Defense Acquisition Performance Assessment – The Recommendation for Time Certain Development: Pipe-dream or Reality?

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All I really need to know about estimation I learned in kindergarten and from Dr. Barry Boehm…

Agenda

- **Objectives**
- **Defense Acquisition Performance Assessment (DAPA)**
  - ❖ What is DAPA
  - ❖ Recommendations to be discussed
  - ❖ The reasons behind Time Certain Development
- **Time Certain Development**
  - ❖ Perspectives on Time Certain Development
  - ❖ Perspectives on making time a Key Performance Parameter
- **Confidence in a Software Estimate**
  - ❖ Estimating software size
  - ❖ Life cycle phase dependency
  - ❖ Risks of cost estimation risk-reduction approaches
  - ❖ The Iron Triangle Fallacies
  - ❖ Technology Readiness Implications for Time Certain Development
- **Conclusions**
- **Acronyms**
- **References**

Objectives

- Explain the context and background of the DAPA recommendation for Time Certain Development
- Contrast acquisition management and engineering perspectives on Time Certain Development
- Explore the underlying estimation issues impacting successful implementation of the recommendation
- Note that the presentation focuses on the acquisition of software-intensive systems

DAPA (Defense Acquisition Performance Assessment)

- **What is DAPA?**
  - ❖ The **DAPA project** is an integrated assessment of every aspect of military acquisition, including requirements, organization, legal foundations, decision methodology, oversight, and checks and balances
    - – It is a response to a 2005 DOD Directive by Mr. Gordon England, then Acting Deputy Secretary of Defense
  - ❖ The **DAPA report** is the result of this project
    - – Developed by a panel lead by Lieutenant General Ronald Kadish (Retired), USAF
    - – 107 experts and 130 other, government and industry acquisition professionals were interviewed
    - – The full report is available at [DAPA 2006]

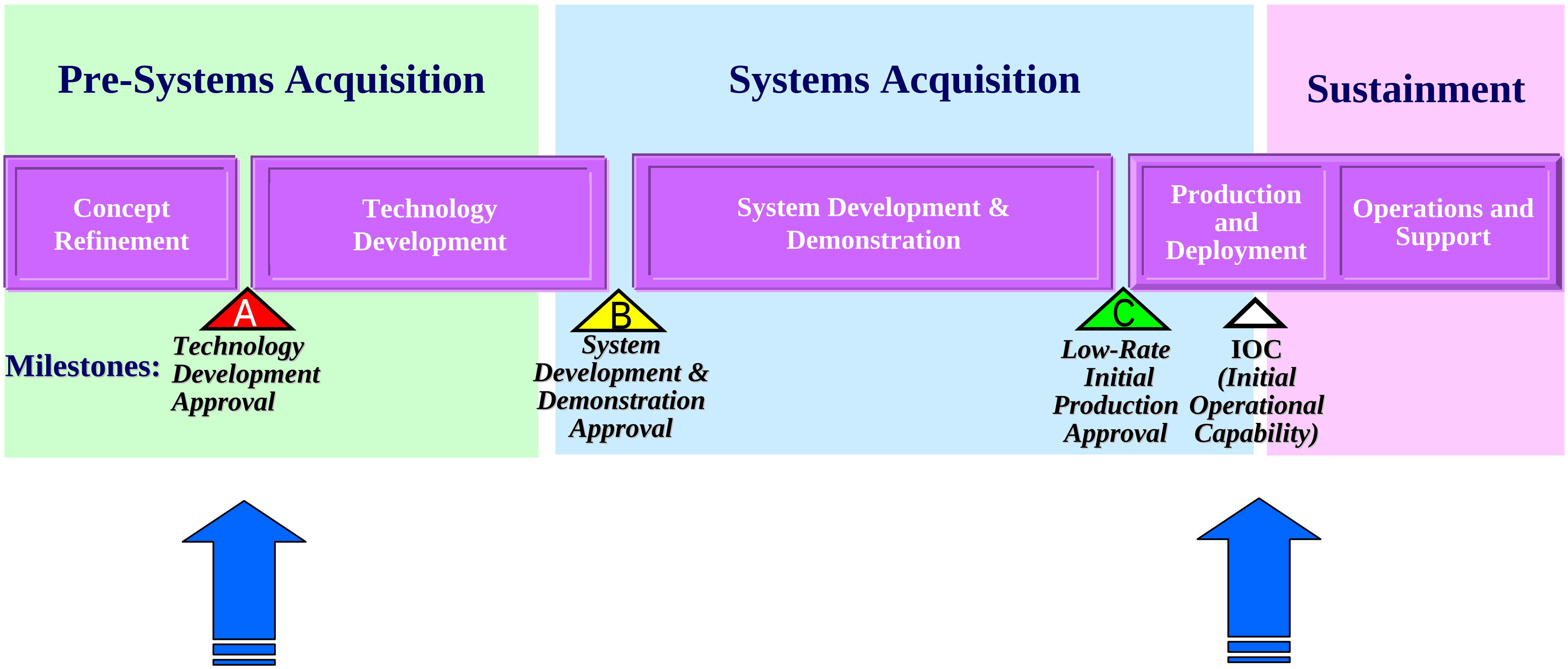
DAPA Recommendations To Be Discussed

- **Budget**
  - ❖ Transform and stabilize the PPBE (Planning, Programming, Budgeting, and Execution) process
    - – Adjust program estimates to reflect high confidence
      - – **High confidence programs defined as a program with an 80% chance of completing development at or below estimated cost**
    - – Major acquisition programs would be fully funded at a level that would cover the program from Milestone A through the first delivery of low rate production
- **The Acquisition Process**
  - ❖ Establish Time Certain Development as the preferred acquisition strategy for major weapons system development
    - – Time Certain Development adds "time" as a factor critical to the discussion of the need to balance cost and performance
    - – Deliver useful military capability within a constrained period of time
    - – Make time a KPP (Key Performance Parameter)

The Reasons Behind Time Certain Development

- **Tension between the DOD acquisition culture and the needs of Combatant Commanders**
  - ❖ The prevalent culture is to strive initially for the 100% solution in the first article delivered to the field
  - ❖ On the other hand, Combatant Commanders have urgent needs that are tied to ongoing operations
- **Making time a KPP seems to be the vehicle to express this customer urgency to the Developer**
  - ❖ Making time a KPP is a value statement of the Customer

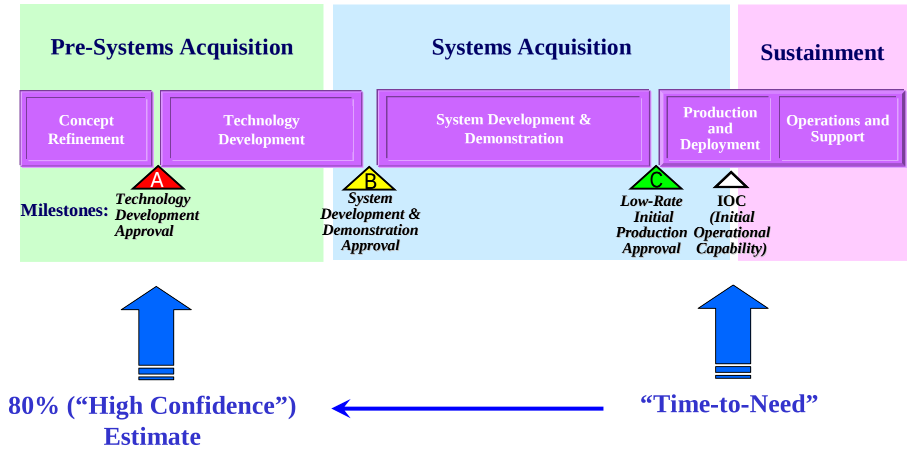
Time Certain Development – What is it?



80% ("High Confidence") Estimate ← **"Time-to-Need"**

Acquisition Life Cycle Model Source: [DODI 2003]

A Little Hair-Splitting…



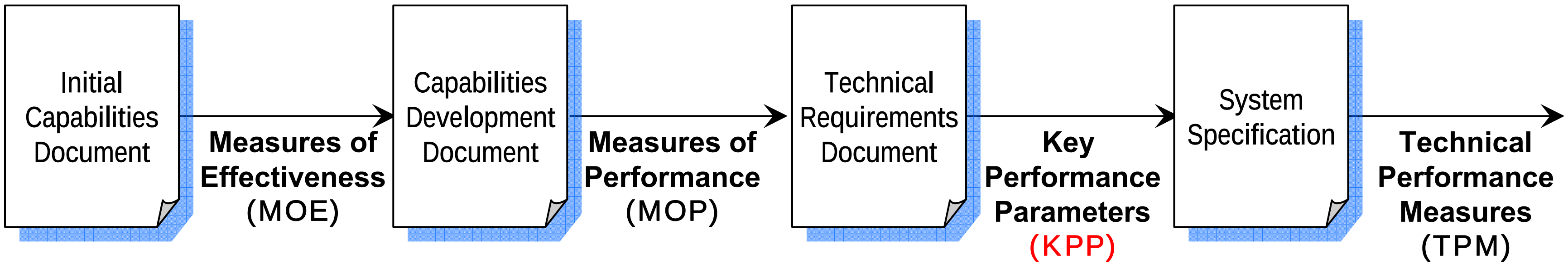
- **The DAPA text says "Adjust program estimates to reflect high confidence, defined as a program with an 80% chance of completing development at or below estimated cost"**
  - ❖ What they probably mean is **budget** the program at the 80/20 level (i.e., having an 80% chance of completion at or below budget,) and not adjusting the estimate
  - ❖ We need to separate the **estimation** considerations from **budgeting** considerations (See next slide)

Elements of the Total Cost Framework*

- **Software Cost (Effort) estimation is usually done via the use of Cost Estimation Relationships (CERs)**
  - ❖ The process yields a **point estimate** on the basis of
    - – Software size
    - – Cost Drivers
    - – Development Life Cycle Model
    - – Work Breakdown Structure or Architecture
  - ❖ The comprehension of cost estimation risk sources yields a **probability distribution**
    - – CER error
    - – Cost Driver/Configuration uncertainty
- **Budgeting/Funding decisions**
  - ❖ Effort loading is based on **affordability**
    - – Uncertainty arises from phasing, inflation, etc.

** Discussion is based on [Covert 2007]*

Key Performance Parameters



Measures of Effectiveness (MOE)

A qualitative or quantitative measure of a system's performance or a characteristic that indicates the degree to which it performs the task or meets a requirement under specified conditions.

Measures of Performance (MOP)

A quantitative measure of the lowest level of physical performance (e.g., range, velocity, throughput) or physical characteristic (e.g., height, weight, volume, frequency).

Key Performance Parameters (KPP)

Minimum or threshold attributes or characteristics considered most essential for an effective military capability; KPP's are not considered for further trade-off.

Technical Performance Measures (TPM)

Selected key, high-risk, performance requirements or design characteristics. The System Specification and the KPPs are used to negotiate the selected TPMs with the System Developer Contractor.

Perspectives on Making Time a Key Performance Parameter

- **Customer Perspective**
  - ❖ If something is important then the best, forceful way to express its importance is to designate it as a KPP [Boudreau 2003]
  - ❖ The DAPA recommendation represents the same philosophy: Having the availability of a capability on time is important, hence make time a KPP
- **Acquisition Management Perspective**
  - ❖ The previous slide illustrates that the term "performance" supposed to refer to attributes of the objective system and not to the performance of the contract
    - – In reality, Cost and Schedule are neither "performance parameters" nor "variables" (Like in CAIV and SAIV)
      - – **Cost and Schedule are constraints**

Everything is Always Important …

- **There has always been an "Important Issue of the Day"**
  - ❖ CAIV (Cost As Independent Variable)
    - – "In establishing realistic objectives, the user shall treat cost as a military requirement" [DODI 2003]
  - ❖ R-TOC (Reduction of Total Ownership Cost)
    - – "Serious consideration must be given to elevating TOC to KPP status" [Boudreau 2003]
  - ❖ Mission Success
    - – "Re-establish mission success (quality) as primary criteria in managing acquisition process" [Young 2003]
- **Selecting Time as a Key Performance Parameter is not helpful**
  - ❖ KPP's are more than simply important planning considerations
    - – Note how they become manageable on a practical level via the decomposition into supporting Technical Performance Parameters
      - – **Their progression and the progression of the dependent TPM's are closely tracked and monitored during development**

Perspectives on Time Certain Development

- **Contractor perspective on Time Certain Development:**
  - ❖ Still only means schedule constraints, regardless of the noble intentions
- **Prevailing misconceptions:**
  - ❖ It is Timebox Development
  - ❖ It is SAIV (Schedule As Independent Variable)
- **It is neither:**
  - ❖ Both approaches are based on adaptive project management principles
    - – They might be helpful but do not ensure success
  - ❖ The main challenge is still providing a "High Confidence" Estimate at the front-end
    - – Adaptive or agile project management strategies can only provide minor corrections and/or the renegotiation of customer requirements during the course of development

Key issue: Renegotiating requirements without jeopardizing the mission!

Confidence in a Software Estimate

- **Never mind the actual quantification of confidence, just how confident one can be in a software estimate?**
  - ❖ Software cost estimation's "dirty little secret":
    - – For most CERs and related parametric cost estimation models software size is a major driver but size estimation accuracy is not part of the published cost estimation model accuracies
      - – **Software Cost Estimation Model accuracy data assumes a 100% software size accuracy**
  - ❖ Estimating software size is actually quite difficult
    - – The following Actual/Estimate KSLOC (**T**housand **S**ource **L**ines of **C**ode) data was published for three different datasets [Bozoki 2005]:

Dataset	Size Range (KSLOC)	Actual/Estimate Mean
1	6 - 71	1.61
2	45 - 320	2.38
3	7.9 - 532	1.49

Major estimation risk: Software size is always chronically underestimated

Accuracy Dependency on the Development Life Cycle Phase

- **E.g., the COCOMO II (Constructive Cost Model) family of models* distinguishes between three different estimation strategies/objectives associated with life cycle phases:**
  - **Early prototyping** stage
    - The objective is to estimate the cost of early risk-reduction activities.
  - **Early design** stage
    - The objective is to explore the cost of alternative software/system architecture options and the concept of operations.
  - **Post-architecture** stage
    - The objective is to estimate the cost of actual development for the software product.
- **Caveats:**
  - The number of available data-points for calibration (and consequently the estimation accuracy) is low for the early stages
  - The models can only be used successively, and their use is dependent on facts learned and design decisions made in prior stages

** Source [Boehm 2000]*

Risks of Cost Estimation Risk-reduction Approaches

- **The common "recipes" to reduce estimation risks:**
  - ❖ Pay close attention to calibration issues:
    - – Chose models that were calibrated with more data points
    - – Carry out a local calibration of the model
    - – Try using models that were calibrated in the appropriate domain
  - ❖ Estimate on lower levels of the Work Breakdown Structure and do a bottom-up integration of estimates
    - – This approach can also build on the domain calibration idea
- **Caveats:**
  - ❖ Estimating on lower levels improves the component estimation accuracy but creates difficulties for estimating integration efforts
    - – Estimation of developmental phasing* of concurrent efforts is not in scope for parametric models
    - – Methods to estimate integration, test, and rework efforts are not as accurate and effective as the methods used for estimating routine development activities
  - ❖ Past performance is no guarantee of future success
    - – With respect to organizational capability (see [Ferguson 2002])
  - ❖ Past performance might not be relevant
    - – E.g., the estimation of the impact of technology risks

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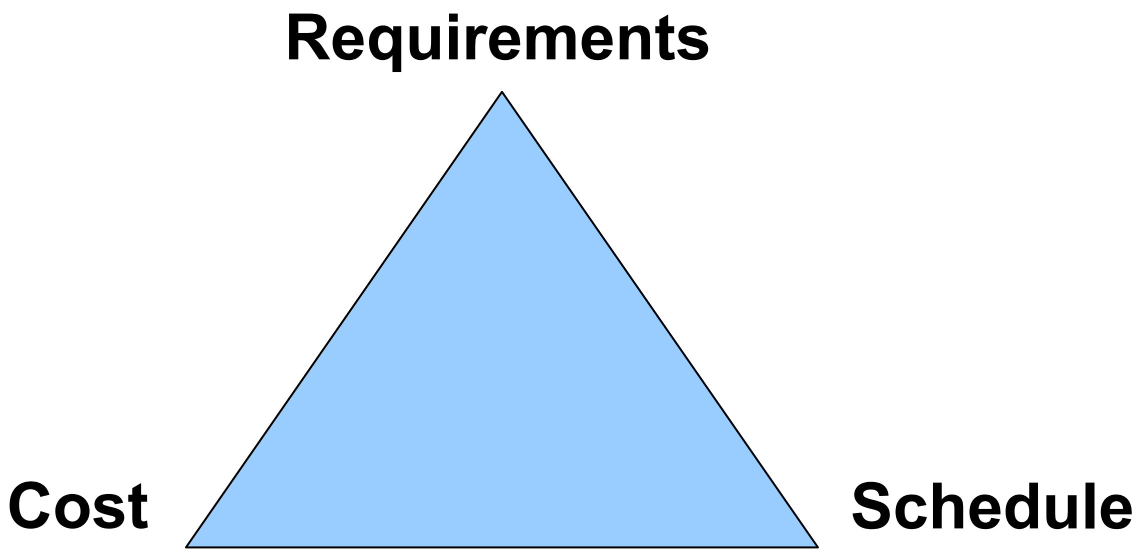
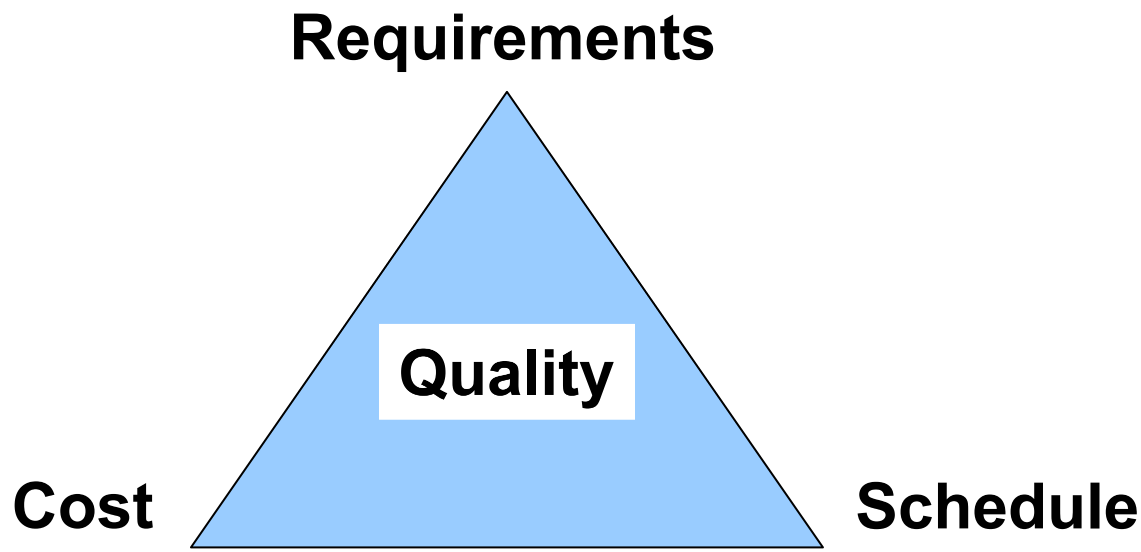
** Not to be confused with phasing concerns related to budgeting*

The Iron Triangle in Theory



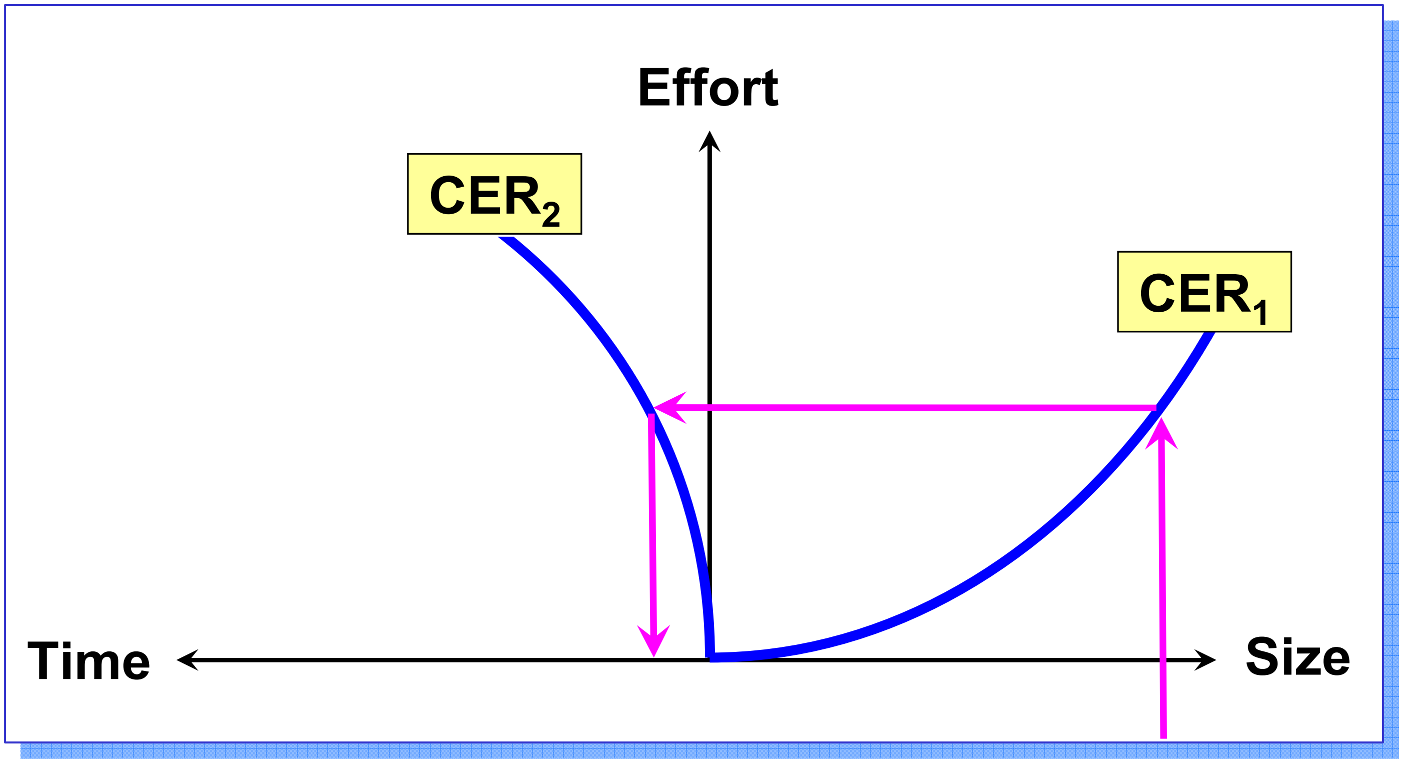
- **Fallacies:**
  - ❖ Pick two of the Cost, Requirements, Schedule triad and negotiate the third factor
  - ❖ This "negotiation" can be carried out as a seamless trade
    - During early project negotiations
    - Continually, during project execution

The First Fallacy of the Iron Triangle is that it is a Triangle …



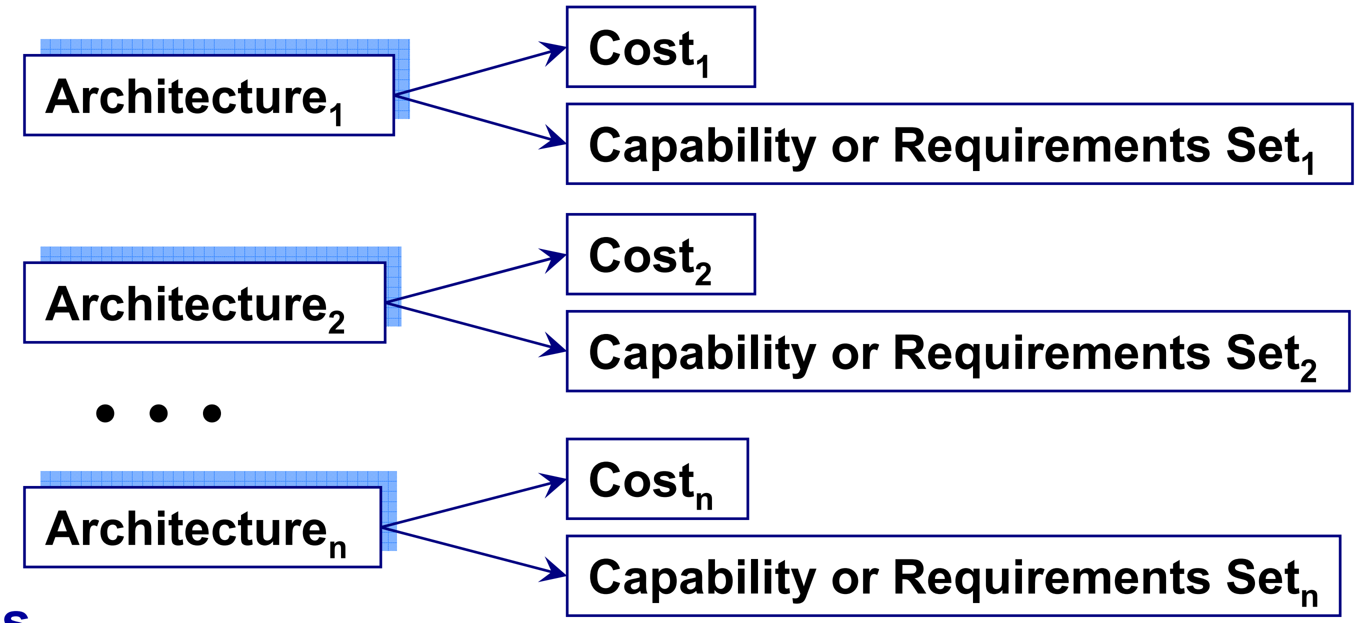
- **Abusive approaches to quality with serious estimation consequences:**
  - ❖ It is viewed “free” or it is “expected” without quantification
- **Quality must be explicitly considered and quantified**
  - ❖ Quality is integral part of mission success
    - – However, it is difficult to determine the cost of quality or explicitly design for quality
      - – **It is more than just cost of non-conformance, as Crosby defined it in his seminal book [Crosby 1980]**

The Fallacy of Seamless Trade



In reality, we are dealing with a finite number of architectural options.

Architectural Options (Solution Sets) and Cost*



- **Consequences**
  - ❖ During initial estimation:
    - – For the ***Cost – Schedule – Capabilities*** trade we have only a few options
  - ❖ During development:
    - – Requirements can not always simply "dropped" in order to maintain cost or schedule objectives

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** Diagram is based on [Rice 2000]*

Capabilities vs. Requirements

- **Note the language of the acquisition domain: "Deliver useful military capability"**
  - ❖ Customer needs are expressed in form of capabilities
    - – The intent is not to impose unnecessary, technical implementation constraints on the Contractor
- **However, development contracts are written with "Requirements" in mind**
  - ❖ During the source selection process the Government Program Office must understand, interpret, and translate customer needs into tangible, feasible requirements and communicate them to the competing contractors
  - ❖ These requirements are the basis for developing detailed **system specifications** by the contractor
  - ❖ These requirements are also used for developing **cost/schedule estimates**
    - – **Caveats:**
      - – **It is impossible to provide accurate cost and schedule estimates for delivering abstract capabilities**
      - – **During estimation the capabilities must be mapped into solution sets (designs) as the previous slide showed**

Technology Readiness*

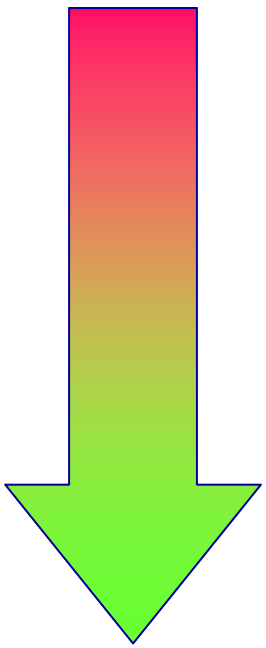
- **Technology Readiness Assessment (TRA) is a key element of the Milestone B decision**
- **TRA Process**
  - ❖ The Program Manager is responsible for identifying Critical Technology Elements (CTEs)
  - ❖ A TRA is conducted by an independent entity on the basis of the information provided by the Program Manager
    - – The result of the TRA is a TRL (Technology Readiness Level) rating for all identified CTEs
- **The entry criteria for entering into System Development & Demonstration Phase (Milestone B decision) is TRL ≥ 6 for all CTEs**

** Reference: [DUSD 2005]*

Technology Readiness Levels*

- **The program's Critical Technology Elements are assessed and a Technology Readiness Level (TRL) is determined:**

LOW



HIGH

- ❖ TRL 1 Basic concepts observed and reported
- ❖ TRL 2 Technology concept and/or application formulated
- ❖ TRL 3 Analytical and experimental critical function and/or characteristic proof-of-concept
- ❖ TRL 4 Component and/or breadboard validation in laboratory environment
- ❖ TRL 5 Component and/or breadboard validation in relevant environment
- ❖ TRL 6 System/Subsystem model or prototype demonstration in relevant environment

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- ❖ TRL 7 System prototype demonstration in an operational environment
- ❖ TRL 8 Actual system completed and mission qualified
- ❖ TRL 9 Actual system proven through successful mission

** Reference: [DUSD 2005]. Rating scheme is applicable to both hardware and software.*

Implications for Time Certain Development

- **TRLs represent milestones of the technology development life cycle in the Technology Development phase**
  - ❖ Essential characteristics of this life cycle:
    - Technology development is a learning process:
      - **Steps are strictly sequential – can not be executed concurrently**
      - **Success of steps depends on the success of preceding steps**
    - Most activities are un-precedented
      - **The routine, repetitive part is insignificant**
      - **No historical data; estimation must be based on heuristics**

The presence of any technology uncertainty jeopardizes the accuracy of estimates obtained at Milestone A

Conclusions

- **Time Certain Development – although based on noble intentions – is not a feasible acquisition strategy**
  - ❖ Making Time a Key Performance Parameter is counter-productive
  - ❖ Even state-of-the-art estimation and engineering approaches could not support successful implementation for large programs
- **The root-cause of the dissatisfaction with the performance of the Acquisition System lies with misstated or misunderstood, unrealistic, and mismanaged expectations**
  - ❖ While improving estimation accuracy is certainly beneficial, further improvement efforts should focus on deeper understanding of engineering practices and the human dimensions of the Acquisition System.

Acronyms

CAIV	Cost As Independent Variable
CER	Cost Estimation Relationship
COCOMO	Constructive Cost Model
DAPA	Defense Acquisition Performance Assessment
DOD	Department of Defense
IOC	Initial Operational Capability
KPP	Key Performance Parameter
KSLOC	Thousand Source Lines of Code
MOE	Measures of Effectiveness
MOIE	Mission-Oriented Investigation and Experimentation
MOP	Measures of Performance
PPBE	Planning, Programming, Budgeting, and Execution
R-TOC	Reduction of Total Ownership Cost
SAIV	Schedule As Independent Variable
TPM	Technical Performance Parameter
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
USAF	United States Air Force
USC	University of Southern California
WBS	Work Breakdown Structure

References

Boehm 2000	Boehm, B.W., et al, Software Cost Estimation with COCOMO II, Prentice Hall, 2000
Boudreau 2003	Boudreau, M.W., and Naegle, B.R., Reduction of Total Ownership Cost, Acquisition Research Sponsored Report Series, Naval Postgraduate School, September 2003
Bozoki 2005	Bozoki,G., Software Sizing Model (SSM), Price US Symposium, Tampa Bay, FL, March 23-25, 2005
Covert 2007	Covert, R.P., Cost Risk Methods, DOD Cost Analysis Symposium, May 31, 2005
Crosby 1980	Crosby, P. B., Quality is Free: The Art of Making Quality Certain, New American Library, 1980
DAPA 2006	Defense Acquisition Performance Assessment Report, February 2006
DODI 2003	DOD 5000.2 Instruction on the Operation of the Defense Acquisition System, May 12, 2003
DUSD 2005	DOD, Technology Readiness Assessment (TRA) Deskbook, May 2005
Ferguson 2002	Ferguson, J., and Penn, L.M., New CMM Math, CMMI Conference, November 2002
Rice 2000	Rice, R.E., CAIV…NOT!!!, <http://www.mors.org/publications/phalanx/feb00/Caiv/caiv.htm>
Young 2003	Young, T. et al, Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs, May 2003

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