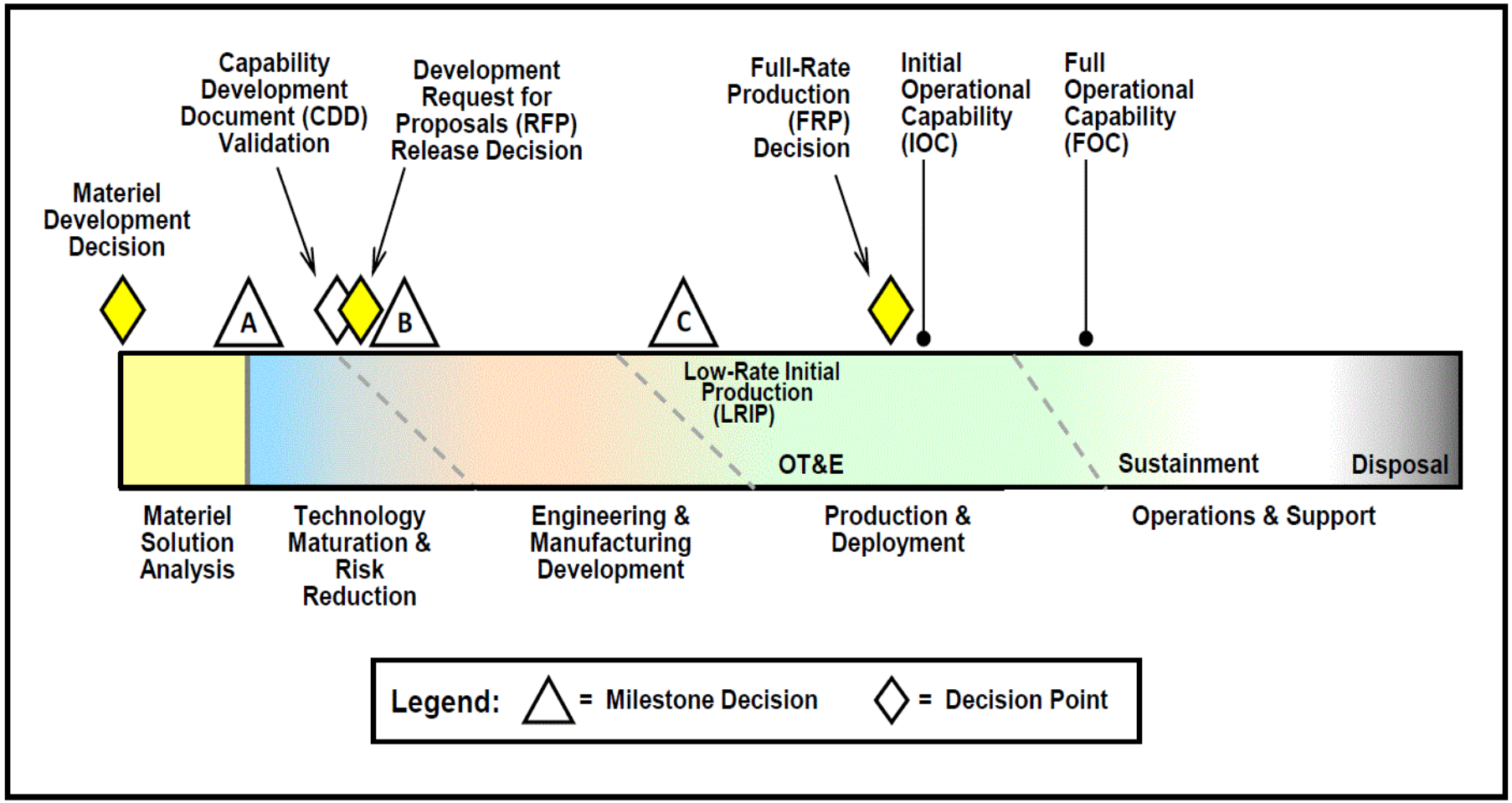
- The word **"Procurement,"** which is the act of buying goods and services for the government, is often (and mistakenly) considered synonymous with acquisition; it is, instead, only one of the many functions performed as part of the acquisition process.

Traditional DoD Acquisition Phases



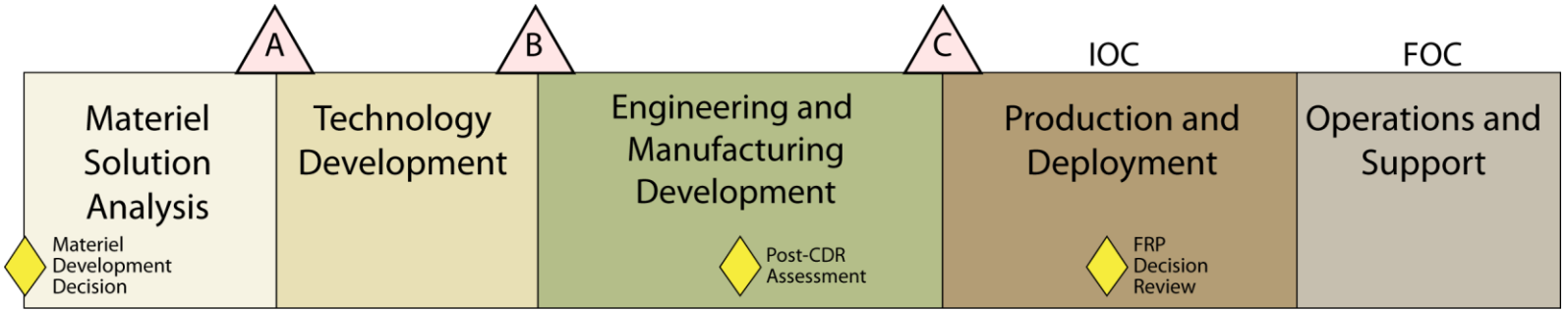
Source: DOD Instruction 5000.2 – Operation of the Defense Acquisition System; 12 May 2003 (CANCELLED)

Interim DoD Life Cycle Model



Source: Interim DoD Instruction 5000.02 – Operation of the Defense Acquisition System (25 Nov 2013)

Technology and Manufacturing Readiness



TRLs 1-3	TRL 4	TRL 5	TRL 6	TRL 7		TRL 8	TRL 9
Analytical/ Experimental Critical Function/ Characteristic Proof of Concept	Component And/or Breadboard Validation In a Laboratory Environment	Component And/or Breadboard Validation In a Relevant Environment	System/ Subsystem Model or Prototype Demonstrated In a Relevant Environment	System Prototype Demonstrated In an Operational Environment		Actual System Completed Qualified Through Test and Demonstration	Actual System "Mission Proven" Through Successful Operations
MRLs 1-3	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
Manufacturing Feasibility Assessed. Concepts defined/ developed	Capability to produce Technology In Lab Environment. Manufacturing Risks Identified Manufacturing Cost Drivers Identified	Capability to Produce Prototype Components Cost Model Constructed	Capability to Produce System/ Subsystem Prototypes Detailed Cost Analysis Complete	Capability to Produce Systems, Subsystems Or Components in a Production Representative Environment Cost Model Updated To System Level Unit Cost Reduction Efforts Underway	Pilot Line Capability Demonstrated. Ready for LRIP Engineering Cost Model Validated	Low Rate Production Demonstrated. Capability In Place for FRP LRIP Cost Goals Met Learning Curve Validated	Full Rate Production Demonstrated. Lean Production Practices In Place FRP Unit Cost Goals Met

Technology Readiness Levels Defense Acquisition Guidebook Paragraph 10.5.2

Manufacturing Readiness Levels

Draft MRA Deskbook May 2008

Section 2366b of Title 10, United States Code, requires certification that: the technology in a MDAP has been demonstrated in a relevant environment to enter Milestone B. (TRL 6)

ARDEC Technology Process (ATDP)

Phase-Gate Process

- **Phases – Set Periods of Time in Which Tasks Are Accomplished**
  - The Work is Accomplished: Workflow is Organized as Work Packages of Tasks During Each Phase
  - Entrance/Exit Criteria Are Predefined (e.g.: Successful SRR; Successful TRL3, PDR, etc.)
    - Technical Reviews Conducted Within Each Phase

- **Gates - Major Decision Points in the Project Cycle – Event Driven**
  - Formal Review to Status Project and Obtain Concurrence to Proceed

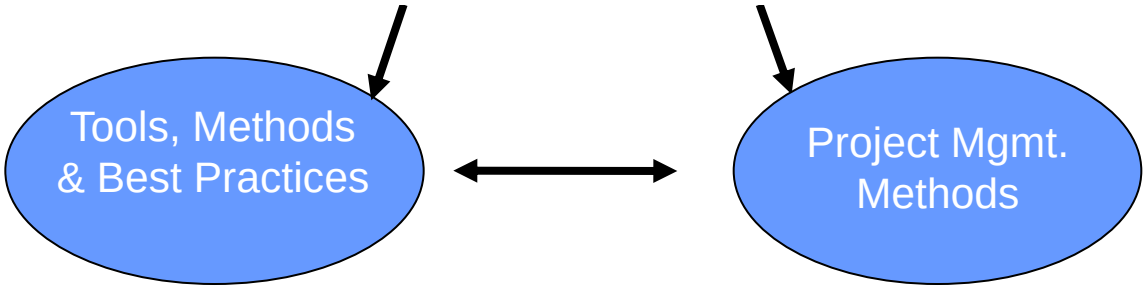
What to Do and When to Do It

<u>Approach:</u> Standardizes Technical Development Work Processes and Tasks into a Disciplined Framework of Project Phases and Gates

•Project Focus; Work Packages Arranged in Logical Sequence to Execute Project to Meet Customer Requirements.

• Process Driven; Process Leverages ARDEC's Knowledge, Expertise and Best Practices in SE, DE, QE, Logistics and PM.

Knowing *<u>WHAT</u>* to do… … & *<u>WHEN</u>* to do it…

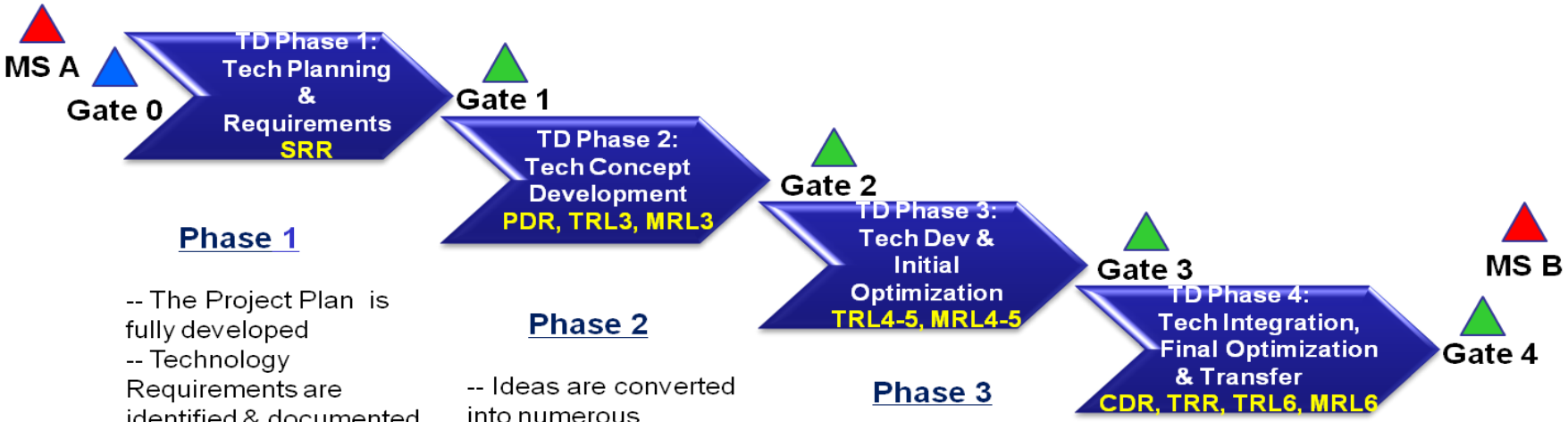


…Through a Selectable Set of Tools, Methods & Best Practices (TMBPs) that are Tailored and Utilized in Each Technology & Product Development Phase

4 Phases of Technology Development

- Phase 1: Technology Planning & Requirements
- Phase 2: Technology Concept Development
- Phase 3: Technology Development & Initial Optimization
- Phase 4: Technology Integration, Final Optimization & Transfer

ATDP Phases & Gates



Phase 1

-- The Project Plan is fully developed
-- Technology Requirements are identified & documented

-- Risk: Unachievable project plan, insufficient understanding of project requirements or unachievable technology requirements with the assigned resources

Phase 2

-- Ideas are converted into numerous, alternative Technology Concepts (TRL 3)
-- Trade Studies are conducted & Best Alternative(s) are selected

-- Risk: Concepts unable to fulfill requirements

Phase 3

-- Technologies are developed, stabilized, made tunable & capable under nominal conditions (TRL4)
-- Technologies are made robust to sources of variation under stressful conditions (TRL 5)

-- Risk: Technologies not functional to requirements, under nominal conditions or not insensitive to stress

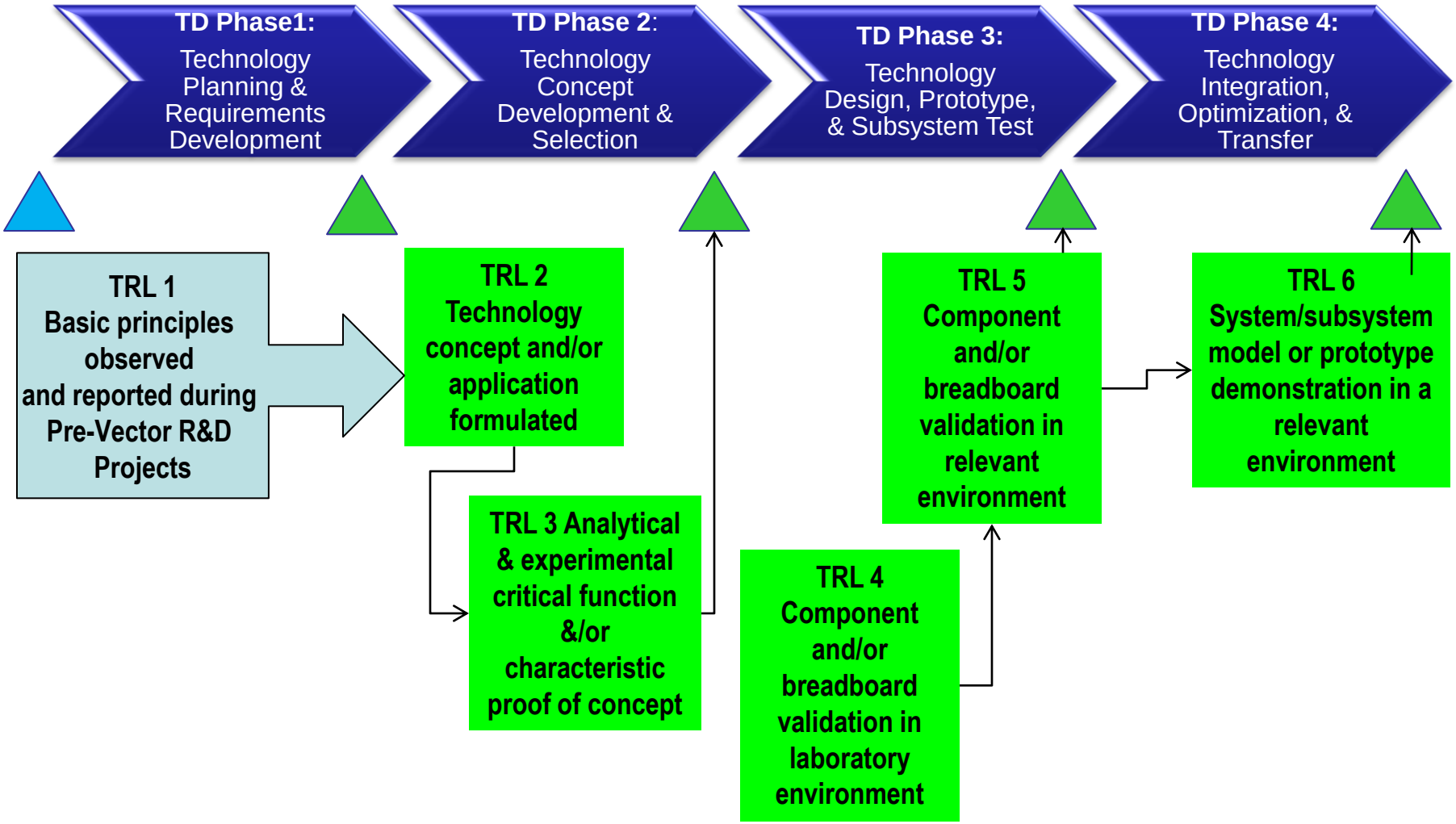
Phase 4

-- Technology elements are made robust as they are integrated
-- Integrated Technology is robust, tunable & capable; meets TRL 6 requirements
-- Technology is ready for transfer to EMD or OCO/ ESIP / PIP process

-- Risk: Technologies not robust in integration, not transferable to intended development / production

Technology Readiness Levels (TRLs) in the ATDP

Technology Development

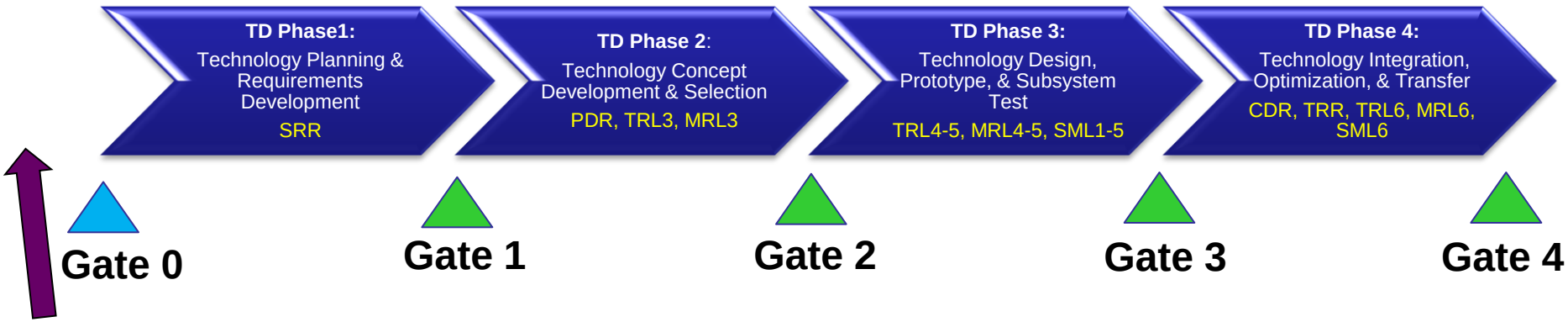


Major Reviews Conducted at Gates

ATDP Process contains several major Gate Reviews:

- Gate 0 is project kick-off
- The Gate Review accounts for prior Phase activity and assesses readiness for the next Phase.

Technology Development

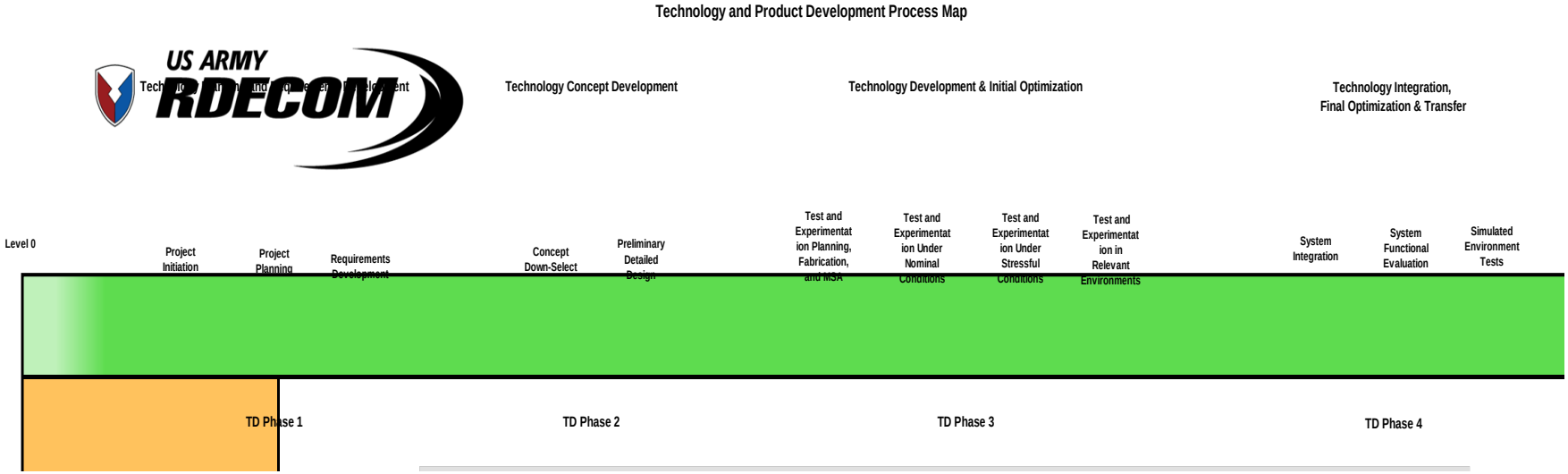


Pre-Gate 0:
Early Planning – End of Initiation

- **Scope Statement**
- **Project Relevancy**
- **APO Chartered**
- **Product WBS**
- **Outline Project Plan**

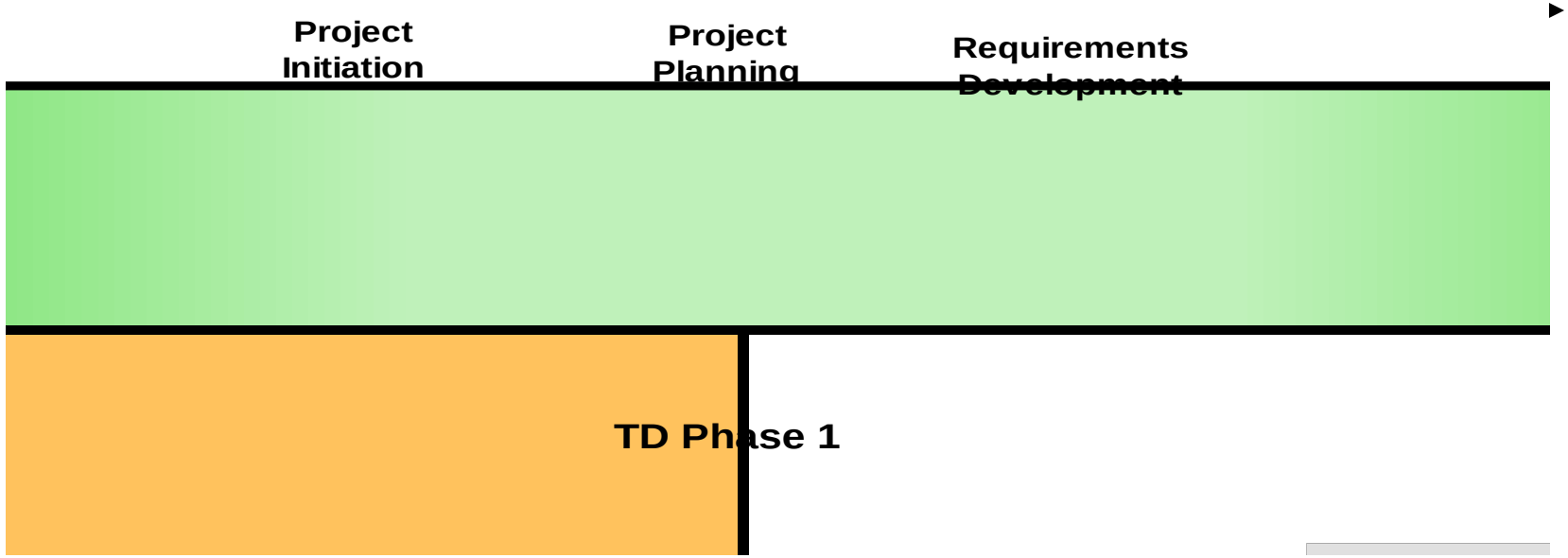
- Additional (special need) Gates, if required
  -- "Breach" Gate, as needed, when Cost, Schedule, or Performance (CSP) objectives exceed acceptable risk
  -- "IPR" during long phases (6-9 months), as desired

Level 0 Process Map: TD Phases 1 – 4

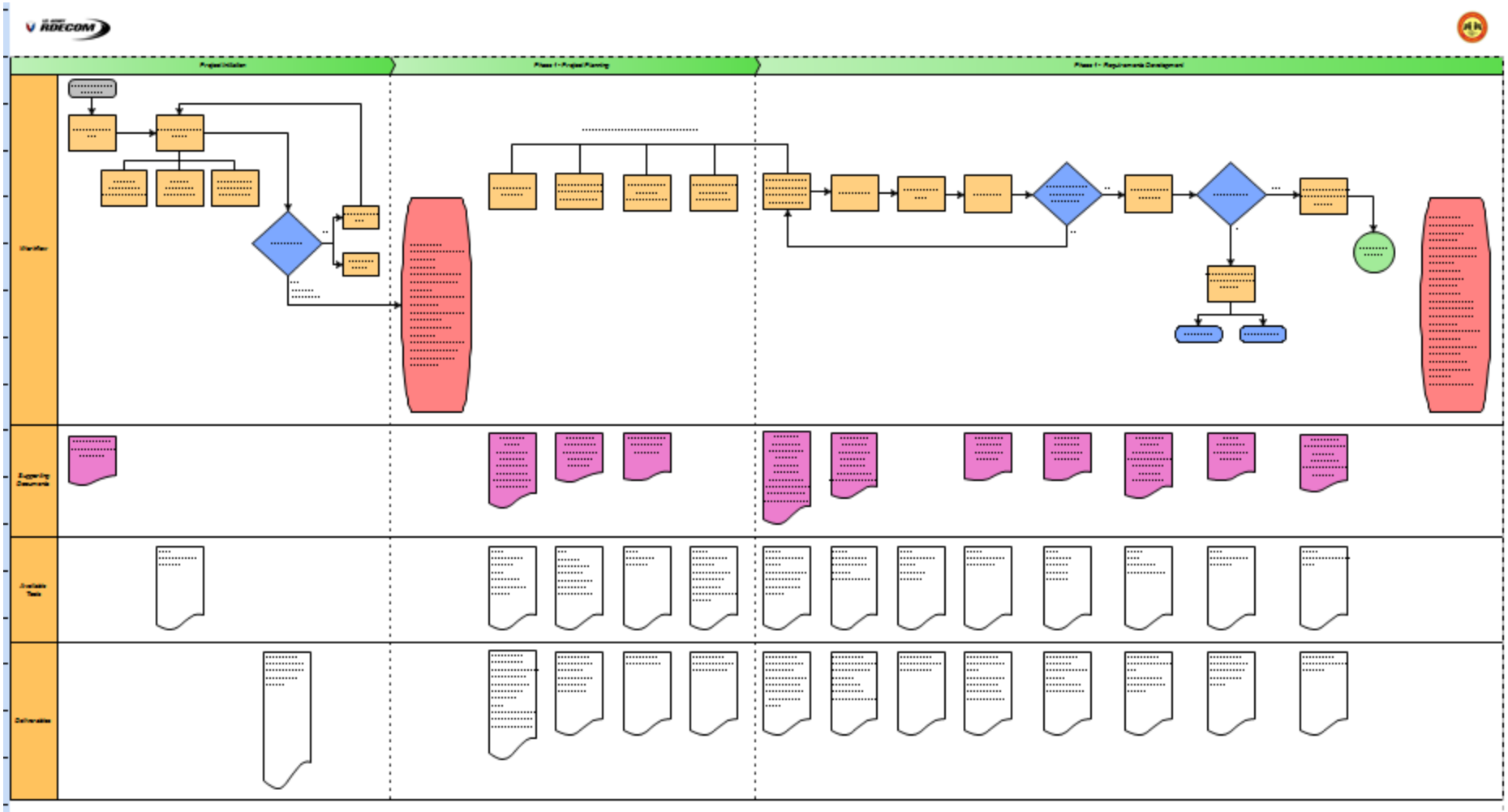


ATDP Phase 1


US ARMY
RDECOM

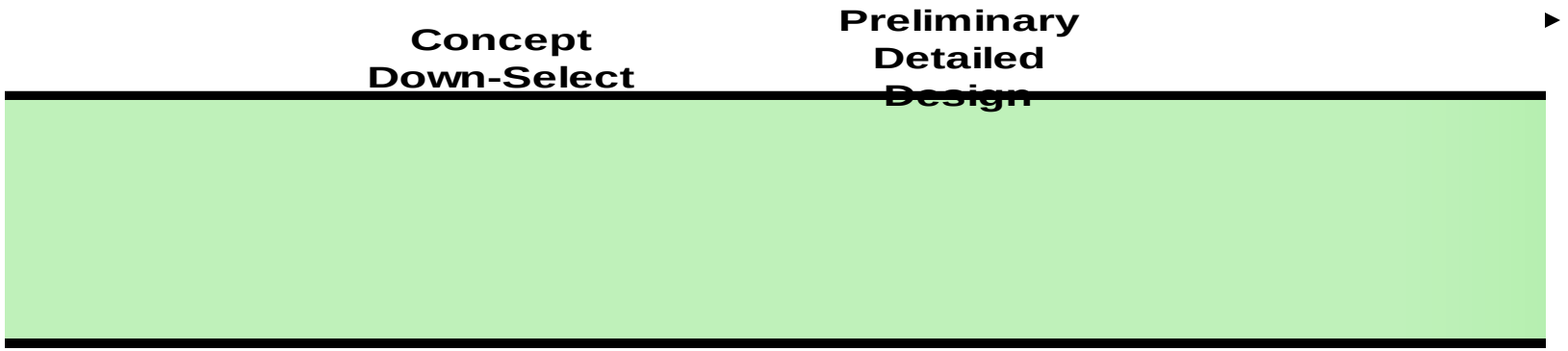

Project Initiation
Project Planning
Requirements Development
TD Phase 1

ATDP Phase 1 – Technology Planning and Requirements Development



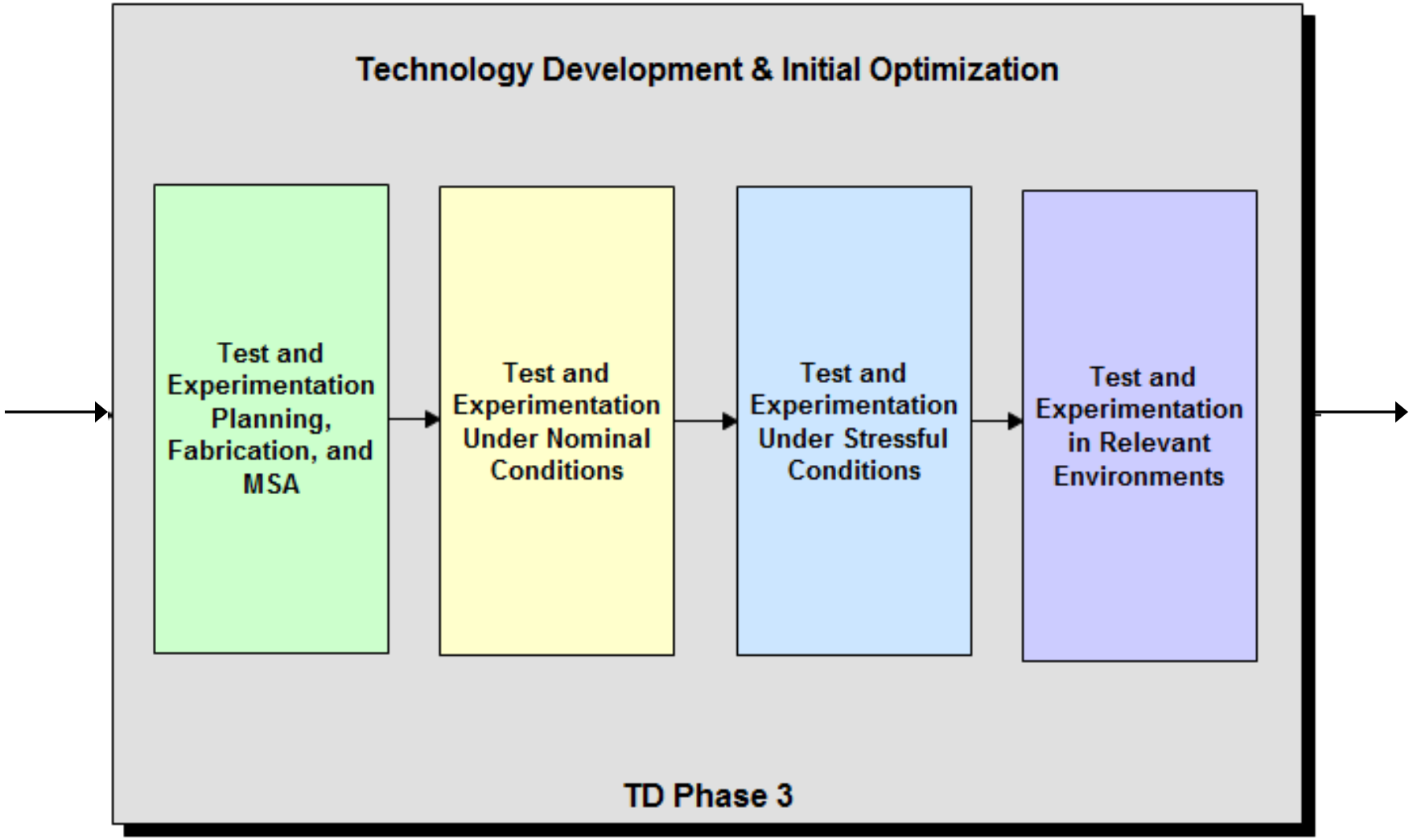
ATDP Phase 2

Technology Concept Development



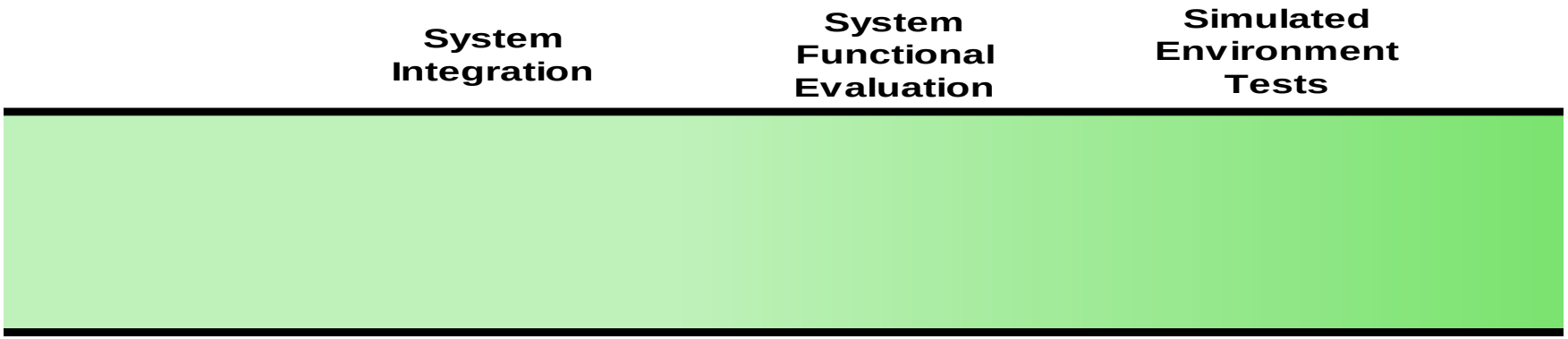
TD Phase 2

ATDP Phase 3


Technology Development & Initial Optimization
Test and Experimentation Planning, Fabrication, and MSA
Test and Experimentation Under Nominal Conditions
Test and Experimentation Under Stressful Conditions
Test and Experimentation in Relevant Environments
TD Phase 3

ATDP Phase 4

**Technology Integration,
Final Optimization & Transfer**



TD Phase 4

Types of Reviews During Project

- **The Gate Review:**
  - The highest level Review conducted for a Project
  - Held at the end of a Phase
  - Looks at summary deliverables associated with Project Cost, Schedule & Performance (CSP) Requirements
- **The Technical Assessment Review:**
  - An intermediary technical Review
  - Held within a Phase usually prior to & preparatory for a Gate Review
  - Looks at summary technical data (especially Key Parameters) related to product & process performance requirements
- **The Peer Review:**
  - An IPT level technical Task Review
  - Held prior to conducting any major task to prevent problems
  - Proactively looks at the readiness of the individual or group of practitioners as they are about to apply selected Tools, Methods or Best Practices (TMBPs) to conduct a major task
  - Reactively looks at the results of the individual or group of practitioners after they have applied selected TMBPs to complete a major task

ATDP Project Gate Reviews

Periodic "Status Check" Reviews with Stakeholders

Gate 0 / Entry Gate: A Project's "Scope" Ready Review

Gate 1: A Project's "Requirements" Ready Review

Gate 2: A Project's "Concept(s)" Ready Review

Gate 3: A Project's "Design" Ready Review

Gate 4: A Project's "Transition" Ready Review
(e.g., "EMD" Ready)

Gate Review Purpose

- An Opportunity for Connection Between the Project Team and ARDEC's Institutional Leadership
- Guides a Technology Through Development
- Ensures the Project's Level of Risk is Acceptable
- Ensures the Project has a Reasonable Probability of Success
- Provides Feedback to Leadership to Affirm the Project is Aligned with ARDEC's Strategic Portfolio.
- Although Not a Technical Review, Includes a Summary of Relevant Technical Progress and Risks Managed.

"Gate Keeper's" Role

The Gate Review is a Way for the "Gate Keepers" to:

- Validate Continued Relevance of the Project.
- Determine if Project Performance to Date Warrants Continuing the Effort
- Provide Guidance, Direction and Support to the IPTs.
- Ensure Consistent Execution of ARDEC Projects and Judge Adherence and Deviations from the ATDP Process.
- Verify Path Ahead:
  - Has Acceptable Risk
  - Uses Correct Tools
  - Work Packages are Balanced with the Right Resources

Gate Review
Project Insight - Progressive View

The Gate Review Addresses a Project's Execution Rationale:

- **Ensures the Technology Development is Feasible and with Manageable Risk**
  - Reconfirms Whether Both the Right Resources and Enough Resources are Assigned
  - Ensures Technology Cost Drivers and Risks are Identified and Understood

- **Reaffirms the Technology Has the Potential to Fulfill the Army's, or Other Customer's, Needs**
  - Documents Warfighter Endorsement of the Project
  - Promotes Timely Development for Fielding

- **Ensures the Best Use of ARDEC's Funding is Allocated for the Project**

Gate Review Scorecard

Project Name: ***Date:*** ***APO:***

Executive Summary	Gate 0	RECOMMENDATION			Red and yellows need summary explanation. Green areas may elect to note the positives.	
Main Objectives for Gate 0	**Description**	**Red**	**Yellow**	**Green**	**Comments , Explanations, Major Issues or Concerns**	**Evidenced By**
Proposal / Scope is achievable		R	Y	G		
Requirements and need statements Per Proposal appear achievable		R	Y	G		
Proposed phase entry point if not Phase 1		R	Y	G		
Supporting Information for Phase 1 Entry / Continuation						
Plans and schedules		R	Y	G		
Technical Approach		R	Y	G		
Funding / Cost		R	Y	G		
Resources		R	Y	G		
Risk Analysis		R	Y	G		
Standard ARDEC Processes Approach		R	Y	G		
Tools, Methods, and Best Practices		R	Y	G		
Phase 1 Entry / Continuation		R	Y	G		

PROJECT SUMMARY / COMMENTS:

Sample Gate 0 Review Scorecard

Main Objectives for Gate 0	Description	Red	Yellow	Green
Proposal / Scope is achievable		R	Y	G
Requirements and need statements Per Proposal appear achievable		R	Y	G
Proposed phase entry point if not Phase 1		R	Y	G
Supporting Information for Phase 1 Entry / Continuation				
Plans and schedules		R	Y	G
Technical Approach		R	Y	G
Funding / Cost		R	Y	G
Resources		R	Y	G
Risk Analysis		R	Y	G
Standard ARDEC Processes Approach		R	Y	G
Tools, Methods, and Best Practices		R	Y	G
Phase 1 Entry / Continuation		R	Y	G

Gate Review Scoring

- **Green: No Concerns**
  - Go Forward, Funding Intact, CSP is On-Track
- **Yellow: Minor Concerns**
  - Some Information May Be Missing
- **Red: Major Concerns**
  - Critical Information Missing
  - Risks Exceed Tolerance

Gate Review Outcomes

- **A "Go" Decision - The "Gate Keepers":**
  - Authorize and Empower the IPT to Proceed Through the Next Phase Based on Clear Performance Deliverables, Criteria, and Plans.
  - Confirm Commitment to the Project (Human Capital, Expenses, Test Facilities, etc.) for the Next Phase

Gate Review Outcomes

- **A "Redirect" Decision:**
  - A Project Can Be Redirected Because the IPT :
    - Has Not Convinced the Gate Keepers That They've Completed the Requirements for the Gate.
    - Has Not Provided the Gate Keepers with the Requisite Data/Evaluation of Risk to make an Informed Go or No-Go Decision
  - A Project may be Redirected Because of New-Found External Project Influence.
  - Gate Keepers Must Provide Specific Guidance and a Timeframe for Another Gate Review.

Gate Review Outcomes

- **A "No-Go" Decision:**
  - Technology / Product Does Not Conform with the CSP Objectives, Does Not Work as Anticipated or is No Longer Needed.
  - When a "No-Go" Decision is Made, the Project is Canceled, and the Resources are Re-deployed.
    - Project is Brought to an Orderly Close/Conclusion, Artifacts / Lessons Learned Are Documented.

Gate Review Metrics Summary

Phase - Specific Information **Project Name**

Milestones - Project Events	SRR			PDR / TRL 3			TRL 4/5			CDR / TRL 6		
	Gate 1			Gate 2			Gate 3			Gate 4		
Schedule - As Approved (mo/yr):	Gate 0			Gate 0			Gate 0			Gate 0		
Schedule - Plan (mo/yr):	Gate 0 (1)			Gate 1 (1,2)			Gate 2 (1,2,3)			Gate 3 (1,2,3,4)		
Schedule - Actual (mo/yr):	Gate 1			Gate 2			Gate 3			Gate 4		
Schedule Variance (mo)	Gate 1			Gate 2			Gate 3			Gate 4		
SV - Schedule Variance ($)	Gate 1			Gate 2			Gate 3			Gate 4		
Schedule Efficiency, SPI	Gate 1			Gate 2			Gate 3			Gate 4		
Planned Completion Date (mo/yr):	Gate 1			Gate 2			Gate 3			Gate 4		
	Gate1			Gate 2			Gate 3			Gate 4		
Project Budget - Avail to Project Work ($)	Gate 0			Gate 1			Gate 2			Gate 3		
Project Cost - Actual ($) (cum by Phase)	Gate 1			Gate 2			Gate 3			Gate 4		
Project Cost Variance ($)	Plan – Actual			Plan – Actual			Plan – Actual			Plan – Actual		
Cost Efficiency, CPI	Gate 1			Gate 2			Gate 3			Gate 4		
ETC ($):	Gate 1			Gate 2			Gate 3			Gate 4		
EAC ($):	Gate 1			Gate 2			Gate 3			Gate 4		
	C	S	P	C	S	P	C	S	P	C	S	P
Gate Result	RYG	RYG	RYG	RYG	RYG	RYG	RYG	RYG	RYG	RYG	RYG	RYG

(#, etc) = Remaining project schedule dates, updated at successive Gates

Tools Methods & Best Practices

- The ATDP Emphasizes the Use of Lean Six Sigma
- TMBP's Use are Linked to Each of the ATDP's Phases
- TMBP's Support the Following Key ARDEC Competencies:
  - Design Engineering
  - System Engineering
  - Quality Engineering
  - Project Management
  - Logistics Management

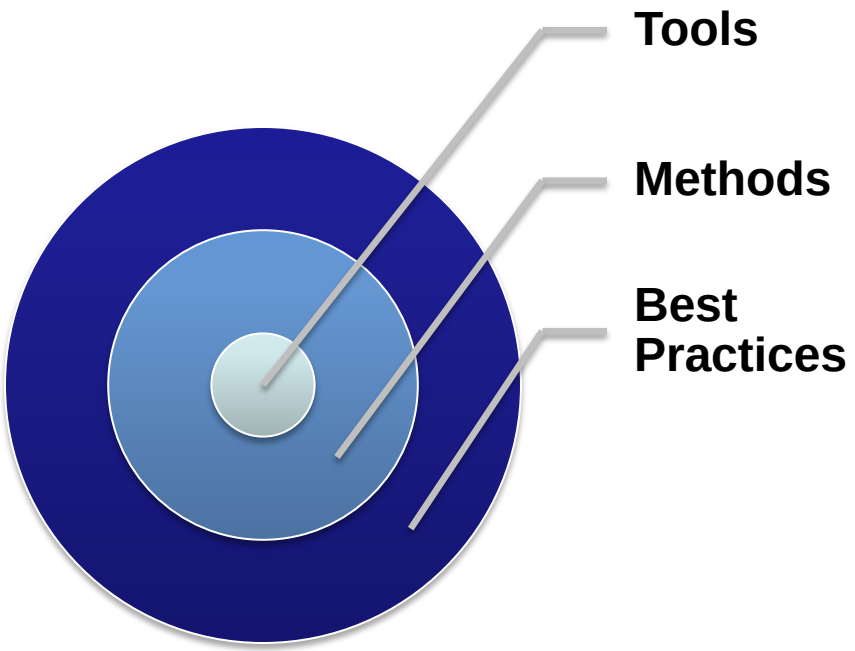
Tools, Methods, & Best Practices

- There is a flow-down relationship that explains **TMBP** links:

Best Practices are often at the top of the hierarchy.

Methods are frequently used *within* a Best Practice Category.

Tools often are used in one or more of the steps within a methodology or Best Practice.



Best Practices

- Time-tested, high level ***Best Practices*** used include:
  - Systems Architecting, Engineering & Integration
  - Design for Six Sigma (DFSS)
  - Concurrent Engineering (DfX integration)
  - Agile / Flexible Development
  - Lean Product Development
  - CMMI for Development Processes
  - Phases & Gates Development Process
  - Portfolio Management
  - Project Management
  - Risk Management
  - Others….

Methods

- ***Methods*** include systematic steps to complete Tasks:
  - **Key Parameter Development & Mgt.**
  - **Probabilistic Design / Monte Carlo Simulations**
  - **Axiomatic Design**
  - **Robust Design**
  - **Design for the 'ilities (DfX)**
  - **Statistical Methods**
    - Design Of Experiments (DOE)
    - Statistical Process Control (SPC)
    - Capability Studies & Analysis
    - Descriptive Statistics (graphical methods)
    - t – Tests of Comparison
    - Hypothesis Formation & Estimating Confidence Intervals
    - Sample Size Determination
    - Distribution ID & curve fitting
    - Regression
    - ANOVA
    - Reliability Growth & Analysis

Tools

- Affinity Diagram (KJ Method)
- House of Quality
- Pugh Analysis
- Functional Flow Diagram
- Parameter Diagram
- Reliability Block Diagram
- Cause & Effect (Ishikawa) Diagrams
- Risk Analysis & Mitigation
- Gage Repeatability & Reproducibility (R&R)
- Various Enterprise Templates
- Voice of Customer (VOC) Surveys
- Kano Analysis
- Design FMEAs
- Noise Diagram
- Interface Boundary Diagram
- Design of Experiments (DOEs)
- Technical Performance Measures
- Earned Value Management (EVM)

Integration of System Engineering and Design Engineering Disciplines

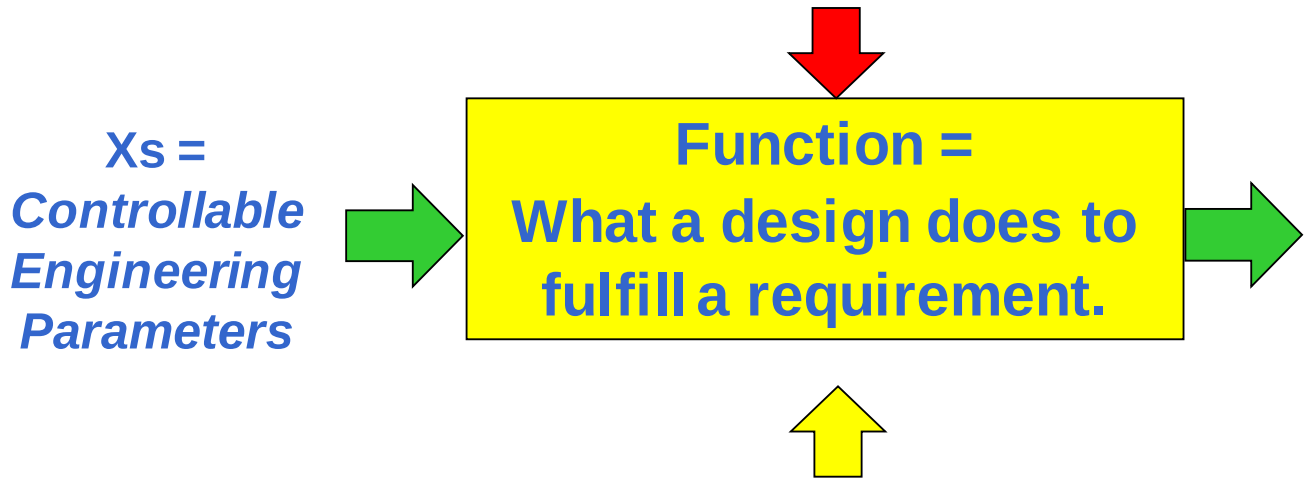
- Focus on developing and documenting a database of normal parameters as well as **the few critical or key parameters that must be controlled** as a system is developed and transferred into sustained life-cycle management.
- The foundation for identifying and learning about parametric relationships, and determining which ones are “Critical” or “Key”, starts with the ***Functions*** of a technology, product or production process. Functions are developed to meet requirements. Parts and materials possess ***Characteristics*** (dimensions, shape factors, surface finishes and bulk material properties) which are designed to support and enable subassembly, subsystem and system functions.

Functional Decomposition

Our focus – linking Functional requirements to functions…

Noise = *Sources of Unwanted Variation*

Y is a function of input Xs & the effect of unwanted Noise…



U.S. ARMY RDECOM

Effective & Efficient Use of TMBPs

- The ATDP is Designed to Promote Efficiency
- Once Tasks are selected from Standard Project Planning Templates, the IPT and APO Must Make their Choices on which TMBPs to Apply to their Project's **Design Guide**.
  - Tasks are **Adaptable** & their Flow is **Flexible**
  - Adaptive TMBP Use is Based on:
    - Common Sense & Value to Help Complete Tasks
    - Specific Project Requirements / Deliverables
      - Project Requirements Drive Task Selection & Flow
      - Desired Level of **Integrity** of Data & Deliverables

Proactive Focus on Problem Prevention

- The ATDP Emphasizes Risk Management with a Bias Towards ***Problem Prevention***
  - It was Designed to Proactively Identify Potential Problems
  - Where Possible, Avoid Them Altogether Through Preventive Action
  - Define Contingency Plans to Adaptively Switch Plans to Mitigate the Early Onset of a Problem
    - The Goal is to Reduce “Firefighting” & Unnecessary Rounds of Problem Solving
    - Reduce or Eliminate Development Scrap & Rework

Summary

- A New Standardized Phase-Gate Process for Technology Development Has Been Implemented at ARDEC that is Aligned with the DoD Acquisition Framework.
  - Phase 1: Project Planning and Requirements Development
  - Phase 2: Concept Down-Select and Preliminary Detailed Design
  - Phase 3: Engineering Experimentation and Test
  - Phase 4: System Integration and Evaluation
- Renewed Emphasis on Capturing the “Big-Picture” Needs of Warfighters to Identify and Pursue Technology Development Opportunities that Satisfy our Stakeholders
- Paradigm Shift in Design Theory to a Creative, Rational, Systematic Approach to Find New and Improved Solutions to Requirements Instead of Past “Trial and Error” Practices Using Known Solutions.