



# Evolutionary Acquisition and Risk "Spiral Development" - We Hardly Knew Ye

*29 April 2010*

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# Overview of Presentation

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- **DoD's evolving policy on acquisition management**
  - How our systems management model has changed
- **Previous Research on Life-Cycle Models**
  - How many “control gates” do you need?
- **Evolutionary Acquisition and its implications**
  - Case studies
  - Organizational and System Dynamics modeling
- **Recent views of “the System” and how it is today**



# Different Approaches & Terminology

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- Progressive elaboration (vs. “Requirements creep”)
- Iterative design/rapid prototyping
- Pre-planned product improvement
  - Evolutionary acquisition
  - Spiral development
  - Incremental capability
    - Planned upgrades
    - Rational Unified Process Framework

## **VERSUS:**

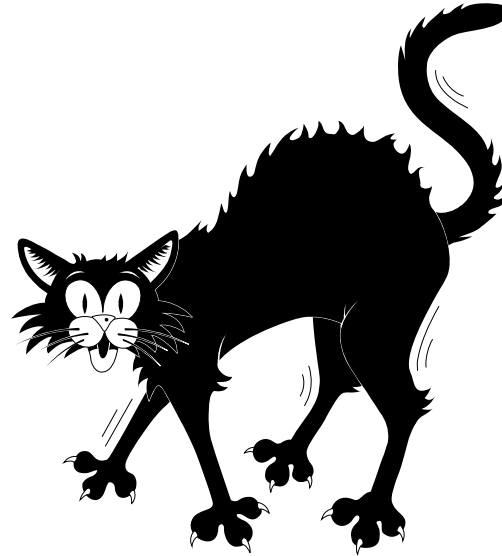
- **Single Step**
  - **Grand design**
    - **Unified Development Method**
      - **Technological leap**
        - **Waterfall**



# Development Life-Cycle Models

***“The best material model of a cat is another, or preferably the same, cat.”***

**Norbert Wiener, 1948**



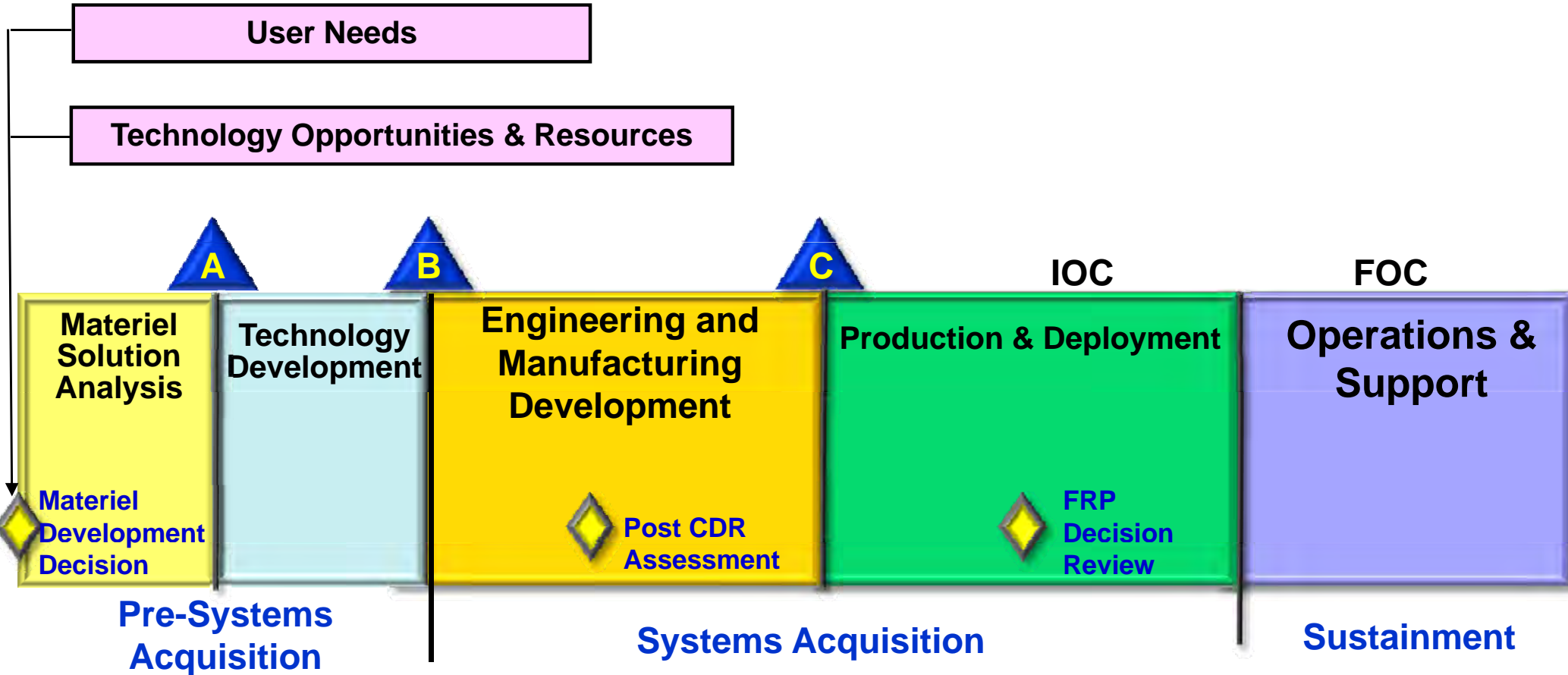
**“All models are wrong. Some are useful.”**

**George E. P. Box, 1979**





# The Defense Acquisition Management System as of December 2008



This general graphic has served for decades as DoD's  
“Life-Cycle Systems Management Model”  
as well as its decision “framework.”



# Acquisition Policy Changes

Mar 1996

DoD Directive 5000.1  
DoD Regulation 5000.2-R

Oct 2000

- DoD Directive 5000.1
- DoD Instruction 5000.2
- DoD Regulation 5000.2-R

Oct 2002

**“Interim Guidance”**  
- The Defense Acquisition System  
- Operation of the Defense Acquisition System  
- Interim Defense Acquisition Guidebook

May 2003

- *DoD Directive 5000.1*
- *DoD Instruction 5000.2*
- *Interim Defense Acquisition Guidebook*



# DoD Leadership's Stated Intent for DoD 5000 Revision

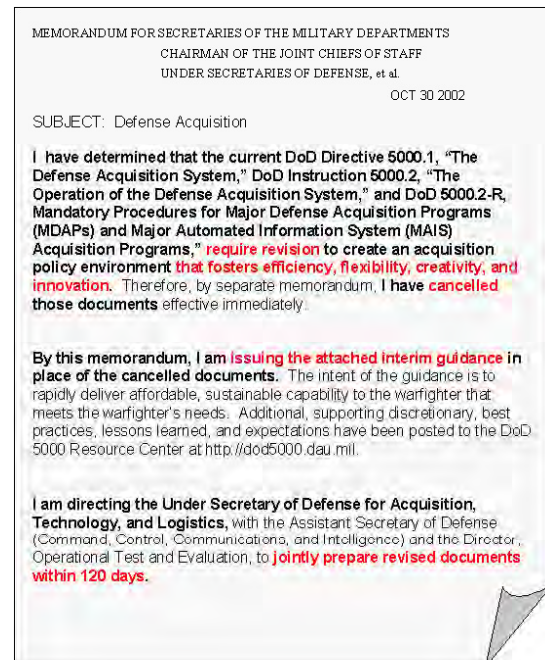


***“...create an acquisition policy environment that fosters efficiency, flexibility, creativity, and innovation.”***

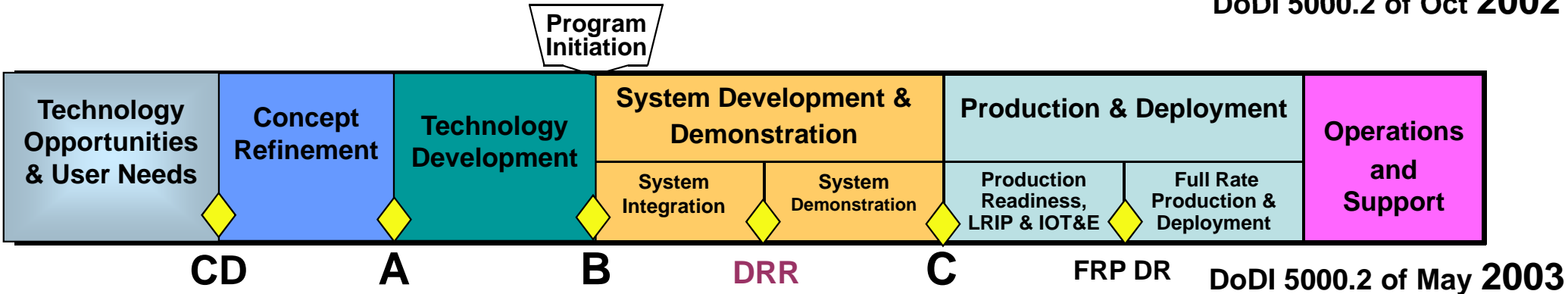
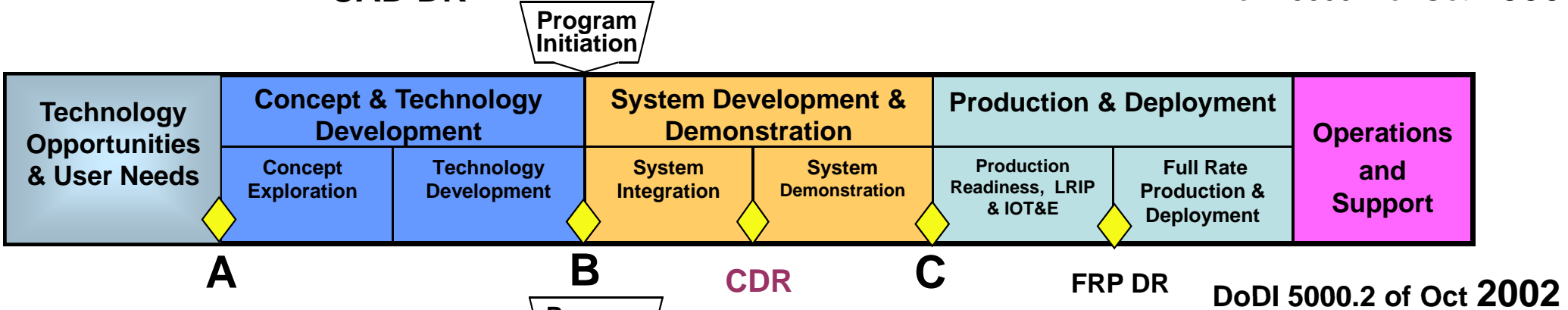
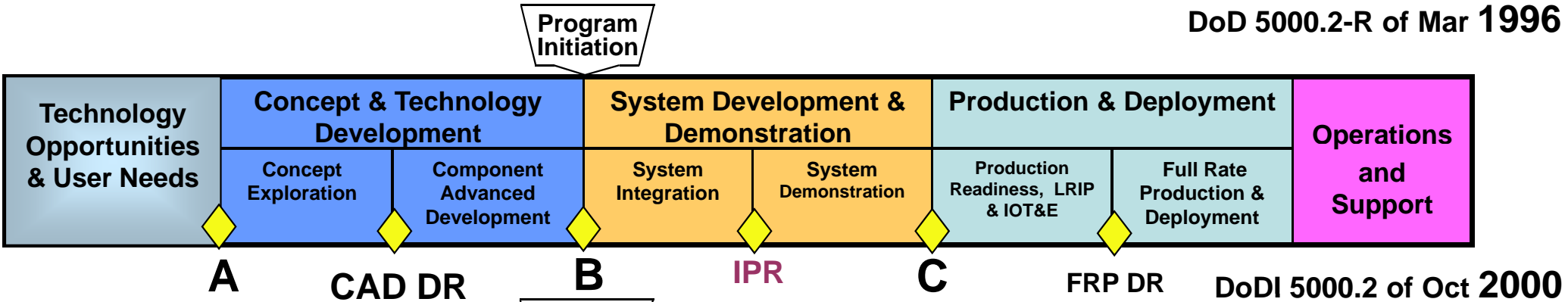
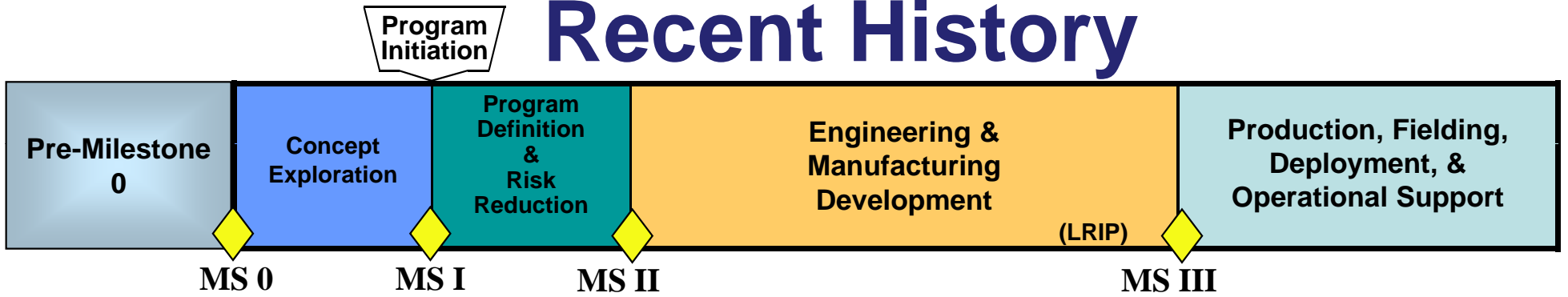
***DEPSECDEF Wolfowitz, 30 Oct 2002***

## ***Revised Policy Objective:***

- Encourage innovation and **flexibility**
- ***Decentralized responsibility to be maximized***
- ***Empower PM's*** to use the system vice being hampered by over-regulation
- ***Minimize reporting requirements***



# Recent History

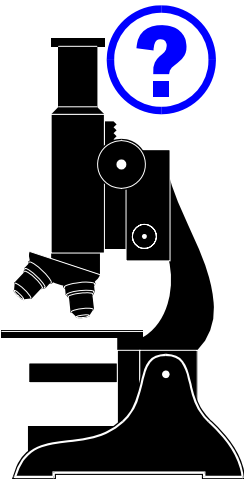




# Initial Research Methodology



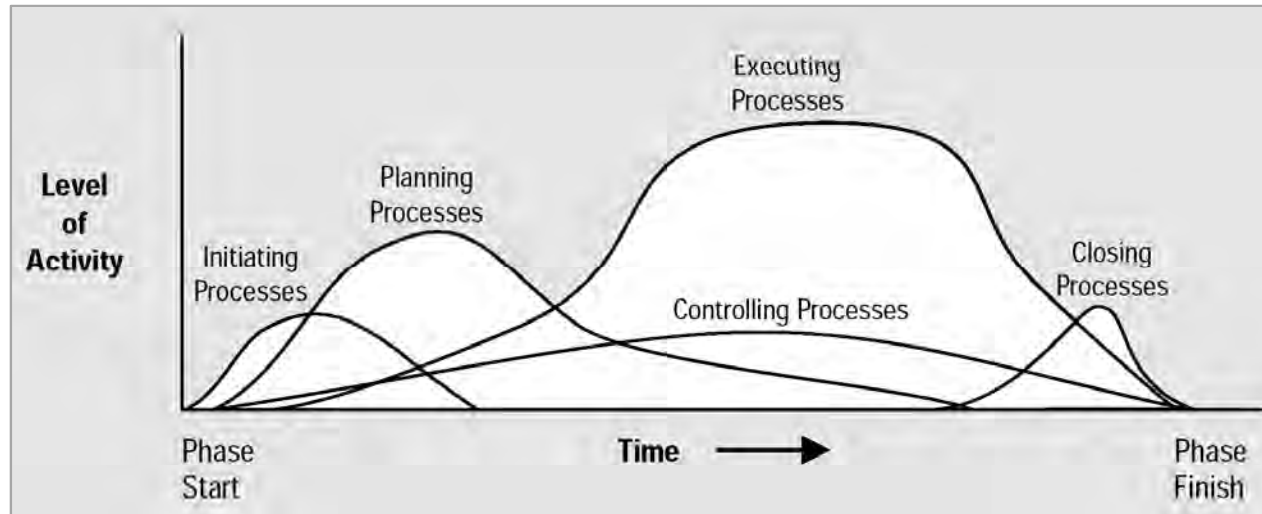
- **Turbulence in policy & confusion in the field**
- **Complexity of the new model:**
  - **More decision reviews**
  - **Higher level of reviews**
  - **Placement of reviews and project events**



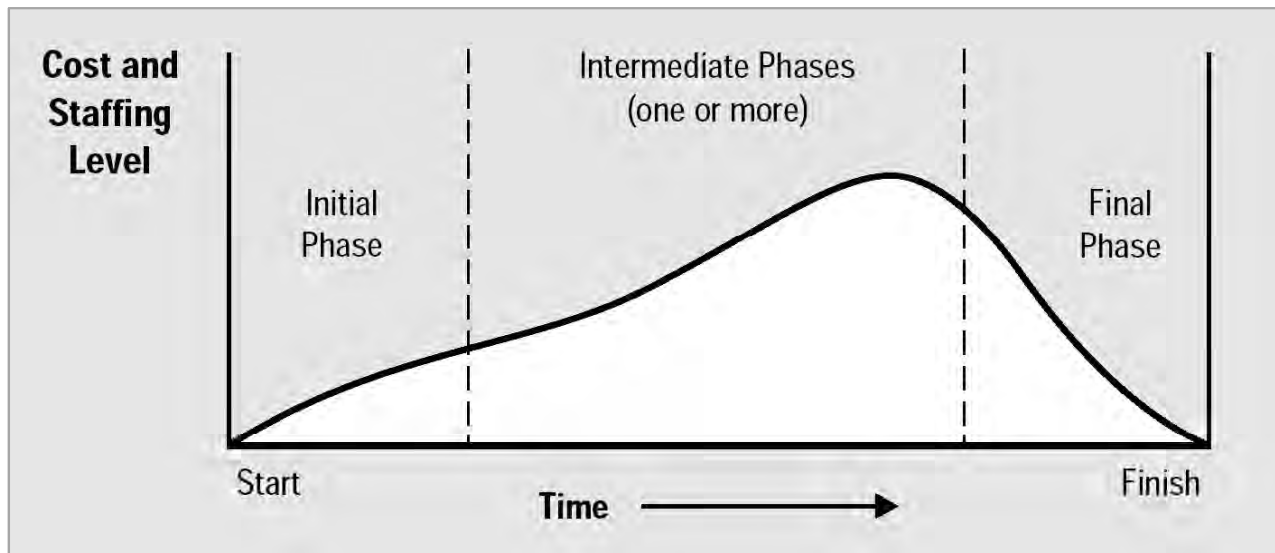
1. **What other Project Management models exist?**
2. **(Explicit and) Implicit aspects of the new model?**
3. **Congruent with stated policy?**
4. **Best fit to environment vis-à-vis Organizational theory?**



# Project Management Institute's Generic Project Models



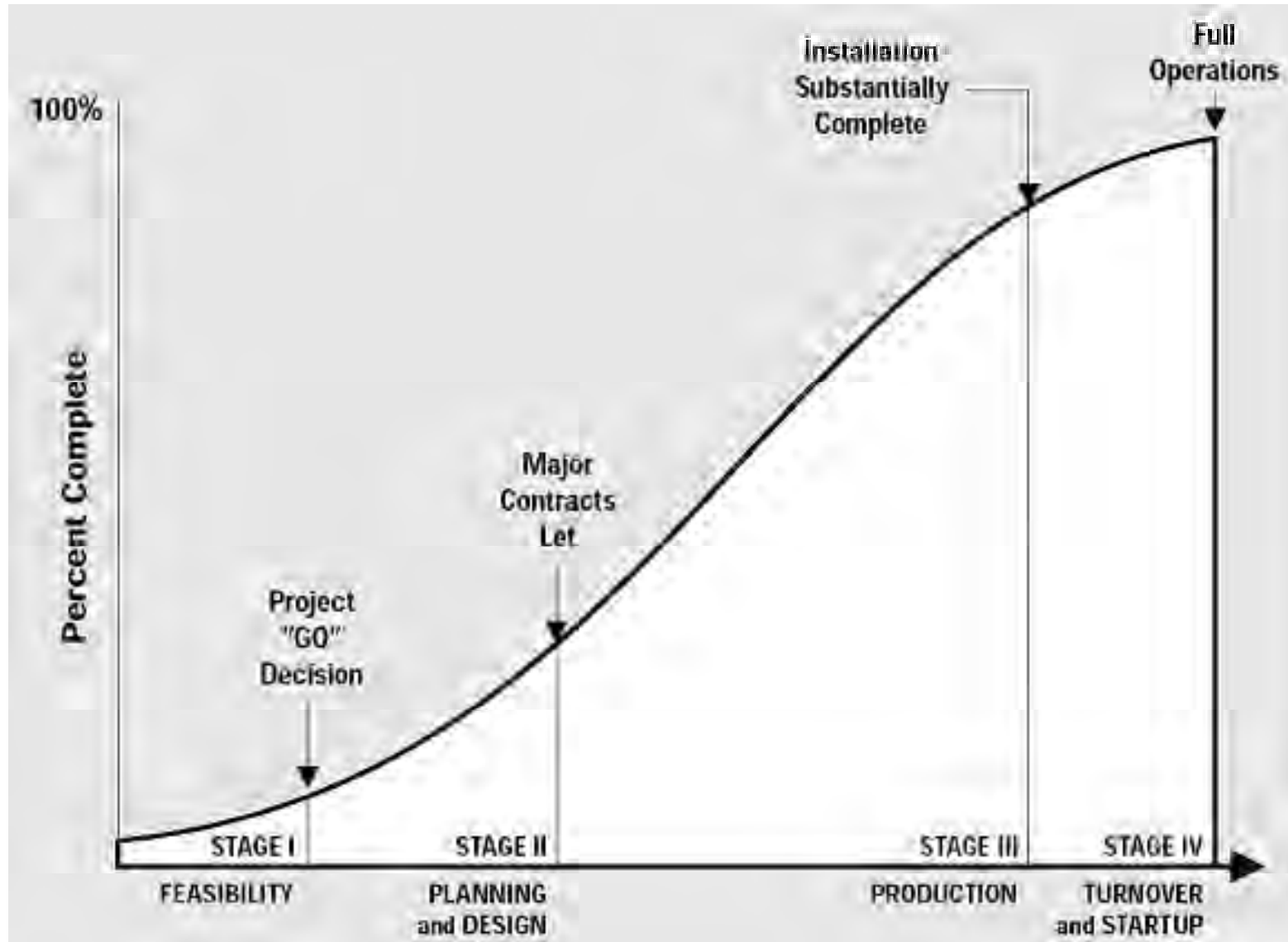
**Key Tenets  
of Projects:**  
**-- Concurrency**



**-- Phasing**  
**"Control Gates"**

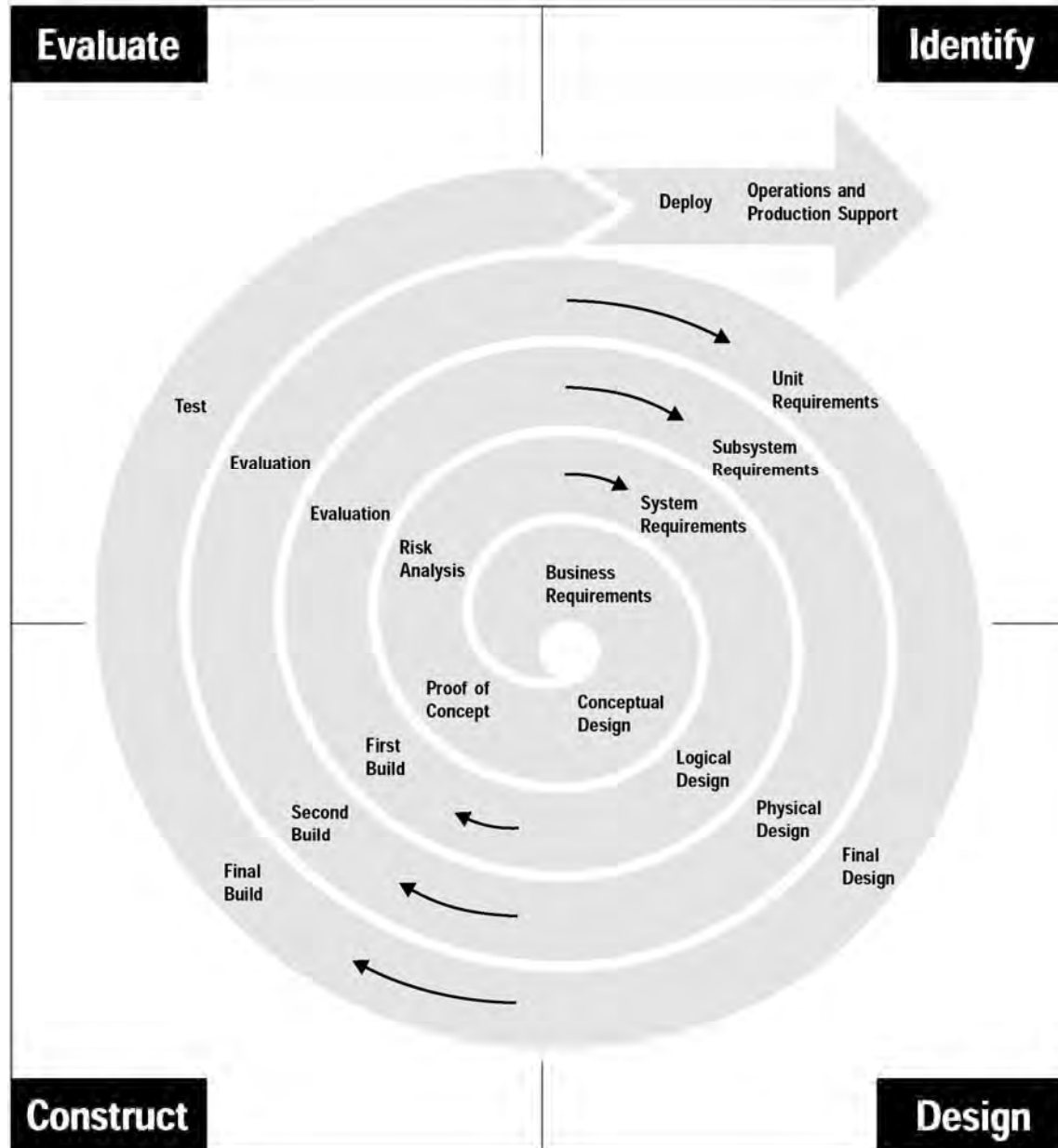


# Construction Industry Project Model



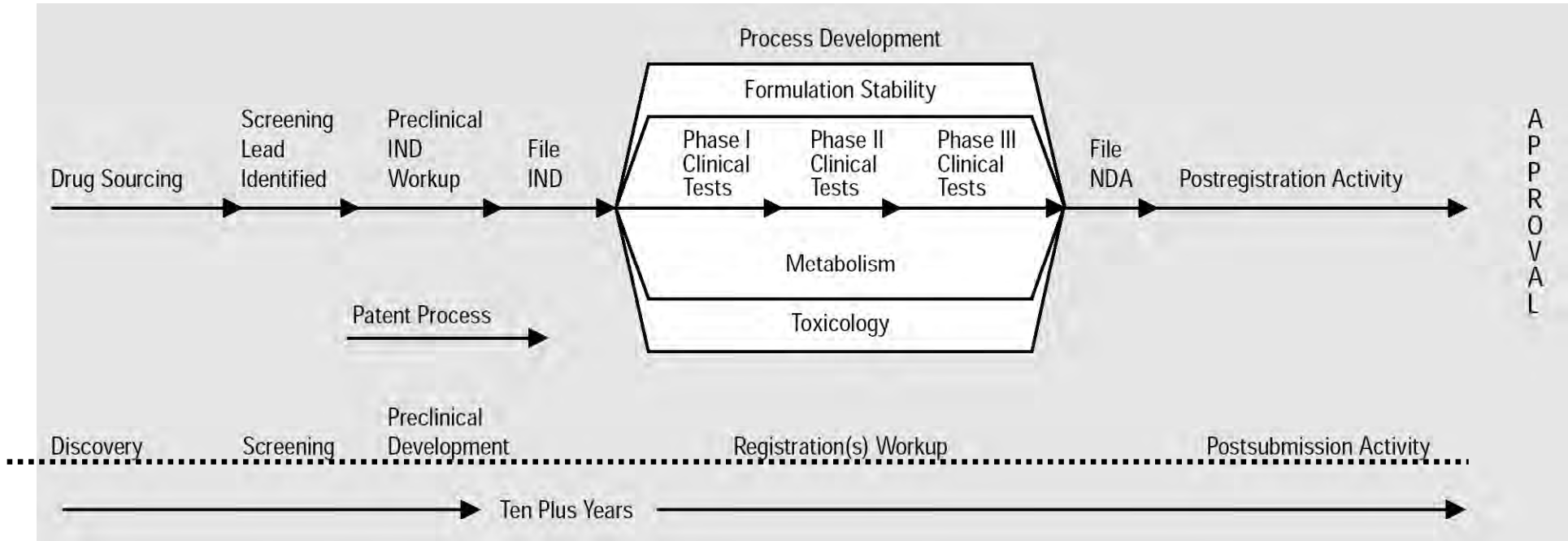


# Software Industry Project Model





# Pharmaceutical Industry Project Model

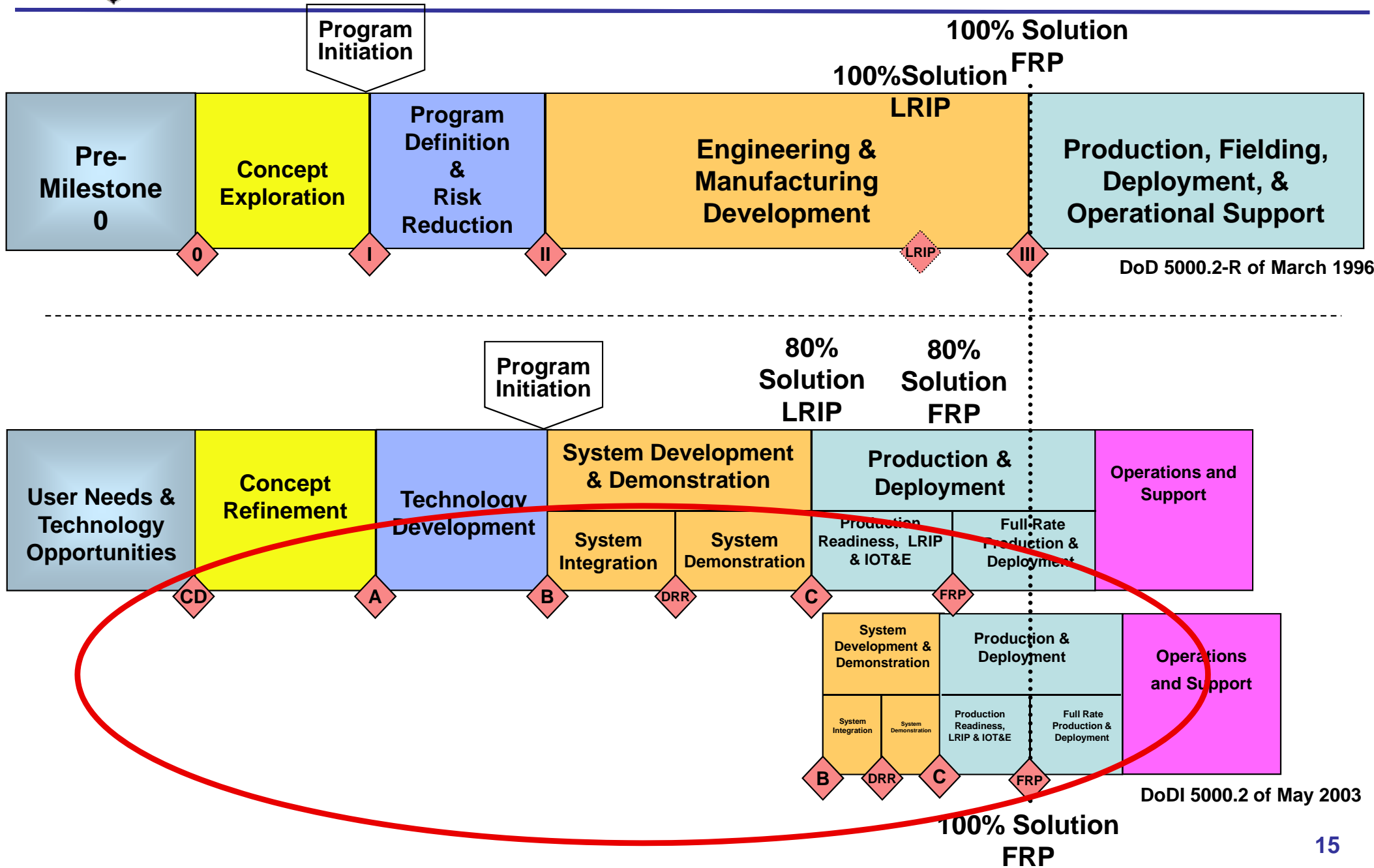


## Most similar to DoD?:

- Serial vs. Concurrent Orientation
- Primary Metrics: Safety & Efficacy
- Average Project: \$897M & 10 yrs
- Both Govt and Private funded R&D
- Lengthy FDA Review

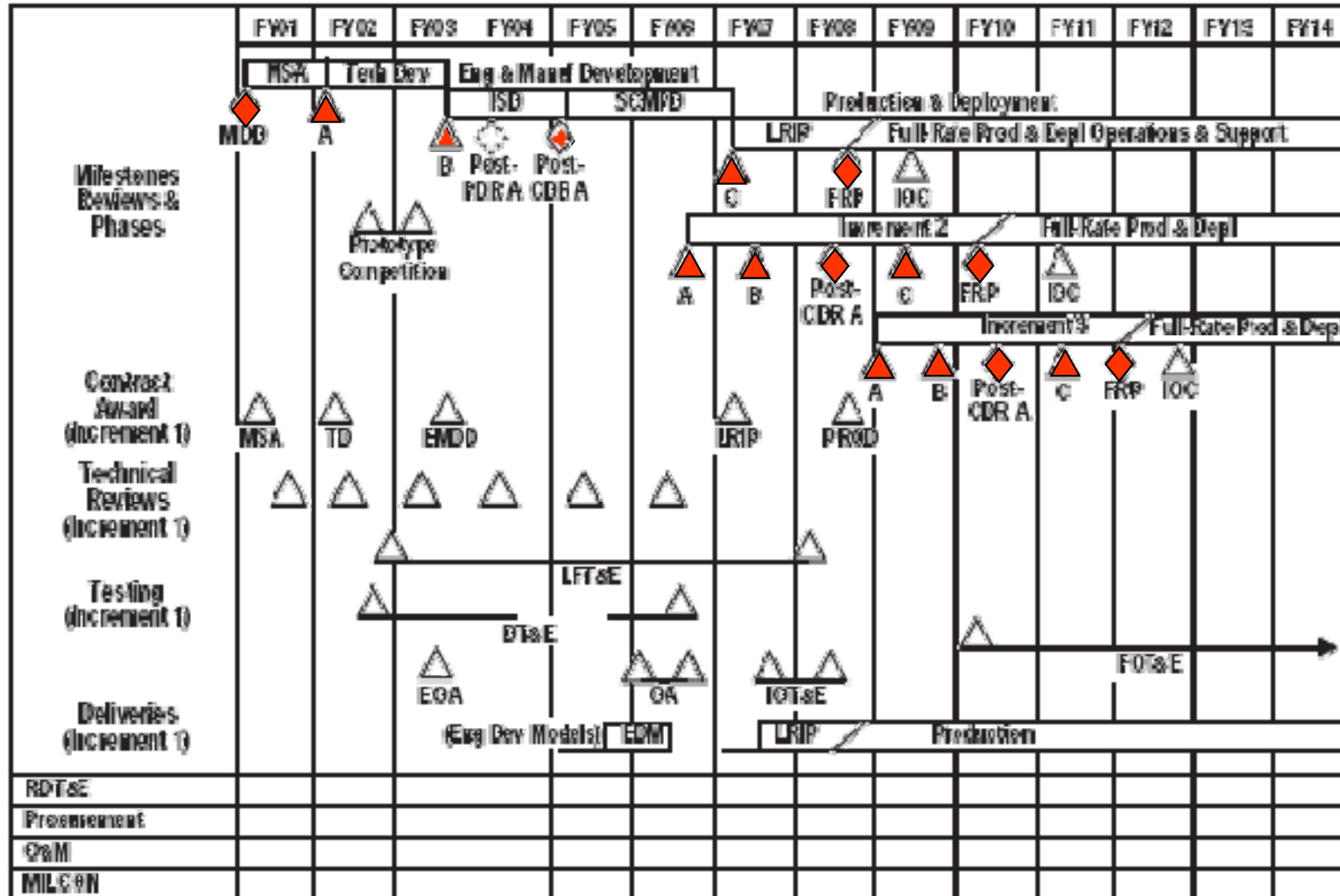


# True Comparison of 1996 and 2003 Models Under an Evolutionary Acquisition Strategy



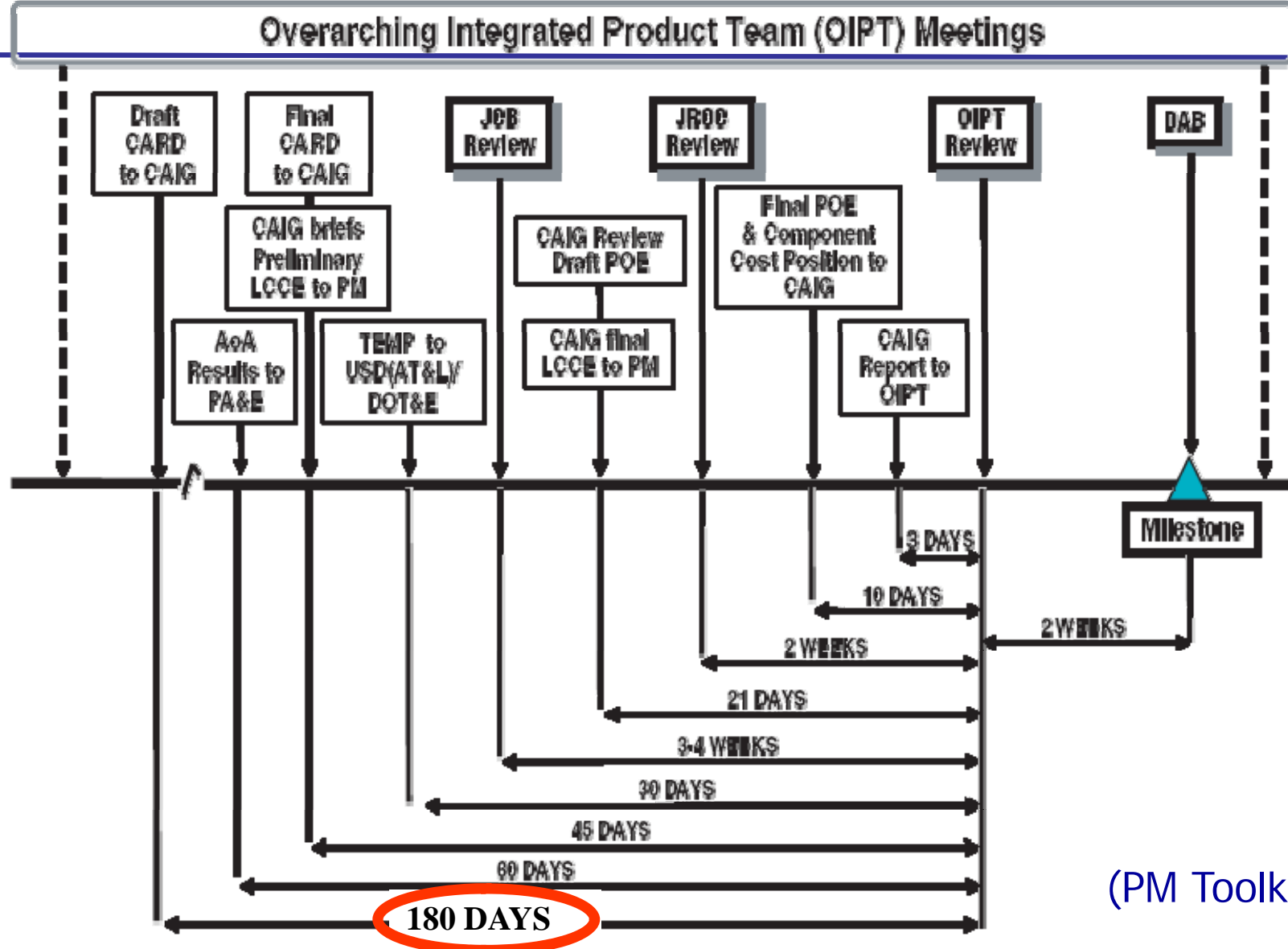


# Typical Program: 16 OSD-Level Reviews in 12 Years





# OSD Review Timeline



(PM Toolkit, 2009)

- ADM - Acquisition Decision Memorandum
- CARD - Cost Analysis Requirements Description
- FRPDR - Full Rate Production Decision Review
- JROC - Joint Requirements Oversight Council
- CAIG - Cost Analysis Improvements Group
- DAB - Defense Acquisition Board
- JCB - Joint Capabilities Board
- LCCE - Life cycle cost estimate(s)



# Defense Acquisition Review Journal

## December 2005



RESEARCH

## TOWARD CENTRALIZED CONTROL OF DEFENSE ACQUISITION PROGRAMS

John T. Dillard

A great deal of turbulence in U.S. defense acquisition policy has contributed to confusion during the last three years within the acquisition workforce in terminology, major policy thrusts, and unclear implications of the changes. The new acquisition framework has added complexity with more phases and delineations of activity, and both the number and level of decision reviews have increased. As a result, program managers may now have fewer resources to manage their programs as they spend much of their time and budgets managing the bureaucracy. This same framework and its associated requirements for senior level reviews are opposed to the rapid and evolutionary policy espoused and are counter to appropriate management strategies for a transformational era.

The issuance of Department of Defense (DoD) Directive 5000.1 (2003) and DoD Instruction 5000.2 (2003) is the third significant revision of acquisition policy in many years. Looking further back, these three revisions of regulatory guidance evolved from two previous versions in 1991 and 1996. Each had its major thrusts and tenets, and perhaps of most importance to program managers; each modified the “Defense Systems Acquisition Management Process” (Defense Systems Management College [DSMC], 2001) or “Defense Acquisition Framework” (DSMC, 2001), which is the broad paradigm of phases and milestone reviews in the life of an acquisition program. The purpose of this research was to examine the evolution of this framework and explain the explicit and implicit aspects of recent changes to the model to better understand its current form. Provided here is a synopsis of the most important findings. The full report of this research, examining both private industry and defense acquisition decision models is available for a more in-depth review (Dillard, 2003).

The very latest DoD 5000 policy changes came during a time of DoD transformation, which is chiefly focused on changes to force structure and weapons employment capabilities. The latest version of the 5000 series was actually drafted in the documents rescinding its predecessor. According to a memorandum signed by Deputy Secretary

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# Contingency Theory

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- **Organizational structures must change in response to contingencies of size, technology, and as external environments become more complex and dynamic.**
- **Command structure must:**
  - (a) demand more information, or
  - (b) enable local forces to deal with the situation.
- **Research supports decentralized control as preferred approach.**

(see Galbraith, 1973 and Van Creveld's *Command in War*, 1985)



# Citations Elsewhere

*Report of the  
Defense Science Board Task Force  
on  
Management Oversight in Acquisition  
Organizations*



March 2005

*Office of the Under Secretary of Defense  
For Acquisition, Technology, and Logistics  
Washington, D.C. 20301-3140*

***Beyond Goldwater-Nichols:  
U.S. Government and Defense Reform  
for a New Strategic Era***

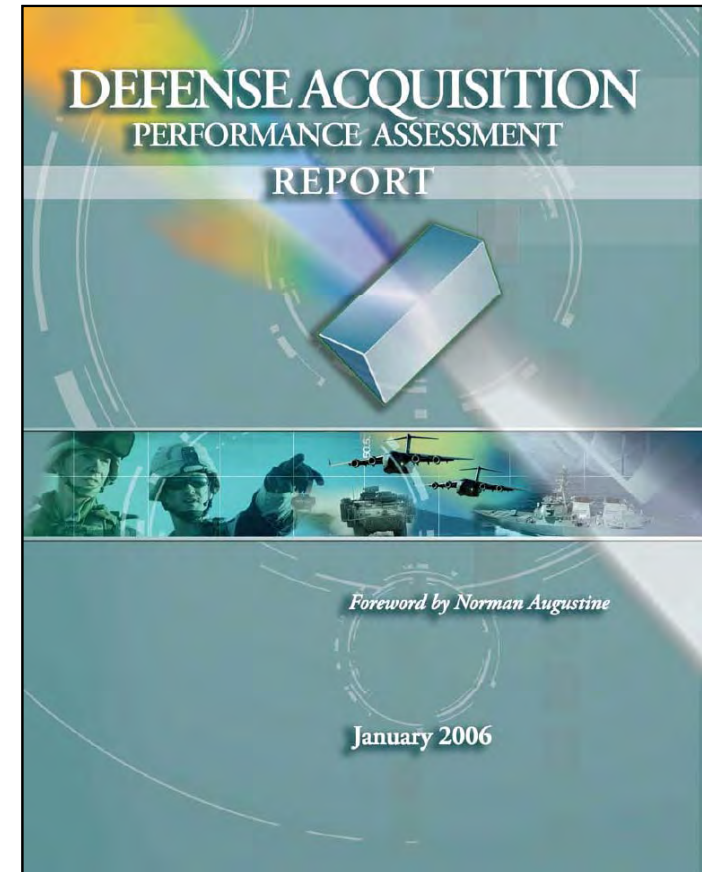
Phase 2 Report

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July 2005





# Affirmations Continue



“We’re in an endless cycle of reviews”



“One review per year is pretty much the norm now... There’s things I’d rather be doing...I just appointed a colonel to a new position – to look across my programs”



## Why Good Projects Fail Anyway

September 2003

**Challenging senior leaders to cede control:**

“Managers expect they will be able to identify, plan for, and influence all the variables and players in advance, but they can’t. Nobody is that smart or has a crystal ball. They can, however, create an ongoing process of learning and discovery, challenging the people close to the action to produce results – “

Nadim F. Matta & Ronald Ashkenus



# Evolutionary Development as Mandate

“Evolutionary acquisition strategies shall be the preferred approach to satisfying operational needs.”

DoDI 5000.2

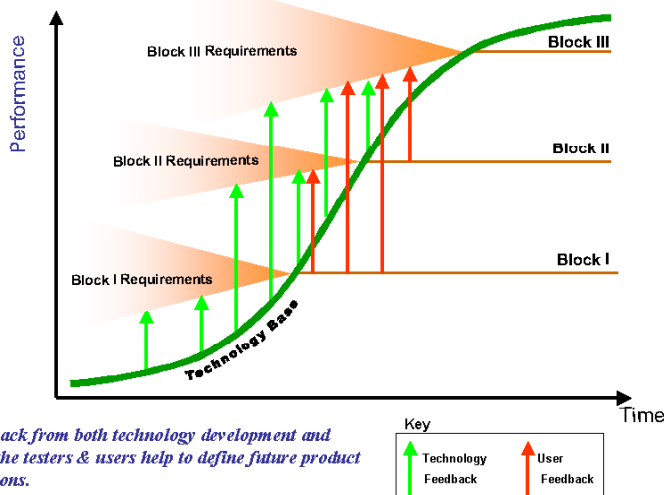
## Evolutionary Acquisition



Further defined:

- **Incremental Development**: A desired capability is identified; the end-state requirement is **known**; and that requirement is met over time by developing several increments, each dependent on available, mature technology.
- **Spiral Development**: A desired capability is identified, but the end-state requirements are **not known** at program initiation. Requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability.

## Evolutionary Acquisition Model



# Development Strategy Comparison Table

Strategy or Development Process Criteria	Single Step to Full Capability	Pre-planned Product Improvement (P <sup>3</sup> I)	Evolutionary Acquisition	
			Incremental Development	Spiral Development
Full requirements defined at outset	Yes	Yes	Yes	No
Useful intermediate capabilities	No	Yes	Yes	Yes
Multiple iterations	No	No	Yes	Yes
All capabilities required in initial increment	Yes	No	No	No
User feedback from earlier iterations used to define final requirement	No	No	Yes	Yes
Other characteristics	Used as the traditional acquisition strategy	Achieves increased capability from maturing technology with architecture in place	Developmental process when full requirements defined at outset	Developmental process when full requirements <b>not</b> defined at outset



# United States Code

## TITLE 10, Subtitle A, PART IV, CHAPTER 144, § 2430

---

**“(g) Definitions.—In this section:**

**“(1) The term ‘spiral development program’, with respect to a research and development program, means a program that—**

**“(A) is conducted in discrete phases or blocks, each of which will result in the development of fieldable prototypes; and**

**“(B) will not proceed into acquisition until specific performance parameters, including measurable exit criteria, have been met.**

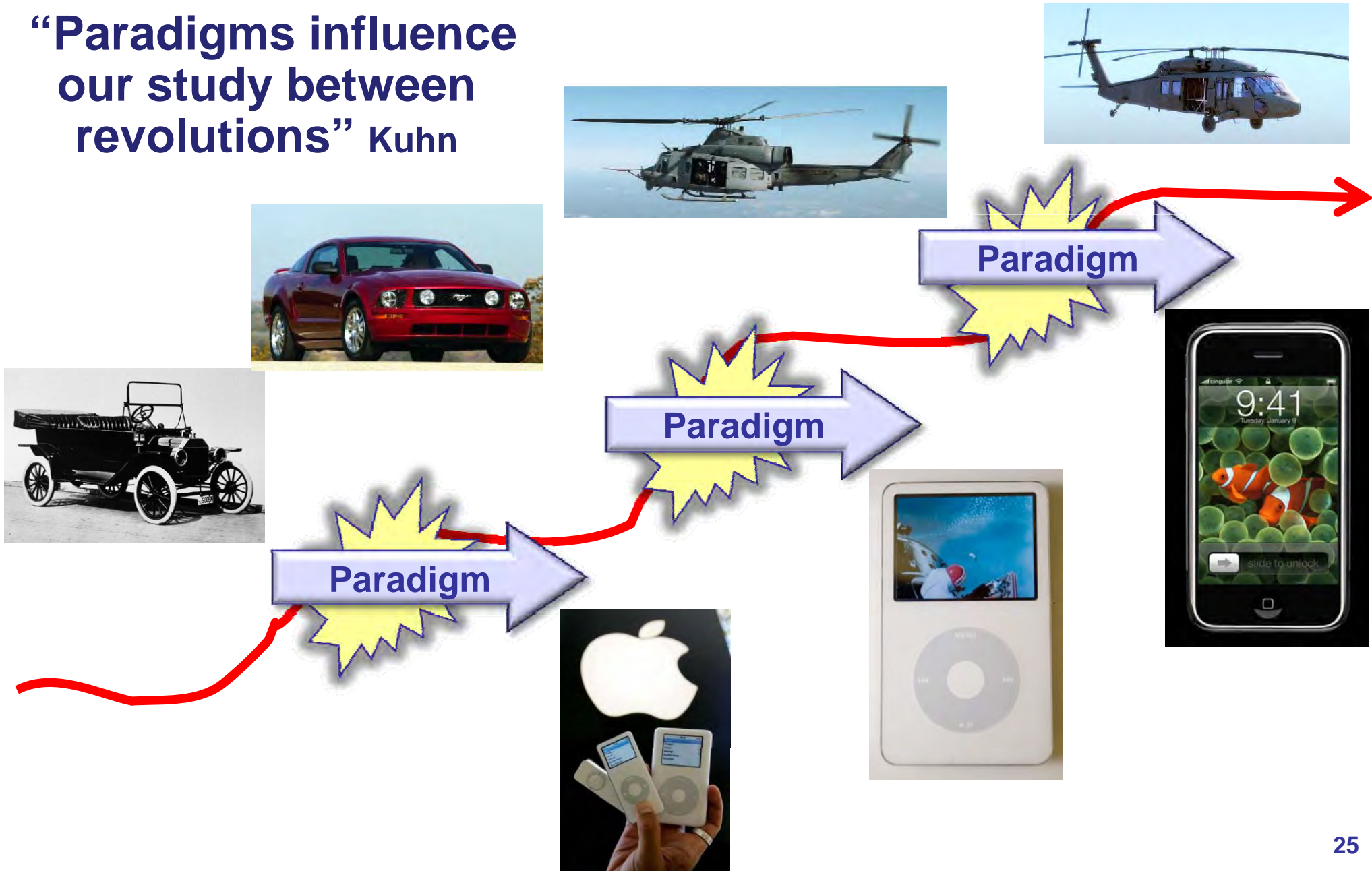


**F-18 E/F Super Hornet**



# Evolutionary Development in Practice

“Paradigms influence our study between revolutions” Kuhn





# Markets Love Product Variety





# Product Variety Has Downsides



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**Supply, Maintenance and Training Impacts**



# Unwanted Variety in Production



AFTER 8.5 SEC



AFTER 7 SEC



AFTER 6 SEC



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## Failures and Failure Mode Identification



# CSIS Study Panel on Spiral Development



Center for Strategic & International Studies  
PROVIDING STRATEGIC INSIGHTS AND POLICY SOLUTIONS

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OPEN EVENT DETAIL

## SPIRAL DEVELOPMENT, REAL OPTIONS, AND OTHER DEVELOPMENT METHODOLOGIES

Events

DATE: **June 5, 2006**

TIME: 8:30 a.m. - 12:15 p.m.

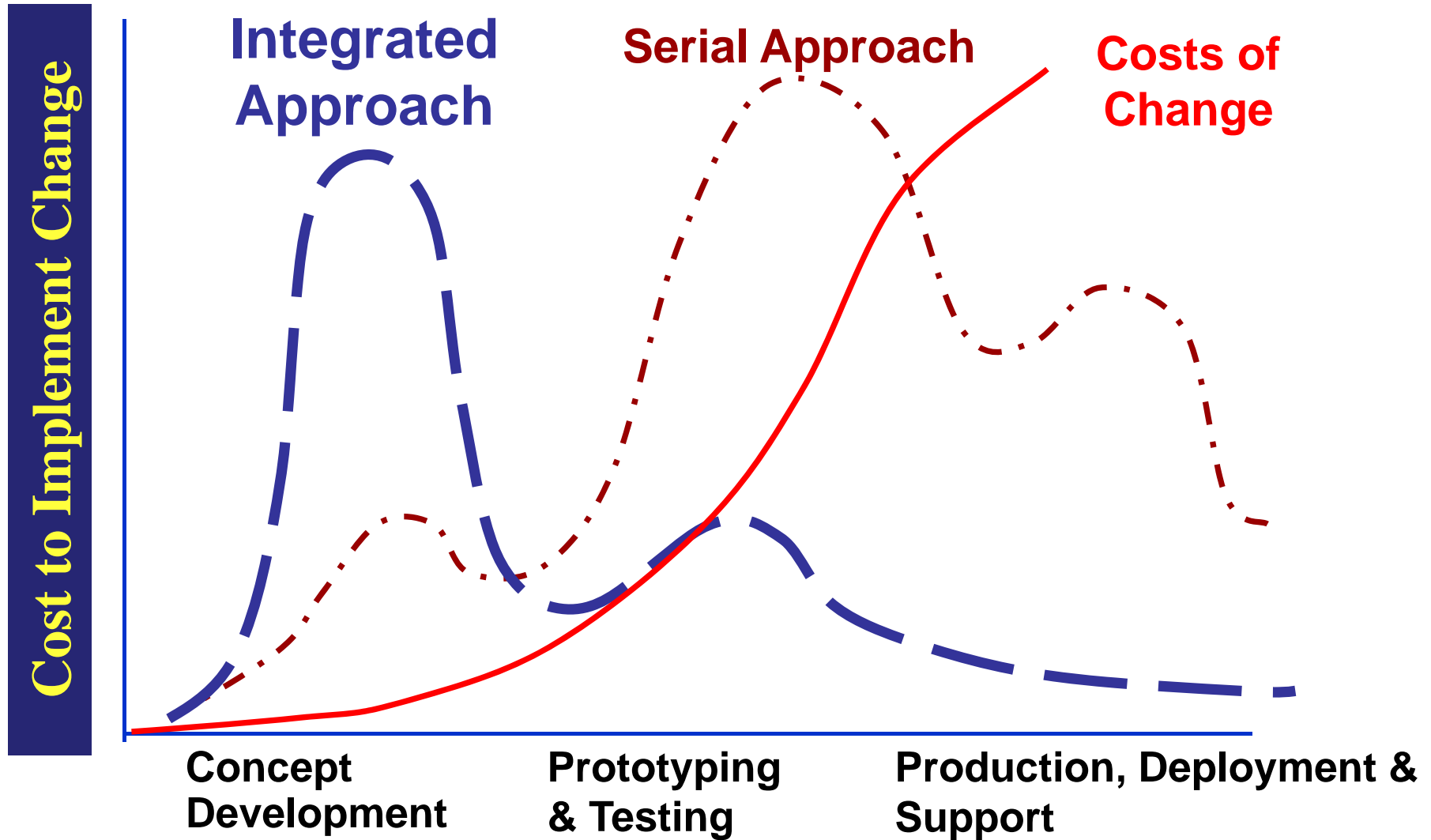
LOCATION: CSIS  
B-1 Conference Center  
1800 K Street, N.W.  
Washington, D.C.

is





# Integrated vs. Serial Approach



***“Intelligent design is way faster than evolution.”***

Robert N. Metcalfe



# Research on Evolutionary Acquisition

**GAO**

March 2007

United States Government Accountability Office

Report to Congressional Committees

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**DEFENSE ACQUISITIONS**



**ATACMS**



**JAVELIN**



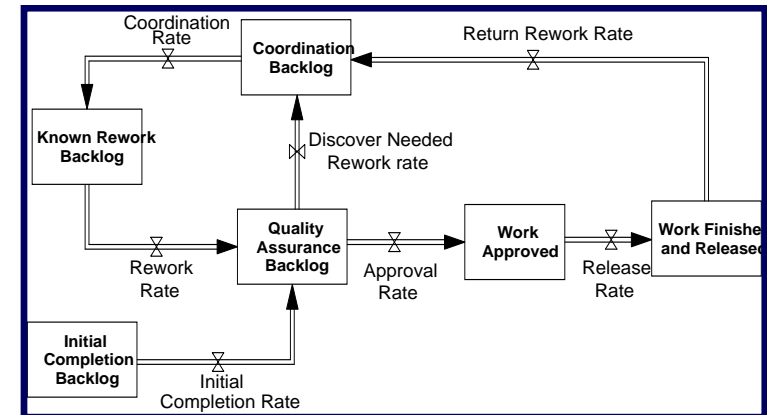
PROJECT AIR FORCE

## RESEARCH BRIEF

### “Evolutionary Acquisition” Is a Promising Strategy, But Has Been Difficult to Implement

In 2003, the U.S. Department of Defense (DoD) specified evolutionary acquisition (EA) as the preferred approach to weapon system acquisition, and spiral development as the preferred means of implementation. EA strategies aim to develop new capabilities in multiple increments, as opposed to the traditional strategy of developing a full capability in a single, lengthier step. EA strategies are meant to reduce the time it takes to field operationally useful equipment, control technical risk and cost growth, and make cost estimates more reliable for each stage of development, while allowing greater flexibility to evaluate and improve a program based on experience in the field. This greater flexibility arises in part from the fact that, with the spiral development approach, the end-state requirements are not known at program initiation, but rather emerge and evolve through an iterative process of phased development and

- RAND RESEARCH AREAS
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- CHILD POLICY
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- EDUCATION
- ENERGY AND ENVIRONMENT
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- POPULATION AND AGING
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- SCIENCE AND TECHNOLOGY





# A Tale of Two Missiles

## Spiral and Incremental Development

**ARMY TACMS**  
**MISSILE DESIGNED FOR GROWTH WARHEADS**

*M74 Submunition*

Weight: 1.3 lbs  
Explosive  
Steel Housing  
Pyrophoric Pellet  
Booster Pellet  
Tungsten Fragment Case  
M219A1E1 Fuse  
2.32 inches

**BLOCK I - APAM**

**BLOCK II - TYPE 1**

**BLOCK II - TYPE 2**

ALTERNATIVE BLOCK II WARHEADS CONTAIN "SMART" ANTI-ARMOR SUBMUNITIONS

## Single Step to Full Capability



Technology Readiness Levels	Level	Hardware (and software necessary to demonstrate capability)	Environment
1 – Basic principles observed and reported	Studies	None	None
2 – Technology concept and/or application formulated	Studies	None	None
3 – Analytical and experimental critical function and/or characteristic proof of concept	Component	Nonscale components (pieces of subsystem)	Lab
4 – Component and/or breadboard validation in lab environment.	Component/ subsystem	Low fidelity breadboard (integration of nonscale components not fully functional or form and fit)	Lab
5 – Component and/or breadboard validation in relevant environment	Subsystem	High fidelity breadboard (functionally equivalent but not form and fit)	Lab or may include flight demo in surrogate aircraft
6 – System/subsystem model or prototype demonstration in relevant environment	Subsystem	Prototype (should be very close to form, fit and function)	Lab or limited flight demonstration
7 – System prototype demonstration in an operational environment	Subsystem	Prototype (form, fit and function)	Flight demo in representative environment such as test bed
8 – Actual system completed and flight “qualified” through test and demonstration	System	Flight qualified hardware	DT&E in actual system application
9 – Actual system “flight proven” through successful mission operations	System	Actual system in final form	OT&E in operational mission conditions



# Technology Maturity – A Key Difference

## Key Program Characteristics - First Increment of Capability

### Program Aspects

DARPA Predecessor  
Ultimate Capability

### Critical Technologies & Readiness Levels:

Munition  
Propulsion  
Flight Control  
Guidance and Control  
Safe/Arm Fusing  
Software Function (Target Acquisition, Fire Control, etc.)  
Sensor

Capability Leap Area  
Cost of development  
Contract Type

### ATACMS

Assault Breaker 1977-82  
"Deep Attack"

9 - Lance M74 Bomblet  
9 - Solid Rocket Motor  
9 - Fin surfaces  
9 - Inertial  
7 - Mechanical  
6 - Various  
N/A

Range  
~\$700M  
Fixed Price

### JAVELIN

Tank Breaker 1981-82  
"Fire & Forget"

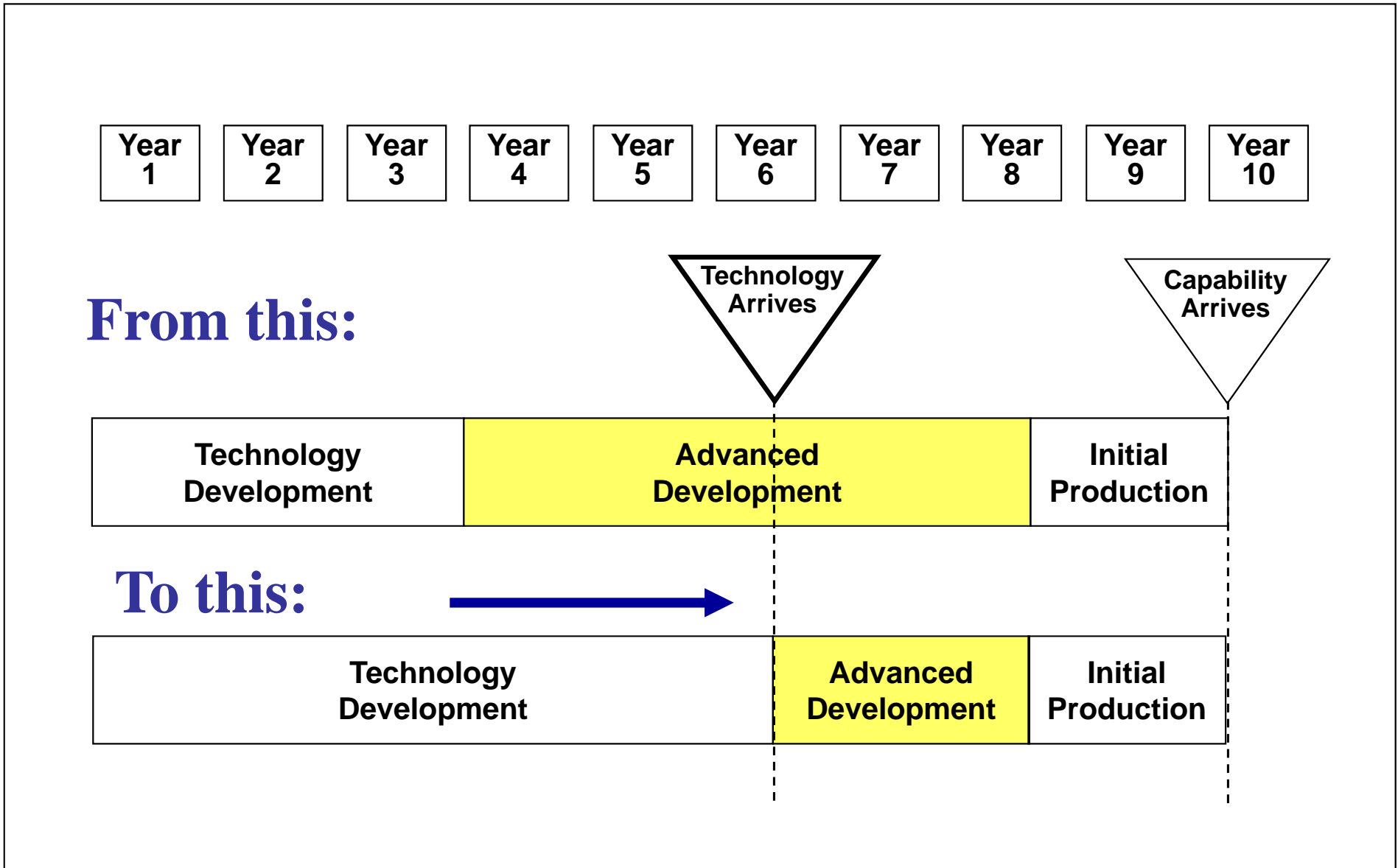
5 - Tandem Shaped Charges  
5 - Two-Stage Solid Rocket Motor  
6 - Fins + Thrust Vector Control Vanes  
4 - Tracker Software Algorithm  
4 - Electronic  
6 - Various  
6 - Focal Plane Array

Range, Lethality, Survivability  
~\$700M  
Cost Reimbursable

Tech Development Phase	0 Months	27 Months
Advanced Development Phase - Planned	48 Months	36 Months
Advanced Development Phase - Actual	51 Months	54 Months
<b>Total Time in Development</b>	<b>51 Months</b>	<b>81 Months</b>
Advanced Development Phase Contract Cost Growth	0%	>150%

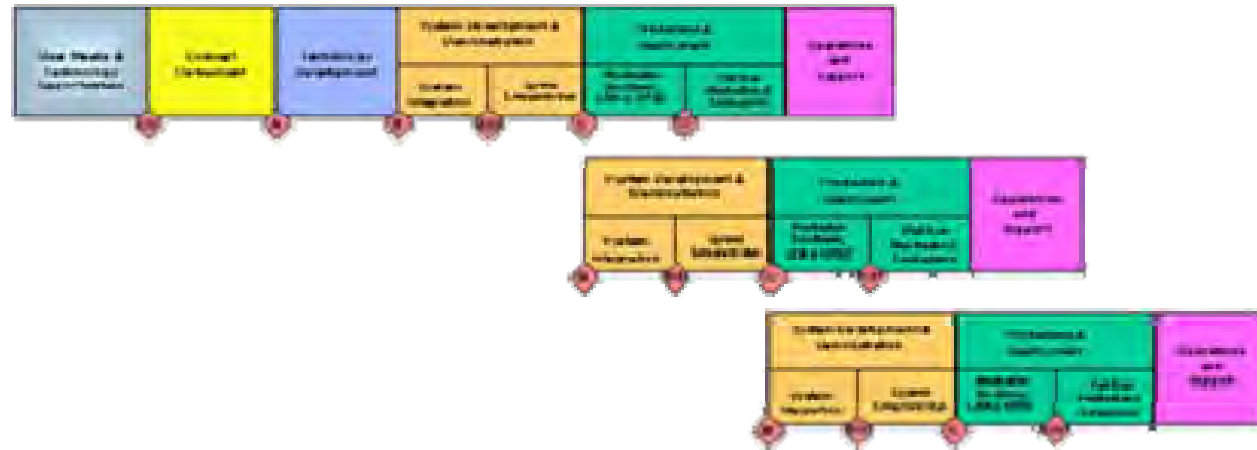


# Technology “Push or Pull” ?

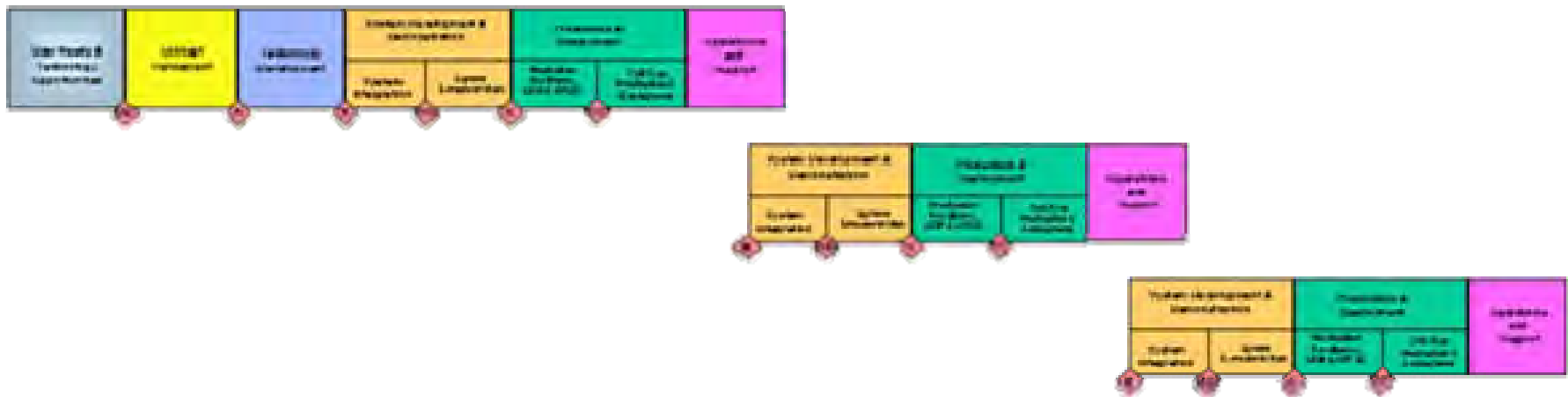




# Relative Concurrency of Increments And Concomitant Organizational Impacts



## Development Increments Concurrent with Initial Production



## Development Increments Concurrent with Later Production



# Evolutionary Acquisition Issues

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- **Continued conceptual and definitional ambiguity (RAND)**
- **Number of OSD-Level Reviews**
  - **Off-Core Activities**
  - **Significant Transaction Costs**
- **Unplanned work (spiral) is inestimable**
- **Fielding of obsolete technology -- if EMD isn't shortened**
- **1st Increment Focus: All desired capabilities vs. "Militarily useful"**
- **Organizational impacts of concurrent production and development of follow-on increments**
- **Maintaining of funding priority for follow-on increments**
- **GAO examples are mostly from cyclical commercial models, versus fleet ownership (i.e., United, UPS, Fedex)**
- **Variety brings benefits and costs**



# Everything Changes, But...

***A one-size-fits-all development methodology may not be appropriate for all product commodities.***

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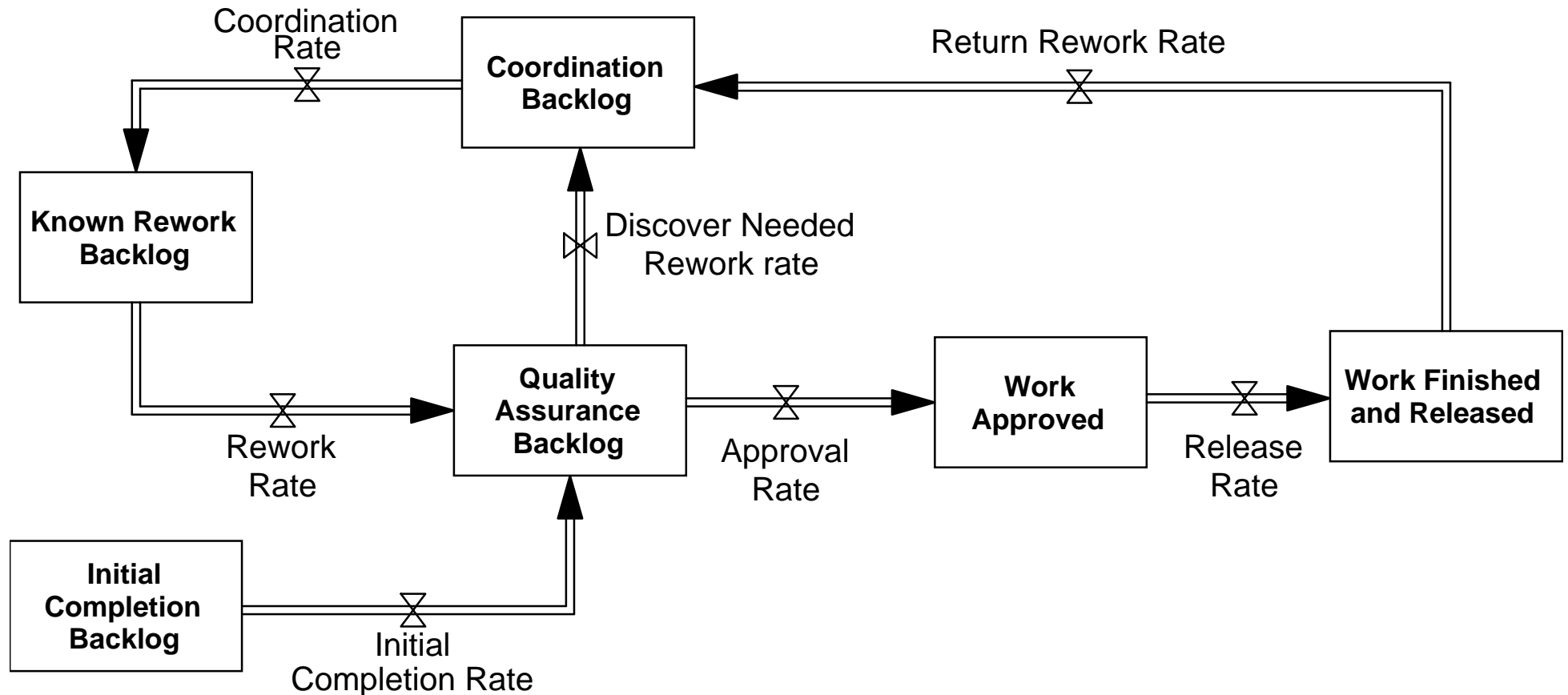
# Product Attributes May Affect the Development Strategy

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- **Production Quantity is not a factor**
- **Mutability**
- **Range of Requirement Attainment (Binary vs. Continuous)**
- **User Risk (Safety and Time Criticality)**
  - **Time-critical or enhanced survivability systems (NMD, ARCI)**
  - **Non-man-rated Systems (UAVs)**
  - **Man-rated Systems (munitions)**
- **Logistical Support Planned During Service/Shelf Life**
- **Net Amount of Change - and the Lure of Modularity**
  - **Changes propagate with relative modular interdependency**



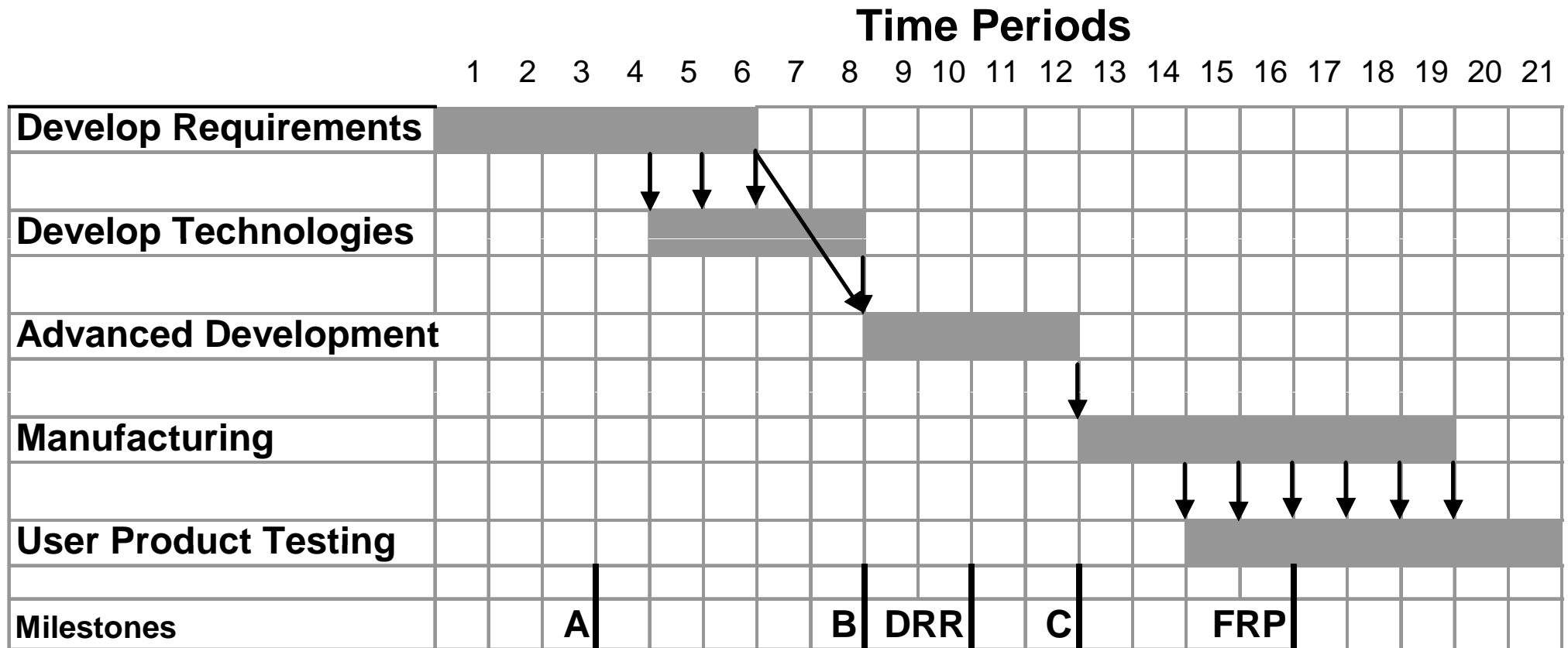
# System Dynamics: Work Flows and Backlogs through a Development Phase



**Work flows are constrained by resources and availability of work**



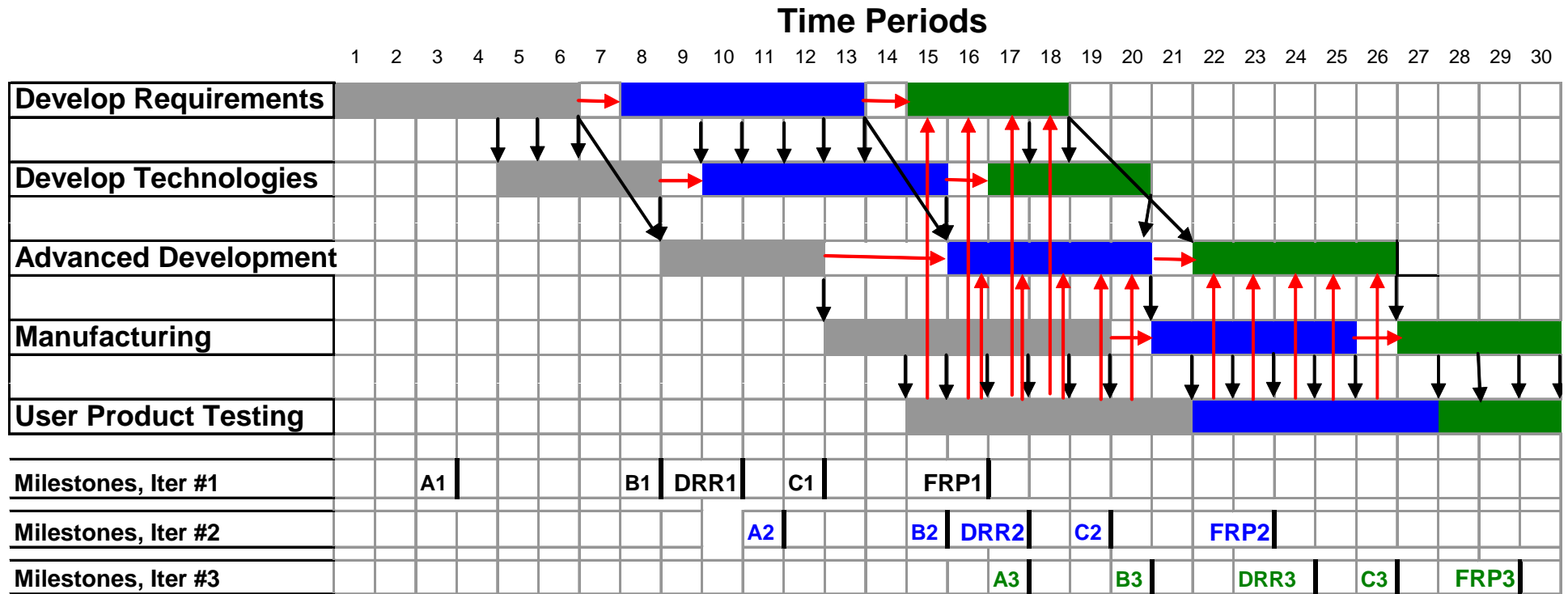
# Information Flows in a Single-block Acquisition Project



**Modeling inter-phase concurrence & information dependencies**



# Information Flows in an Incremental Acquisition Project



- Reveals more concurrence and interdependency
- Contracting, etc. modeled with indirect work at start of each phase
- Reviews modeled with indirect work at end of each phase



# Impacts of Multiple Development Blocks

	Units of Measure	Project Scenario			Best Performance	
		Javelin (single block)	Base Case (single block)	Base Case (3 blocks)		
Performance Measure	Duration to first requirement satisfied	weeks	471	470	397	Base Case (3 blocks)
	Duration to max. requirements satisfied	weeks	520	518	762	Base Case (single block)
	Total development cost	\$1,000,000	\$ 722	\$ 719	\$ 1,555	Base Case (single block)
	Requirements satisfied by deadline	% of requirements developed	100	91	18	Javelin (single block)
	Final requirements satisfied	% of requirements developed	100	91	91	Javelin (single block)

*The (dis)advantages of Evolutionary Acquisition depend on what performance measures are most important*



## Conclusions: Evolutionary vs. Single Block Development Approaches...

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- **First Unit Equipped with some (but not all) requirements satisfied faster**
- **Requires more time to satisfy all requirements**
- **Costs more than single-block development for same requirements**
- **Higher risk of not satisfying all requirements by the time single-block development could do so**



# Our Bottom Line on Risks

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- DoD uniquely outsources development for internal use
  - but owns the product over its entire life cycle
- There are inherent potential risks with incremental development
  - inefficiencies from re-work (duplication)
  - risk of project error (from discontinuous membership)
  - organizational impacts (queuing theory)
  - relative concurrency drives risk
  - variety in the fleet (support, failure mode, training, etc.)
- Defer what you cannot do now – tech readiness
- Don't defer what you can do now
- Product attributes may affect development strategy



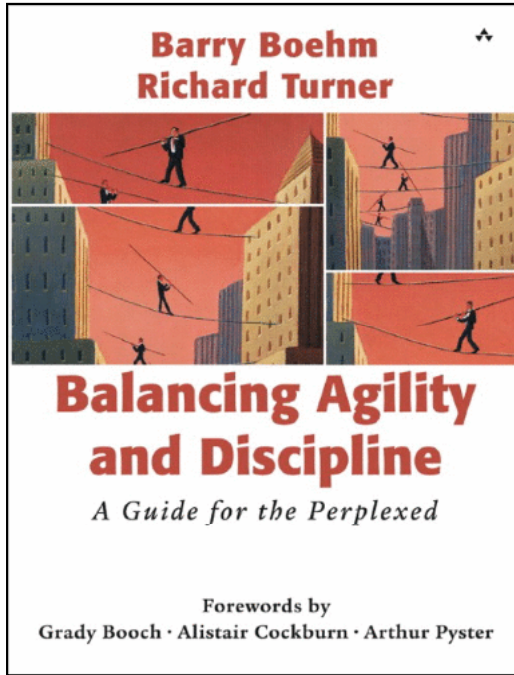
# Our Top Line on Control

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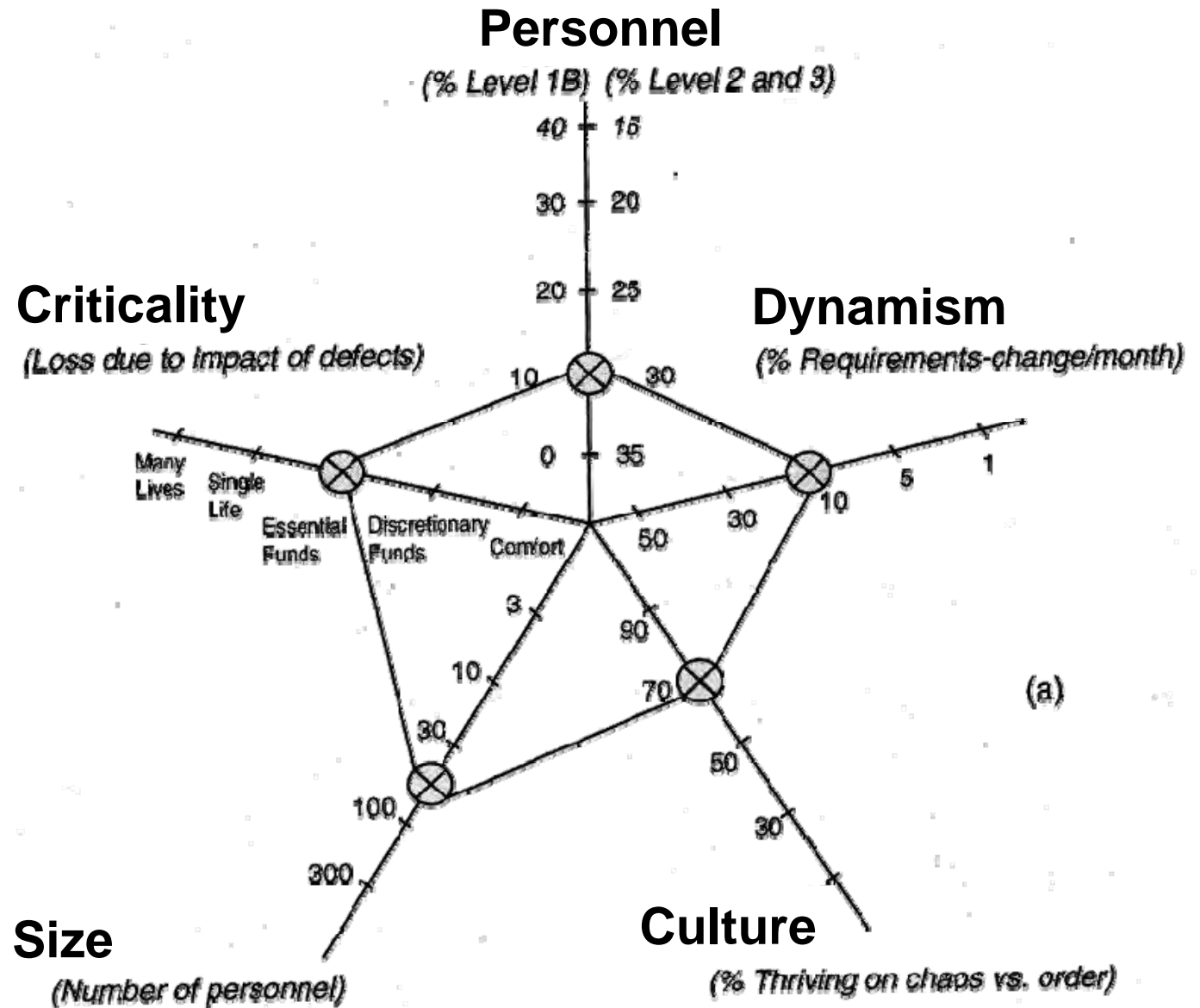
- Rigorous Preliminary Effort on Architecture
- Meticulous Configuration Management
- Individual Accountability
- Other control measures to balance risks
  - Testing, Interface Control, Peer Review
  - Open Architecture Incentives, etc.



# Agile vs. Plan-Driven Software Development

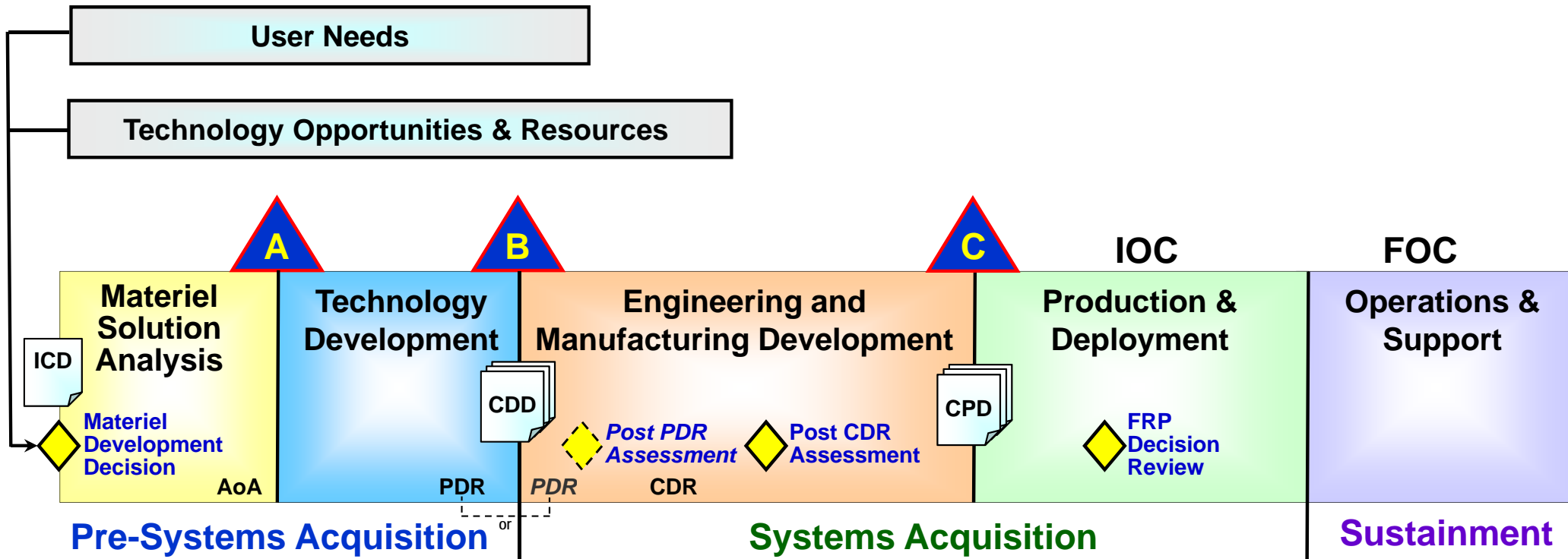


**What Does  
Your  
Project  
Process  
Model Look  
Like?**





# The Defense Acquisition Management System

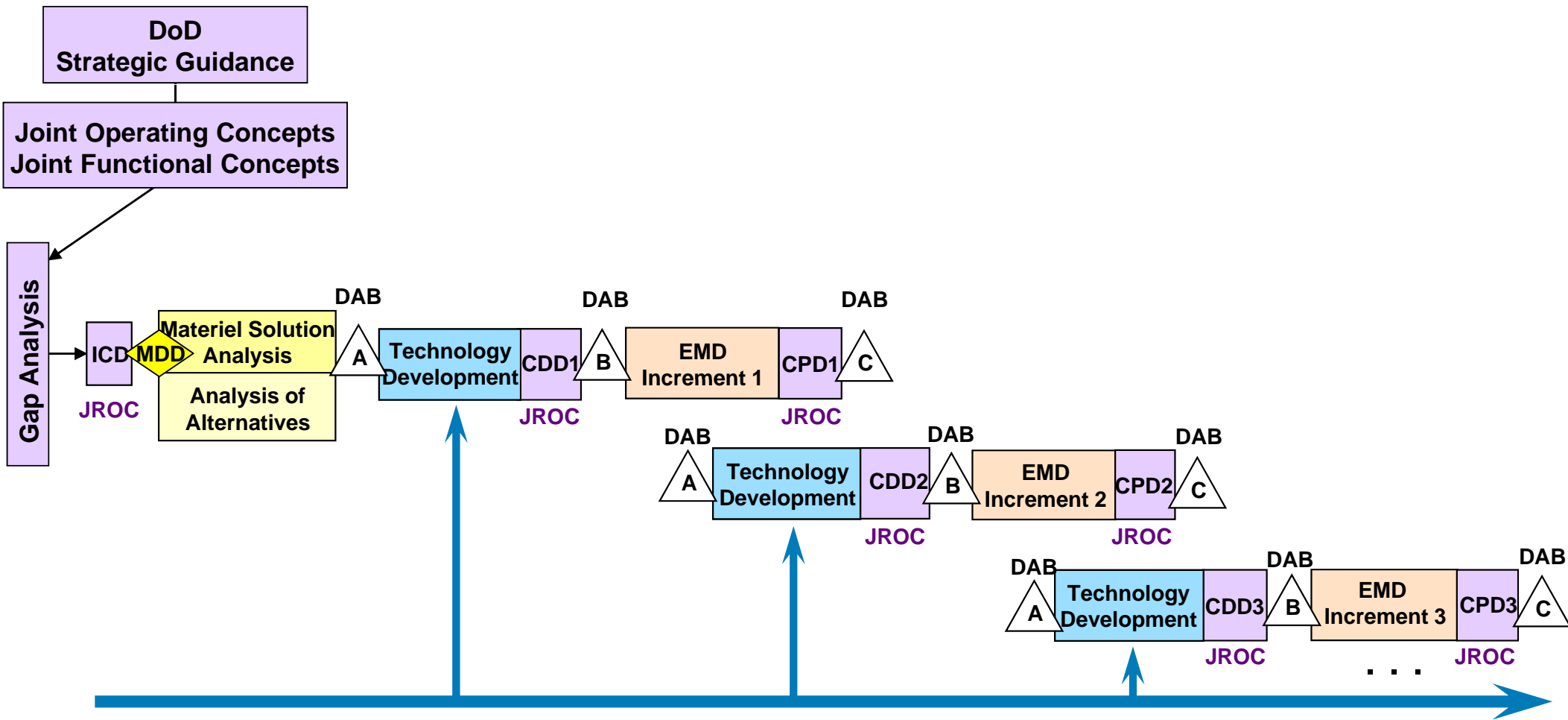


ICD: Initial Capabilities Document  
AoA: Analysis of Alternatives  
PDR: Preliminary Design Review  
CDD: Capability Development Document  
CDR: Critical Design Review

CPD: Capability Production Document  
FRP: Full Rate Production  
IOC: Initial Operational Capability  
FOC: Full Operational Capability



# Today's Evolutionary Approach



MDD: Materiel Development Decision  
JROC: Joint Requirements Oversight Council

EMD: Engineering & Manufacturing Development  
DAB: Defense Acquisition Board

**Questions/Comments?**



# Acronym Listing

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<b>AFRB - Air Force Review Board</b>	<b>JCIDS - Joint Capabilities Integration and Development System</b>
<b>AFROCC - Air Force Requirements for Operational Capability Council</b>	<b>JROC - Joint Requirements Oversight Council</b>
<b>AFSB - Air Force Studies Board</b>	<b>LHA - logistics health assessment</b>
<b>AOTR - assessment of operational test readiness</b>	<b>MRA - manufacturing readiness assessment</b>
<b>ASP - acquisition strategy panel</b>	<b>MS - milestone</b>
<b>ASR - alternative system review</b>	<b>OIPT - overarching integrated product team</b>
<b>CD - concept decision</b>	<b>OTRR - operational test readiness review</b>
<b>CDR - critical design review</b>	<b>PCA - physical configuration audit</b>
<b>CSB - configuration steering board</b>	<b>PCDRA - post-CDR assessment</b>
<b>DAB - Defense Acquisition Board</b>	<b>PDR - preliminary design review</b>
<b>DRR - design readiness review</b>	<b>PEO/SR - program executive officer sufficiency review</b>
<b>DSAB - Defense Space Acquisition Board</b>	<b>PM - program manager</b>
<b>FCA - functional configuration audit</b>	<b>PRR - production readiness review</b>
<b>FRP - full rate production</b>	<b>PSR - program support review</b>
<b>GAO - Government Accountability Office</b>	<b>SDR - system design review</b>
<b>IBR - integrated baseline review</b>	<b>SEAM - systems engineering assessment model</b>
<b>IIPT - integrating integrated product team</b>	<b>SFR - system functional review</b>
<b>IPA - independent program assessment</b>	<b>SRR - system requirements review</b>
<b>IPT - integrated product team</b>	<b>SVR - system verification review</b>
<b>JAT - joint assessment team</b>	<b>TRA - technology readiness assessment</b>
	<b>TRR - test readiness review</b>