



# Estimating Future Capability

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FASTER DECISIONS. BETTER DECISIONS.™

# Agenda

- Defense Transformation: What is it? What does it mean to Cost Estimators/Analysts?
- The Affordability Management Case for Future Capability Estimating
- Answering the Challenges to Starting the Estimating Process
- Understanding the Importance of Time

# Military Transformation

*“The Department seeks to ensure that changes occur not only in the operating concepts we develop and the systems we acquire but also in our military culture and process that drive investment decisions.”*

Arthur Cebrowski, Director, Office of Force Transformation, Office of the Secretary of Defense

# Scope of Military Transformation

- Transforming How We Fight  
Doctrine, organization, training, materiel, leadership, education, personnel, and facilities
- Transforming How We Work With Others  
Integration of military power with other elements of national power and with foreign partners; enhanced coordination with the interagency and across all levels of government (federal, state, and local)
- Transforming How We Do Business  
More adaptive business and planning practices that are more entrepreneurial, future-oriented, and capabilities based.

# Transforming Business Processes

*“The Department is reducing acquisition cycle time and aligning acquisition with a new capabilities-based resource allocation program built around JOCs. Instead of building plans, operations, and doctrine around individual military systems as often happened in the past, the Department will explicitly link acquisition strategy to future joint concepts in order to provide the capabilities necessary to execute future operations.”*

Military Transformation: A Strategic Approach; OSD,  
Fall 2003

# Understanding the Strategy

- Grounded in theory of limited resources to handle rapidly growing transaction rates of needed capabilities
- Everyday Examples
  - Telephone call switching: In 1930s, Operators a limited resource, but call transaction rates were growing rapidly
    - Old thinking: control transactions to available resources
    - Transformation thinking: shift operator function to point of transaction origin
  - Health care today: limited MDs but growing medical transaction rates
    - Old thinking: wait for the doctor
    - Transformation thinking: shift more health care to patient



# Military Transformation

- Understand transaction (capability) rate requirements and evolve the doctrine and systems that satisfy them.
- Implications to Estimators:
  - Must be able to estimate cost for performance/capability
  - Specific systems will be a result rather than an input
  - Estimating will be an integrated component of a collaborative system engineering process
  - Credibility is keyed to continuous knowledge creation and management

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# Why is Future Capability Estimating Important?

- Aging equipment/support mechanisms
- Increasingly costly to maintain and operate
- Stagnant or declining performance
- Eroding reliability increasing O&S costs
- Permanent diminishing funding
- Demand for good stewardship of government resources

*The Death Spiral*

# What is the Objective?

- Develop Solutions (Systems) that provide needed capability
- Ensure capability is met at a reasonable cost
- Employ a development process that meets the 2 objectives above

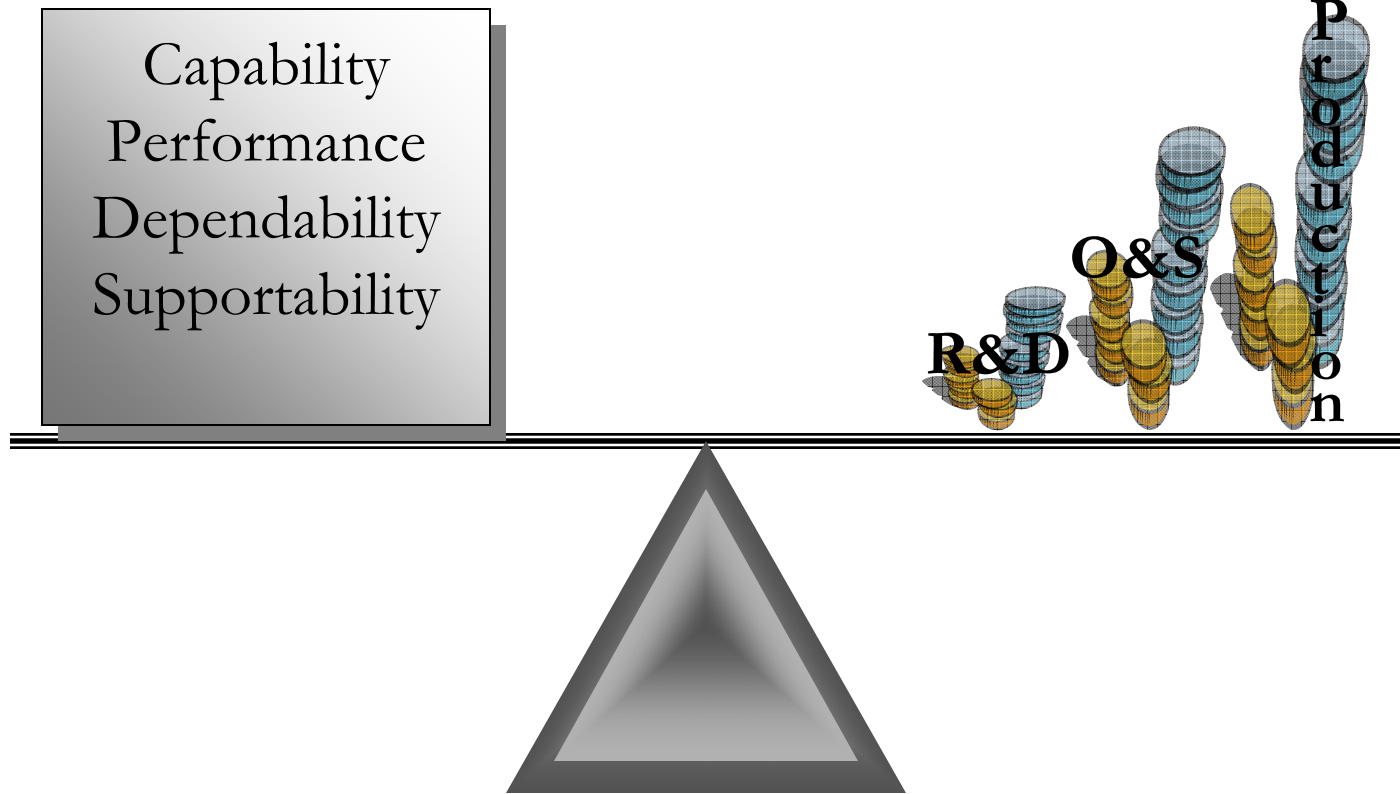
## *Affordability Management*

# What Is Affordability?

An item is affordable if:

- It is needed
- It fits within a budget without displacing other items that are needed as much or more
- There are no less expensive alternatives that meet the need

# Affordability



# Affordability SOW

*“The Supplier shall be responsible for implementing the XXX Life Cycle Cost (LCC) Containment Strategy as defined and in support of program milestones specified elsewhere in this contract. The Supplier shall develop an overall plan consistent with the Containment Strategy to achieve program affordability. The Supplier shall incorporate the principles of Cost as an Independent Variable (CAIV) to balance cost, performance, and schedule. The Supplier shall develop Total Ownership Cost (TOC) estimates to track progress toward meeting containment requirements.”*

**Extract from 2003 Weapon System SOW**

# Cost and Affordability

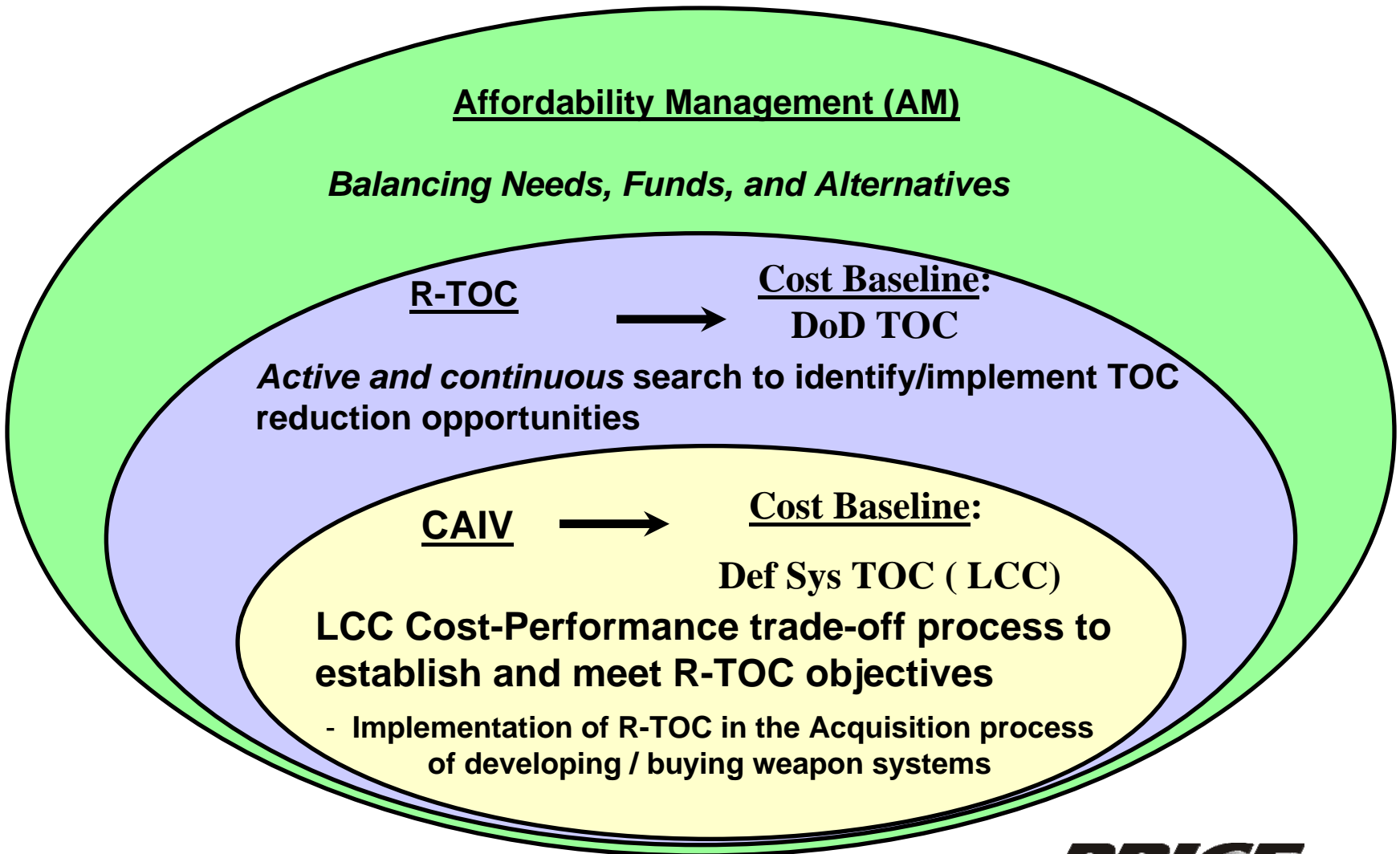
*“Fiscal constraint is a reality ... Cost must be viewed as an independent variable ... Components shall plan programs based on realistic projections of funding likely to be available ... DoD Components shall identify the total costs of ownership, and ... the major drivers of total ownership costs ... the user shall treat cost as a military requirement ... state the amount ... willing to invest to obtain, operate, and support the needed capability over its expected life cycle. Acquisition managers shall establish aggressive but realistic objectives for all programs ... working with the user to trade off performance and schedule, beginning early in the program (when the majority of costs are determined).”*

Department of Defense Directive (DoDD) 5000.1, Paragraph 4.5.2

# TOC is a Primary Affordability Metric

- Total Ownership Cost is:
  - A concept of the totality of costs associated with a weapon system
  - To be managed and, where possible, reduced by a reformed and improved acquisition process
- TOC is an Overarching Umbrella of topics, like:
  - Reduction of TOC (R-TOC)
  - Cost As an Independent Variable (CAIV)
  - Target Costing (TC)
  - Design to Cost (DTC)
  - Activity-Based Costing/Management (ABC/M)
  - Earned Value Management (EVM)
  - and others
- $TOC = LCC$  (per DoD 5000.4M)

# AM, TOC, and CAIV

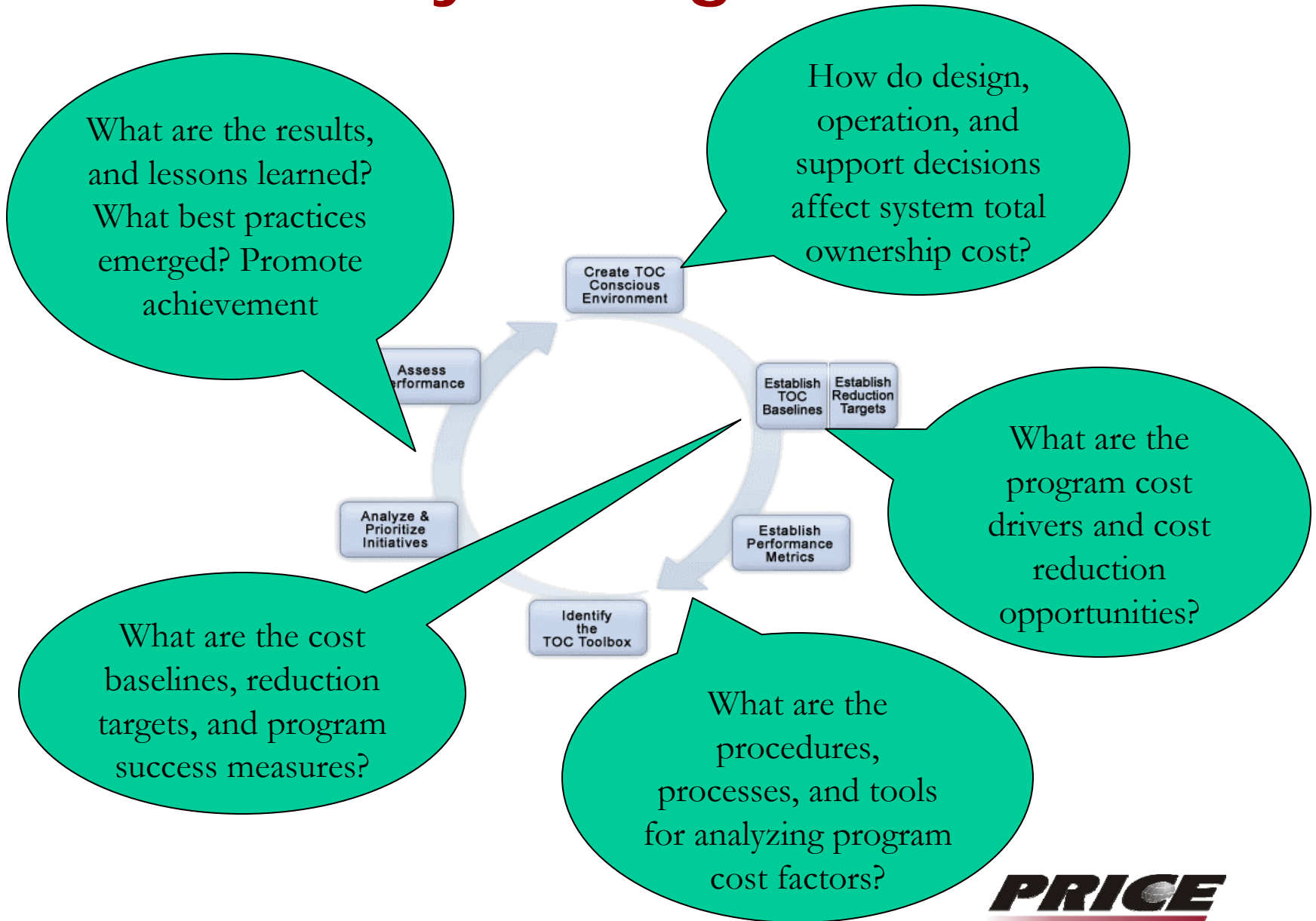




# Affordable Ownership Execution Process – 6 Steps

1. Establish Affordability consciousness by defining TOC goals and developing an Affordability Management Plan and supporting methodology
2. Establish TOC Baselines, Thresholds and Objectives; Identifying TOC cost drivers; Identify and quantify Reduction initiatives
3. Establish meaningful Affordability metrics
4. Identify appropriate tools
5. Analyze and prioritize initiatives
6. Assess (track and measure results against plan)  
Affordability Plan implementation

# Affordability Management Process

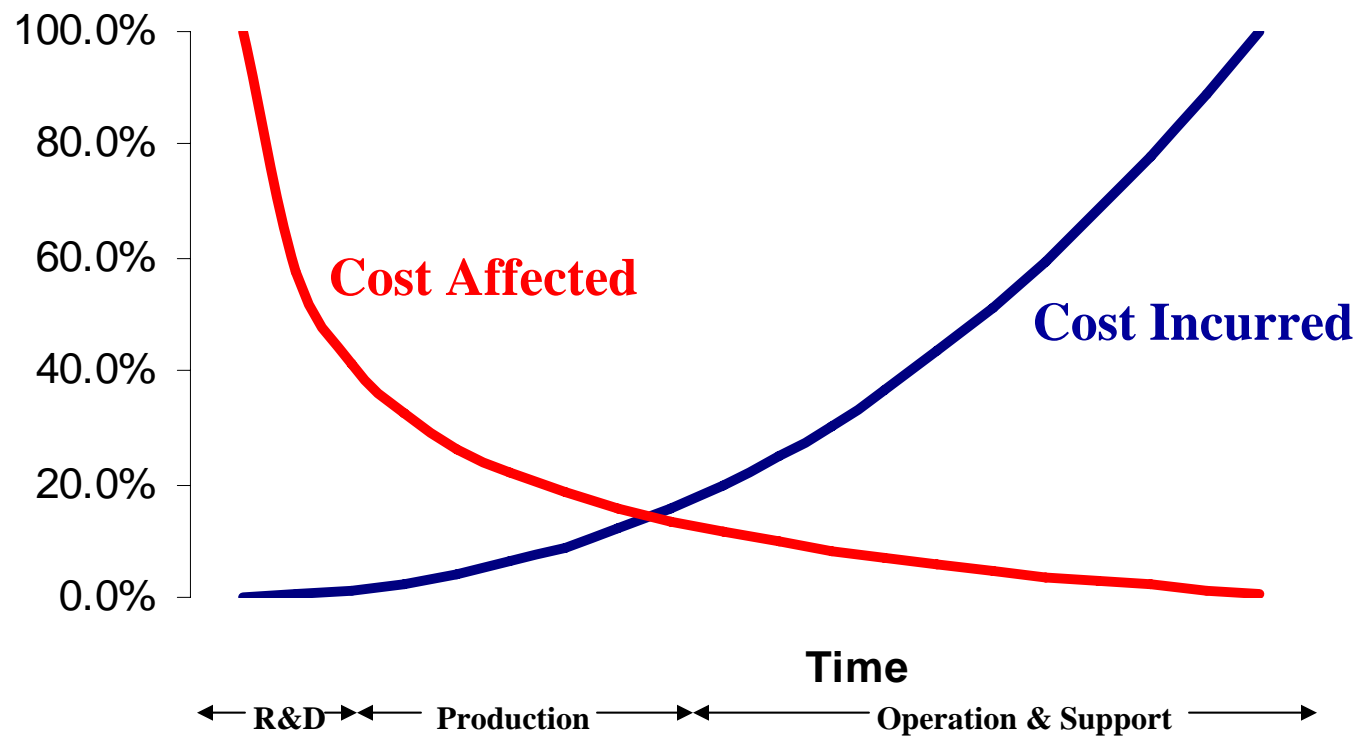


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# Why Start in R&D?

## Cost Incurred Vs. Cost Affected



# Estimating Future Capability

What are some of the biggest problems associated with estimating the cost of future capability systems? i.e. systems to be built with technology that does not yet exist or that is extremely immature; systems that will be tested in 10+ years and operationally deployed in 15 to 20 years.

2 that dominate my experience are:

- How do we start?
- What do we use as reference?

# Starting – The Important First Step

- Overcoming Trepidation (Fear)
  - The person possessing the ability to provide needed answers is a technologist (known as the Source) who dislikes cost estimating
  - The Source’s prevailing attitude is that cost is a result, not a control variable (despite CAIV)
  - Building a trusting relationship with the Source is the best hope
- How to build trust in the Source?
  - Gradually
  - By deflecting, “What do you need?” with, “What do you have?”

# Investing Psychology

- Behavioral Finance
  - Field pioneered by research of Daniel Kahneman (Princeton) and Amos Tversky (Stanford); late 70s
  - Problem framing (gain or loss) importance
- Prospect Theory
  - Based upon subjective experience of feelings
  - Greater distress at prospect of a loss than joy of prospect of an equivalent gain
  - Leads to loss aversion behavior: taking risks (often foolish) to avoid losses.

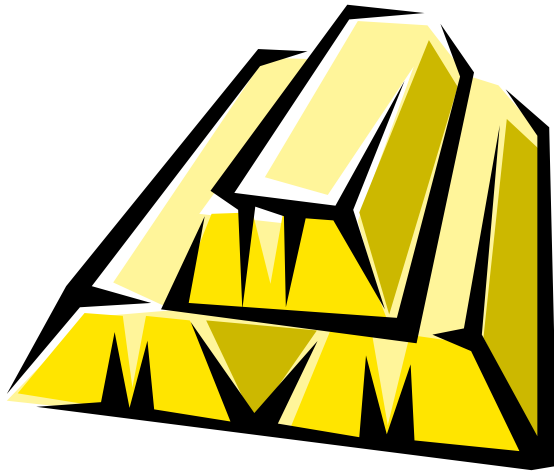
# Investing Psychology

- Anchoring is perilous
  - Giving more weight to recent events than historical perspective
  - Danger in extrapolating a short term phenomena that is at odds with long-term averages.
- Herding: following everyone else even if an objective assessment says it is irrational; a.k.a. Greed
- What's the Response to this bad behavior?
  - Fundamentals: Balance sheet and income statement for investments
  - Balance: Select and adhere to allocation types (stocks, bonds, cash, etc.)

# Estimating Psychology

- Over-Under Theory
  - Excludes “Feel Good” estimating
  - Greater fear at prospect of an underestimate than for an equivalent overestimate
  - How many press articles or GAO reports deal with overestimates?
  - Leads to over-adjustment behavior: magnifying risks to temper expectations; anchoring and herding often set in.
- What’s the Response to this bad behavior?
  - Fundamentals: Relevant, verified data as basis for estimating
  - Balance: Select and adhere to estimating methods (Performance cost models, BOM estimating, etc.)

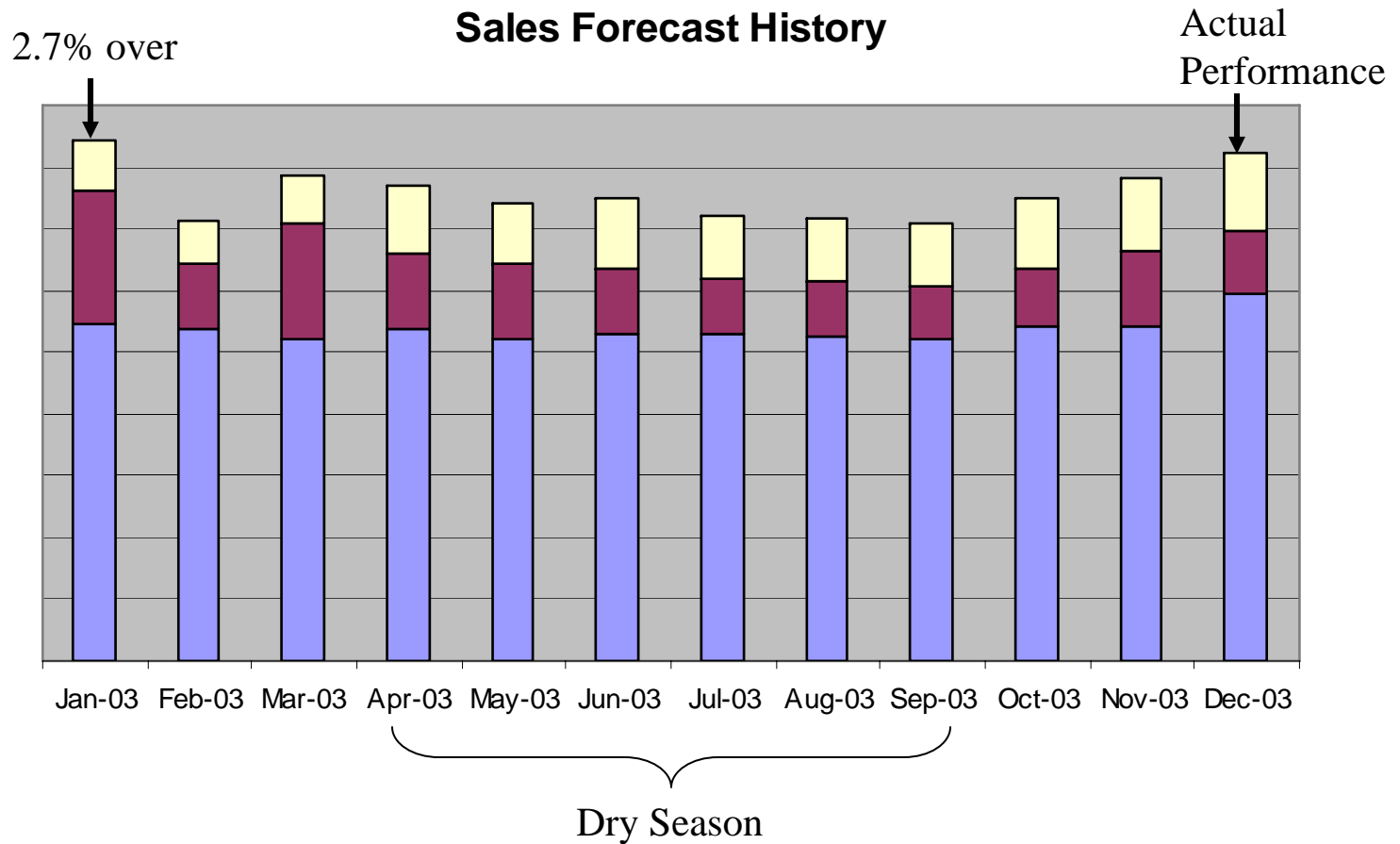
# Estimating Psychology



## Golden Rule

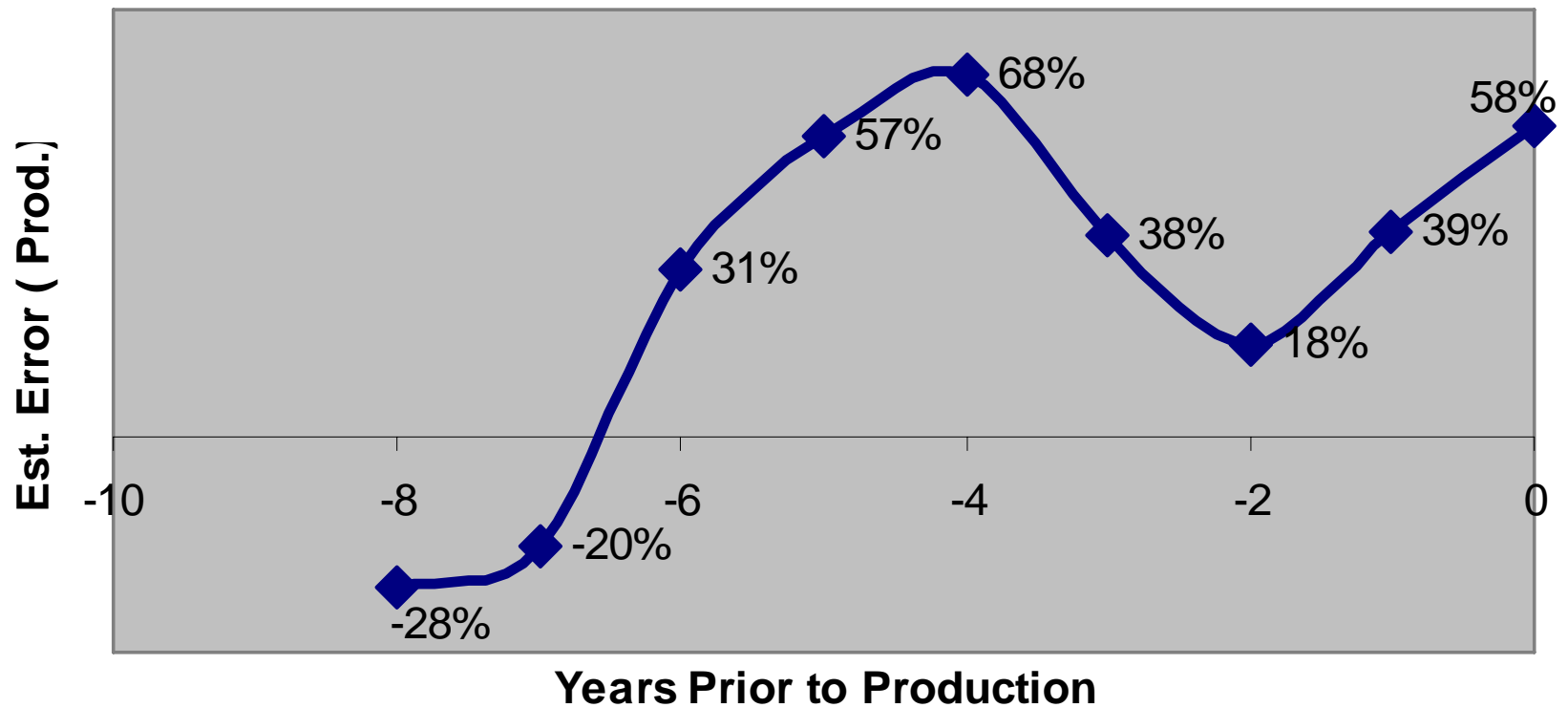
*Do not modify your methods while estimating*  
*...don't "invent" new drivers*  
*...don't add new bias adjustments*  
*...don't ignore history*

# Supporting Evidence



# Supporting Evidence

## Avg. Estimate Error



# Point of Reference

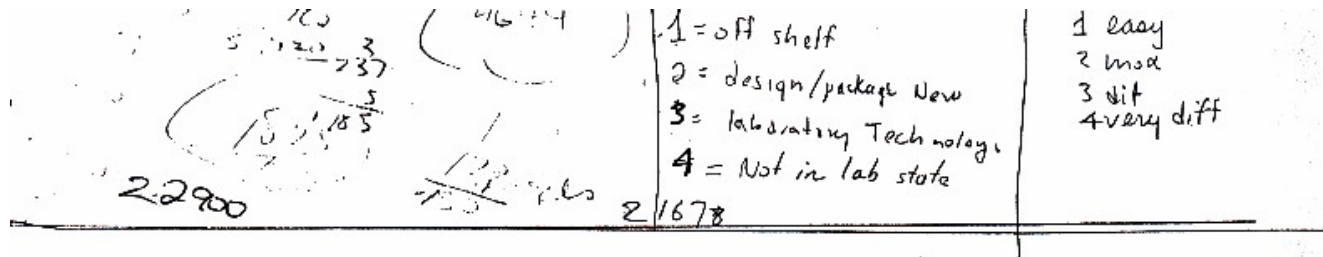
- The most easily obtainable like item (system, product, function) is the best starting point of reference
  - Pride renders any selected reference unsuitable to the Source
  - Quickly engages the Source in costing
- Follow the Fad Axiom

*Most of us are better at being critics  
than we are at being authors*

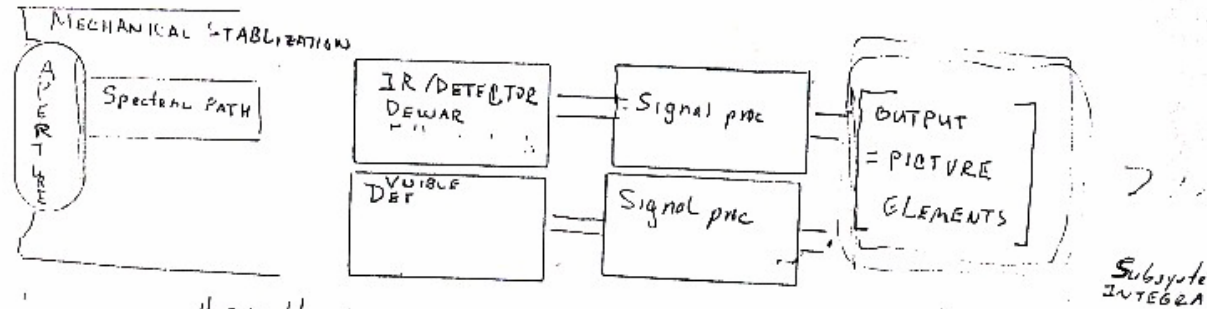
# Starting to Forecast the Future

- Most methods rely on “hard” information
- The future is soft, indiscernible, and full of alternatives
- Quantitative methods, though preferred, often inhibit the initiation of future forecasting
  - Boxes in thinking when concepts are many and varied
  - Intimidates sources of information
- A Qualitative approach often fits better in moving an organization to start dealing with the problem of costing the future
- Once forecasting begins,
  - Alternatives are managed and systematically eliminated
  - Systems Engineering accelerates
  - Quantitative methods gradually usurp qualitative ones

# The Desk Blotter as a tool for Future Forecasting



EO/IR MULTI SPECTRAL IMAGING SYSTEM



420 lbs :

EO/IR APERTURE	5-95/3-5 diameter	Weight	% weight = Electron Complexity (1-4)	
Telescope / Filters / Beam Splitter / Imager		10 lbs - 1"	-0-	2
Mechanical / Stabilization		60 lbs - 1"	5%	2
IR DETECTOR / Dewar		200 lbs	10%	2
Visible DETECTOR		90 lbs	30	3
Signal Processor		20	10	2
		40	60	2

# Desk Blotter Model Ground Rules

<i>Engineering Assessment</i>	<i>Manufacturing Complexity</i>	<i>Engineering Complexity</i>
Existing Technology; Used in Production today	Table complexities for airborne platform	Nominal new design, within product class
Redesigned or Repackaged production technology	Table complexities for next higher platform	New design of new product class
Existing laboratory technology not yet in production	Table complexities for 2 levels higher platform	New design of advanced product class that no one has designed
Non existent technology	Table complexities for 3 levels higher platform (extrapolated)	An advanced design requiring technology development

# Blotter – Rules – Tables - Forecast

An advanced design requiring technology development

ECMPLX Engineering Complexity

		Value
	<b>SCOPE of DESIGN EFFORT: New design different from established product line; must develop new technology/materials and advance state of art or require multiple design paths.</b>	
	Personnel with extensive experience with similar designs. Many are experts in the field. Top talent leading the effort.	1.900
	Normal experience, have completed similar type designs.	2.300
	Mixed experience, some are familiar with type of design while others are new to the job.	2.700
	Unfamiliar with design, many are new to the job.	3.100

Simple Mod / Extensive Mod / New Design / New Product / New Technology / **Advance State Of Art**

Parameter Value: 1.000

OK Cancel

# Transition to more Rigor

Component	WEIGHT	DESIGN ELECTRONICS (ACTIVE) Mechanical Eng Complex Integ Computer				Comments
Low RCS Type ANTENNAS/RADARS PREAMP/SW	200 lbs	30%	70%	3	3	Lab Antennas, -Difficulty is
Down Conversion	20 lbs [10x2lb]	40				
Channelizers	[2x5] = 60 lbs	50				
HF/VHF TUNERS (includes Digitizers)	100 lbs = [20x5]	70				
DF/ADA + pulse processor	750 lbs = [3x50]	70				
ENVIRONMENTAL FILTER - SIEVE (COLAUDE)	150 lbs [3x50]	70				
DR-ADA - CW Processor	150 lbs [3x50]	70				
CONTROL, INTERFACE PROCESSOR	30 lb [3x10]	70				

Component	Weight	% Active Electronics	% Mechanical	Integ Complex	Integration	Comments
Tethered Link (IDL) RT	80 lbs	70	30	1	1	
TETHERED LINK IDL - ANTENNA	30 lbs	30	70	2	2	RCS
CNI	150	70	30	2	2	
CNI Antennas	40	20	80	1	2	
Microwave Relay	50 lbs	70	30	1	2	
Microwave Antenna	30 lbs	30	70	2	2	
Laser Relay	80 lbs	70	30	1	1	
Laser Telescope	720 lbs	30	70	1	2	
STORAGE	100 lbs [2x50]	40	60	2	2	
Control Processors	30 lbs [3x10]	70	30	2	1	
MILSTAR RT Antenna	20 10	70 20	30 80	1 1	2 2	

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**PRICE**

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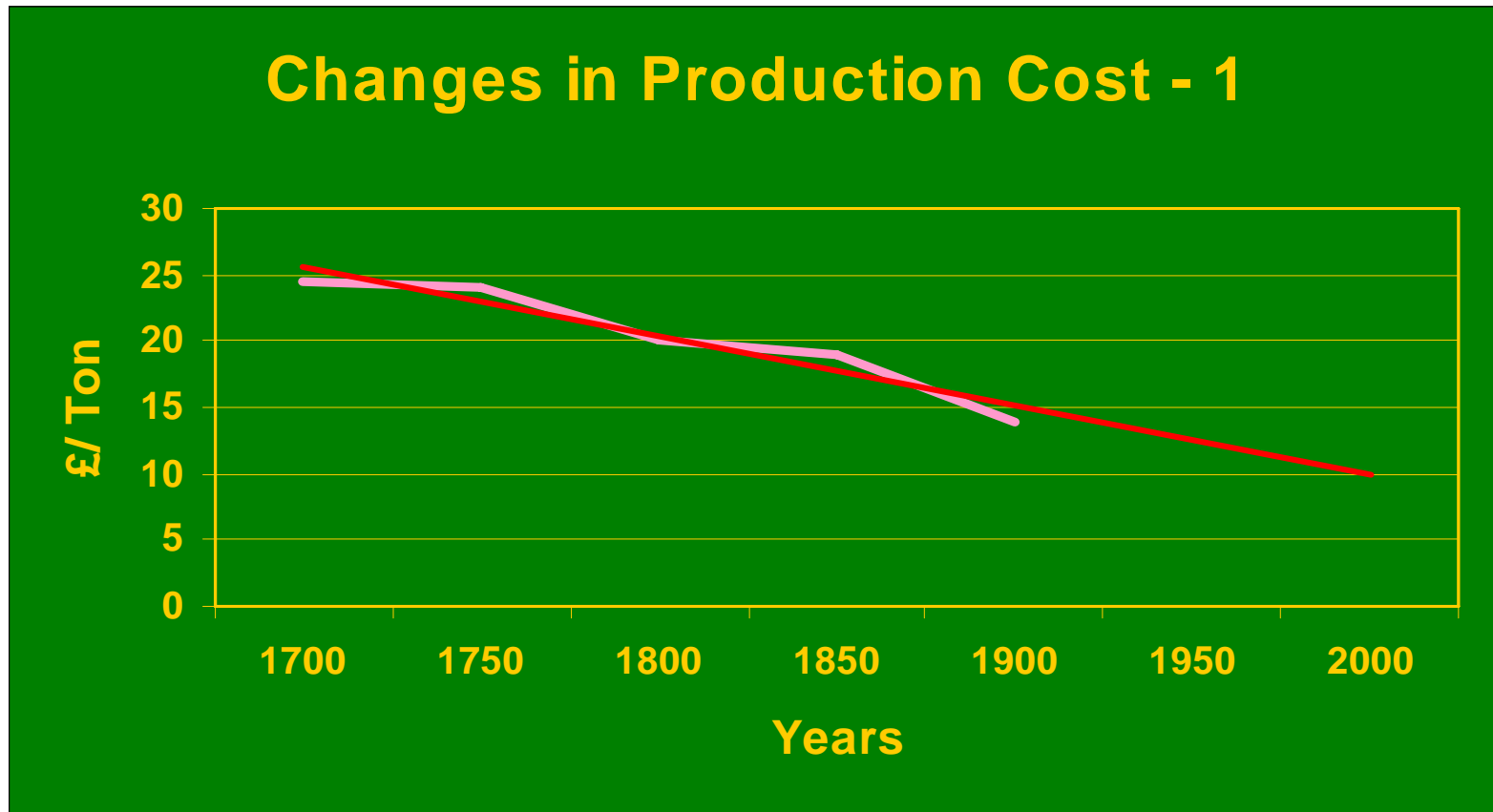
# Forecasting the Future

- Use **time** as the primary determining factor
- Relate time to:
  - Cost variables/complexity
  - Risk and technology
  - Program characteristics
  - Improvements in methods and processes-general
  - Performance
    - Output (computational power, recharge cycles, range, etc.)
    - Performance Efficiency
    - Energy conversion
    - Accuracy (drift rate, resolution)
  - Design Efficiency & Specialized design and manufacturing tools
- Cost and performance is directly associated with time
- Trends are remarkably stable (predictable) over time

# 20th Century Futurology that Flopped

- *It will be 1000 years before man is able to build a contraption that will fly.* Wilbur Wright lamenting to brother Orville, 1902
- *Everything that can be invented has been invented.*  
Charles H. Druell, U.S. Commissioner of Patents, 1899
- *Computers in the future may...perhaps weigh only 1.5 tons.*  
Popular Mechanics, 1949
- *I think that there is a world market for maybe five computers.*  
Thomas Watson, Chairman of IBM, 1943
- *Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools.*  
New York Times, 1921

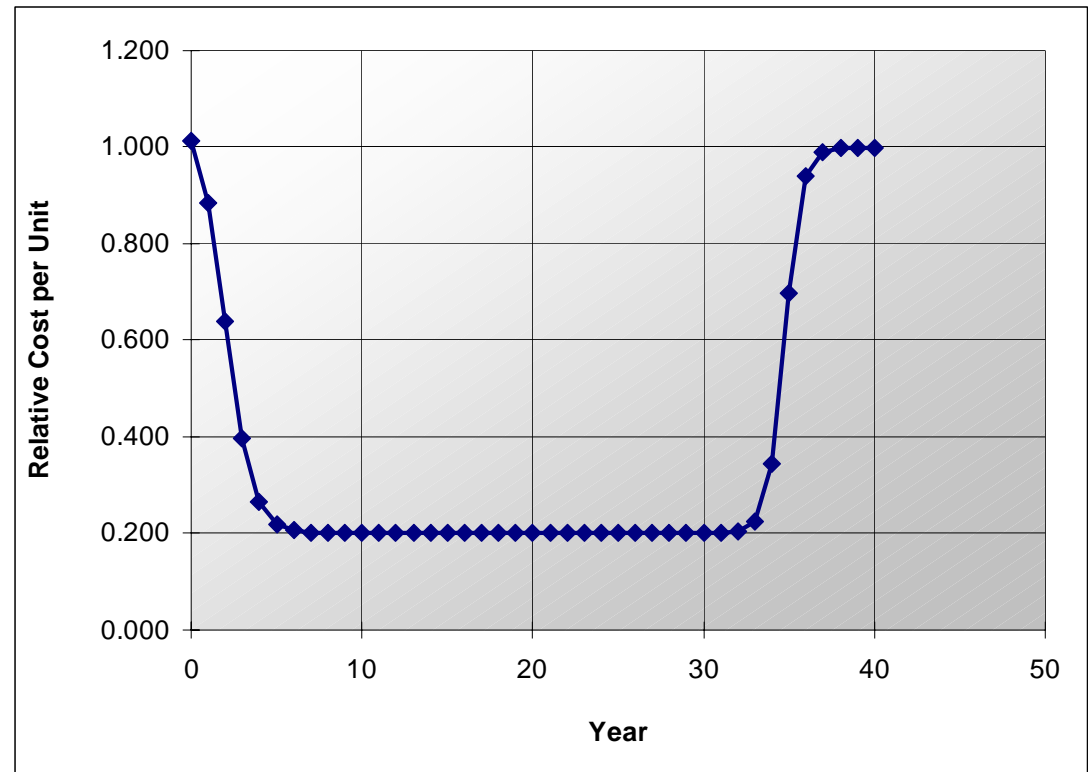
# New or Improved Technology? Know the Difference



Source - Ships of the Line - Brian Lavery

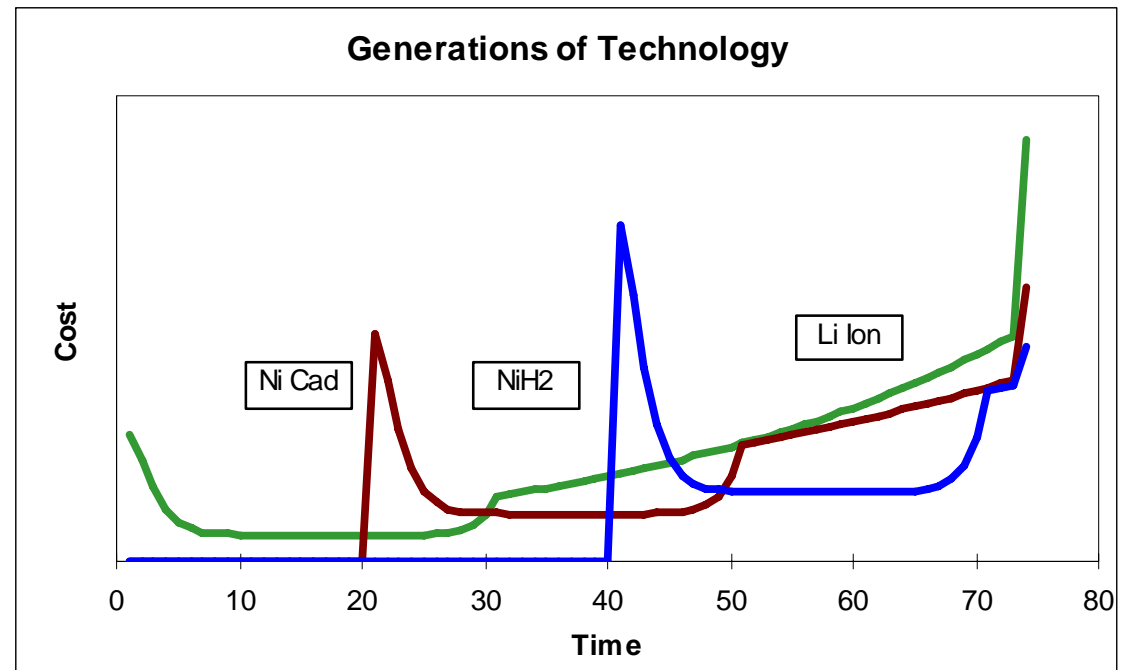
# Cost Life Cycle of a Technology

- Initial part of the curve; high cost due to low producibility, small production runs and limited sources
- Center portion of the curve; low cost due to mature manufacturing processes, high yields and multiple sources
- Latter part of the curve; increase in cost due to outdated processes, low procurement quantities and limited sources
- Depth of curve a function of market size and number of applications



# Generations of Technology

- Three generations of battery technology depicted
- Initial high peaks of each generation caused by subcontractor processes maturity costs, prime contractor design integration costs and low producibility
- When obsolete for several generations, cost is higher than current technologies of much greater performance





# Quantitative Application Example

## **Program:**

Future Digital Processing Capability

## **Task:**

When will technology be available for multi-function hand-held battle management?

What will it cost and what will the size be?

## **Highlights:**

- Trend analysis of computing development over past 60 years
- Demonstrates steady and predictable improvements in packaging
- Demonstrates steady and predictable improvements in cost/performance/size metrics

## **Return on Investment:**

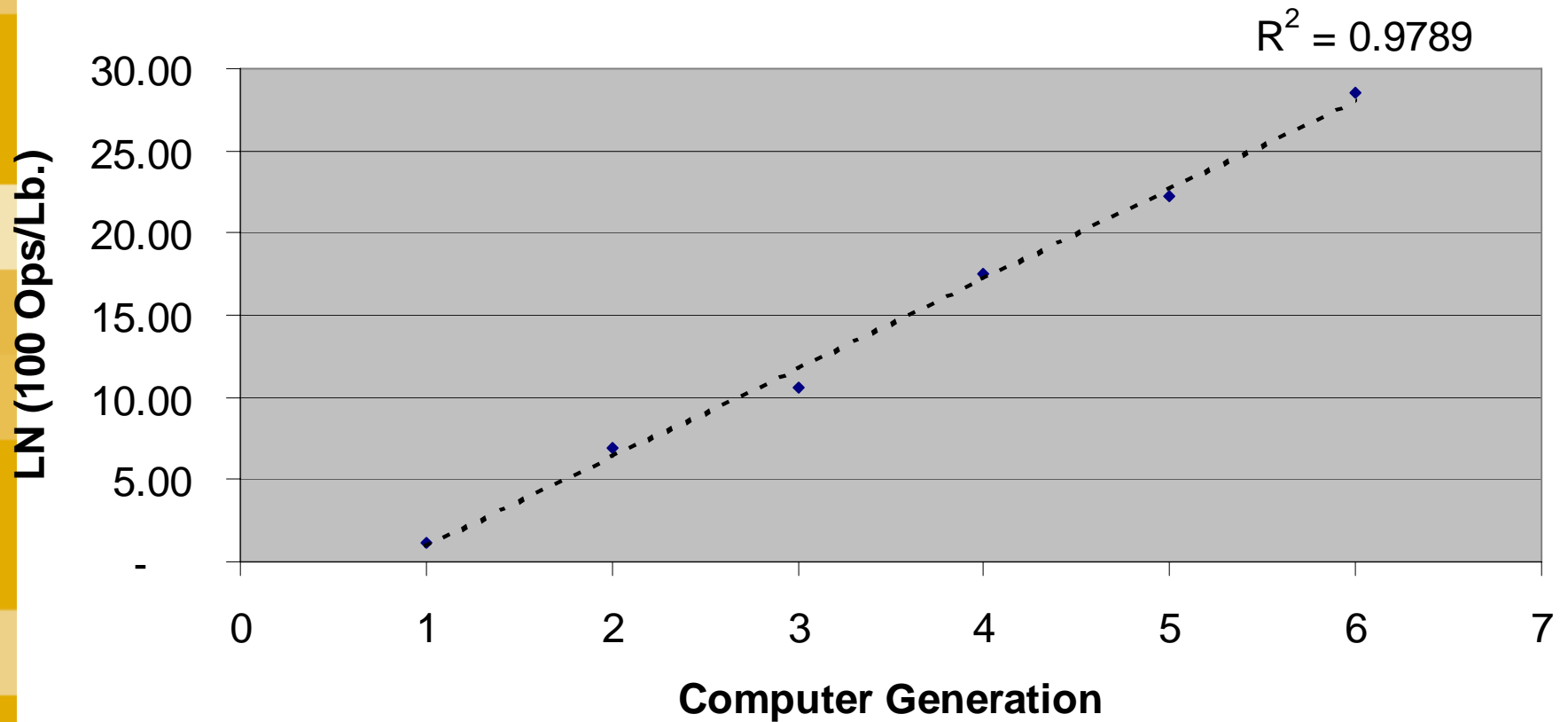
- Credible expectations established
- Viable planning undertaken

# Future Digital Processing Capability

Generation	Time	Weight (lbs)	Size (Cuft)	Cost	Operations/sec.	Technology	Examples
1	1937 - 1953	60000	6300	\$ 486,804	1,000 - 3,000	Vacuum Tubes (18,000)	ENIAC, EDVAC, UNIVAC
2	1954 - 1962	30000	58	\$ 1,250,000	150,000 - 400,000	Solid State (Diodes & Transistors)	TRADIC, IBM 709/7094
3	1963 - 1972	12000	3750	\$ 400,000	1,000,000 - 10,000,000	IC	CDC 6600, IBM 360/91, ILLIAC IV
4	1972 - 1984	250	10	\$ 75,000	50,000,000 - 100,000,000	LSI	CRAY, CYBER 205
5	1984 - 1990	22	1.1	\$ 8,000	500,000,000 - 1,000,000,000	Parallel Processing (RISC)	Sequent Balance 8000, MP-1
6	1990 -	4	0.1	\$ 2,000	100,000,000,000	Network	Toshiba Tecra

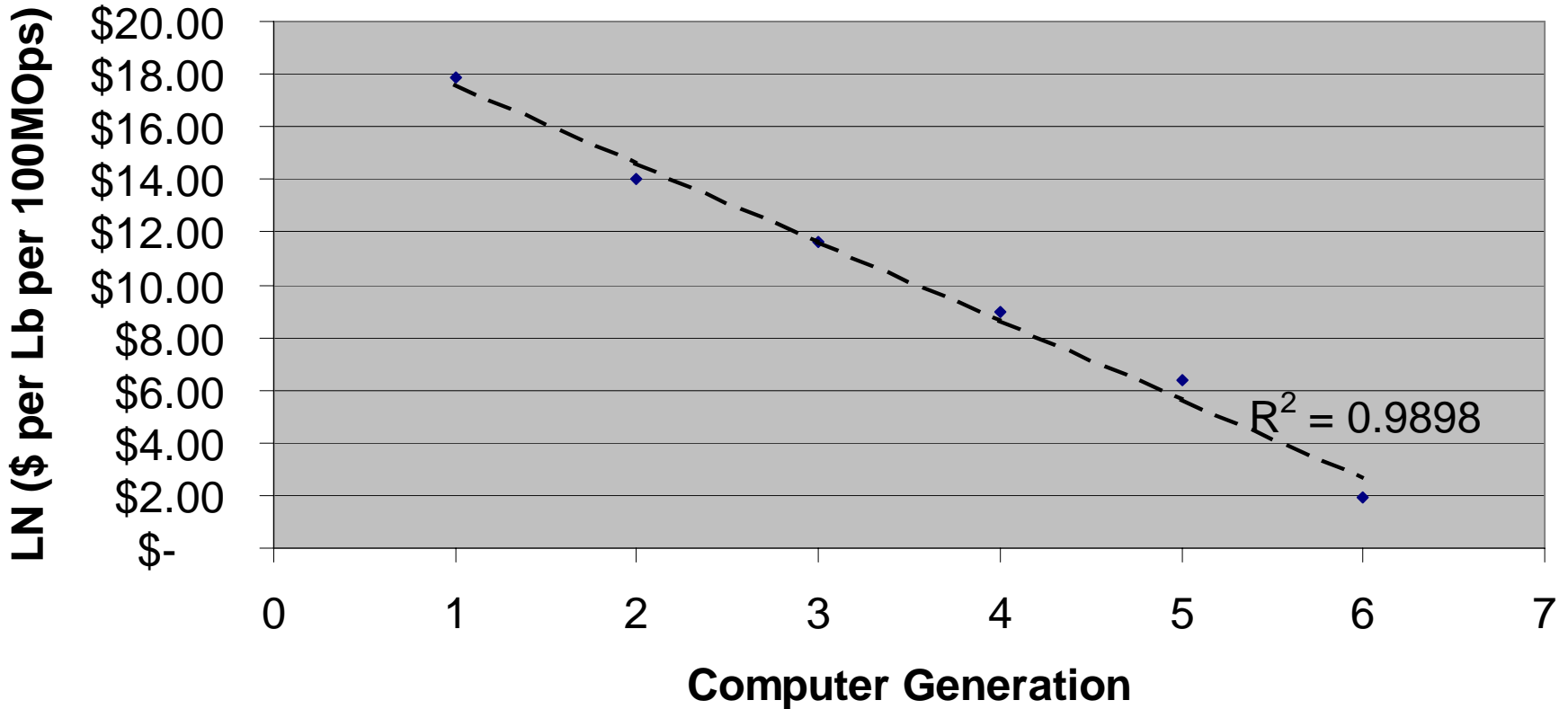
# Future Digital Processing Capability

## Relative Performance (Ops per Lb)



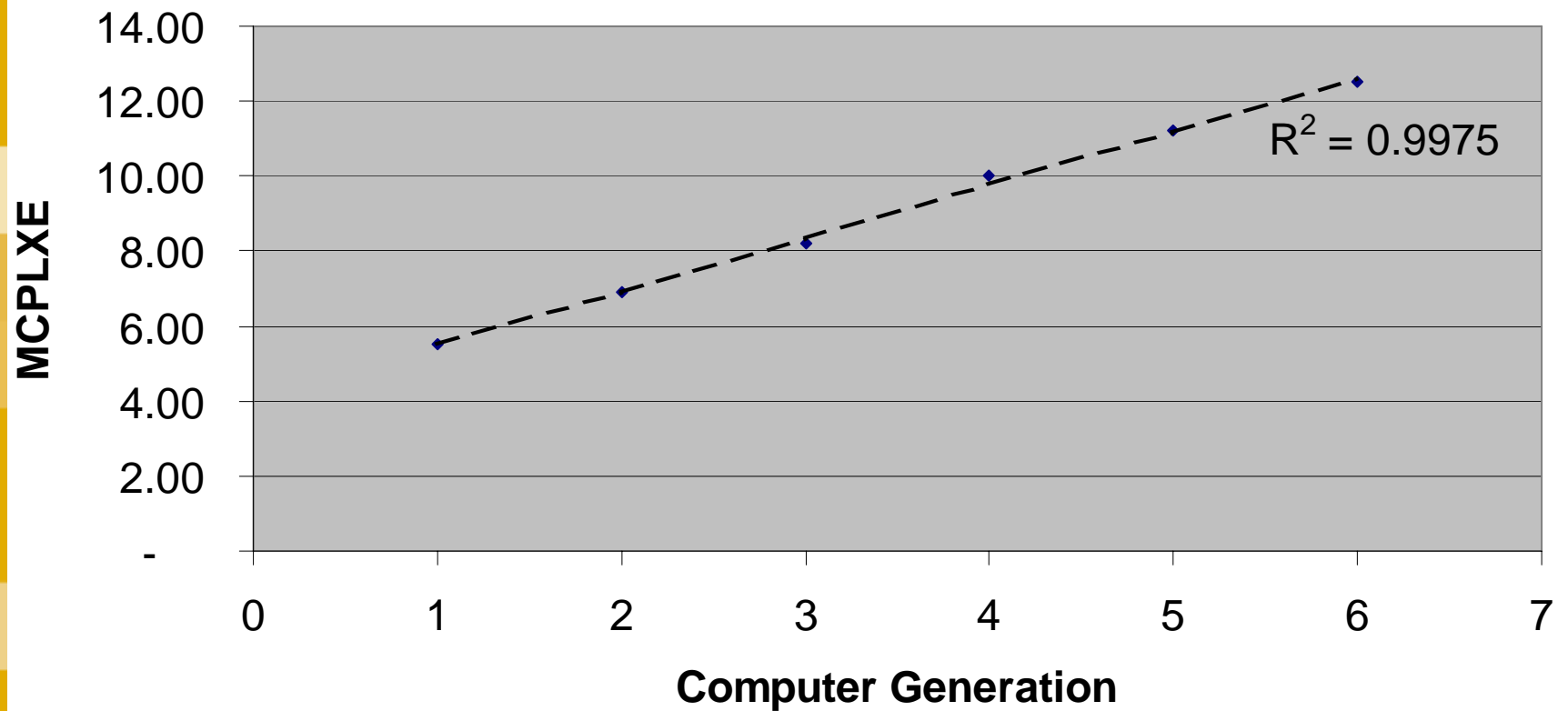
# Future Digital Processing Capability

Relative Cost (per Lb per 100MOp)



# Future Digital Processing Capability

## MCPLXE by Generation



# Future Basis from Knowledge

PRICE KnowledgeManager

STORE SEARCH ADMINISTRATION HELP CONTACTS TERMS LOG OFF

Users Groups Currently logged on as admin

- Select **Parameter(s)**. For each parameter, provide EITHER an exact value OR a minimum and/or a maximum value. Click 'Add' to add parameter search criteria to 'Criteria List'.  
 • Click 'Search' to find elements that meet ALL criteria in your list.

Group: All Groups | General Keywords: Select general keyword | Hierarchical Keywords: [ ]

Parameter: Select a parameter | Minimum Value: [ ] | Maximum Value: [ ] | Exact Value: [ ] [Add]

Criteria List: (NOTE: Use the Remove buttons to eliminate selected criteria from your search.) [Search]

Number	Parameter	Minimum Value	Maximum Value	Exact Value	Keyword	Level	Group
1					Engine		
2					Military Mobile		

Search Results (PRICE H) -- View Item Inputs

Search found a total of 13 elements.

[View Global] [View Financial] [View Escalation] [View Item] [Delete/Replace] [Retrieve] [Analysis]

Delete/Replace	Retrieve	Analysis	Notepad	Element_ID	Element_Type_ID	Element_Name	Element_Type_Des
<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	[...]	2	2	Engine 1	Mechanical/Struct
<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	[...]	3	2	Engine 2	Mechanical/Struct
<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	[...]	4	2	Engine 3	Mechanical/Struct
<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	[...]	5	2	Engine 4	Mechanical/Struct

# Forecasting the Future from Knowledge

The screenshot displays the PRICE KnowledgeManager web application interface. It features two overlapping browser windows. The top window shows the main application header with navigation links: STORE, SEARCH, ADMINISTRATION, HELP, CONTACTS, TERMS, and LOG OFF. The user is logged in as 'admin'. The bottom window displays two data analysis graphs and their corresponding prediction forms.

**Graph 1: Torque vs. MCPLXS**

This graph plots MCPLXS (Y-axis, 3.0 to 4.4) against Torque (X-axis, 0 to 1000). A blue trend line is shown. A red 'X' marks a data point at approximately (500, 3.3). Below the graph is a prediction form:

**Predict a new point**

New 'Torque' Value:

Predicted 'MCPLXS' Value:

**Graph 2: HorsePower vs. MCPLXS**

This graph plots MCPLXS (Y-axis, 3.0 to 4.4) against HorsePower (X-axis, 0 to 800). A blue trend line is shown. A red 'X' marks a data point at approximately (200, 3.3). Below the graph is a prediction form:

**Predict a new point**

New 'HorsePower' Value:

Predicted 'MCPLXS' Value:

**Trend Line Statistics**

Trend Line Types:

Coefficient of Determination (R<sup>2</sup>):

Standard Error:

**MCPLXS Figures of Merit**

Mean:

Std. Dev.:

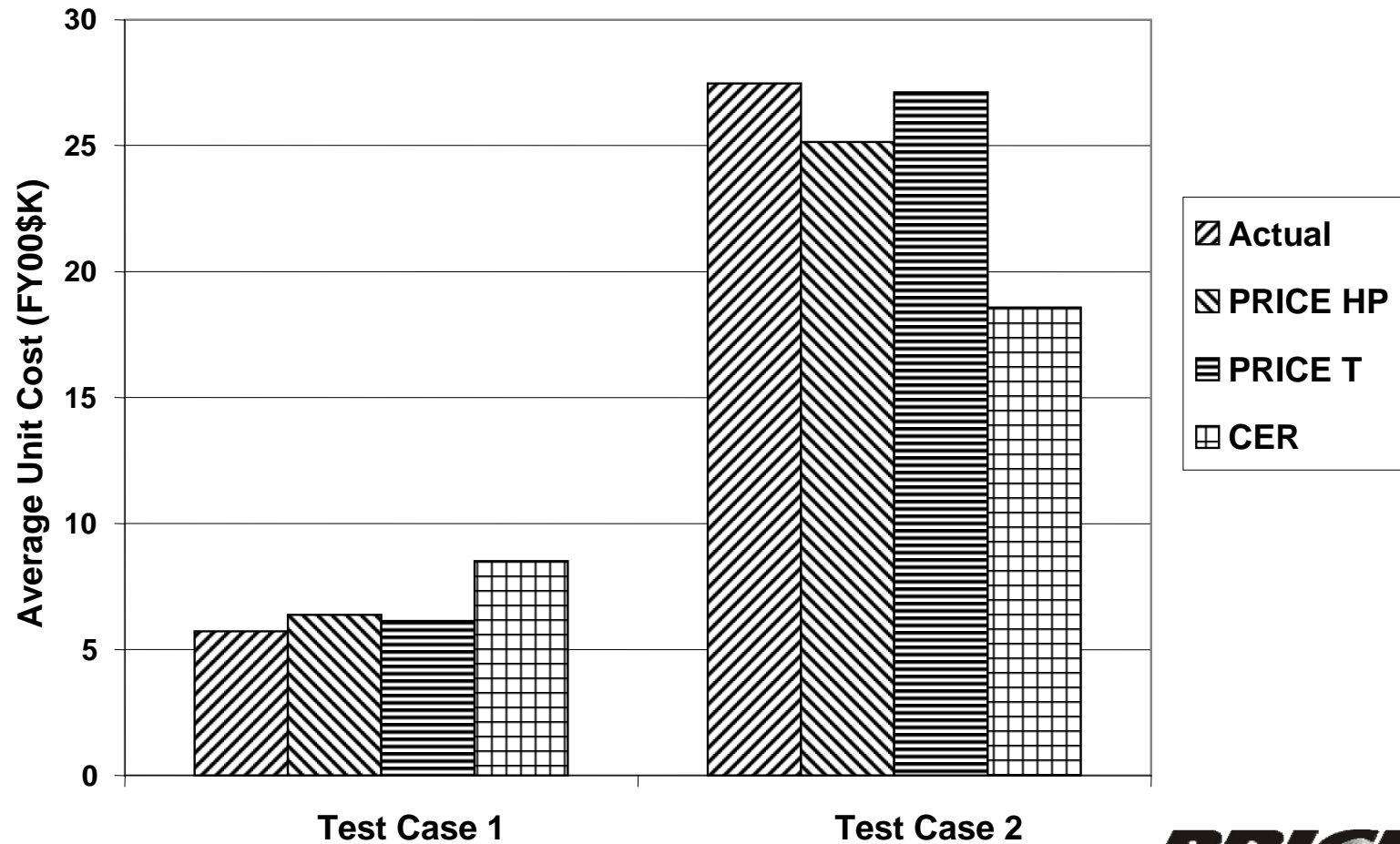
Minimum:

Maximum:

Type: Struct/Mech

# The Value of Applying Knowledge

Test Engine Results



# Summary

- Transformation is driving to more functional or performance based estimating
- Responsiveness dictates prior study and knowledge capture of performance cost drivers over time
- Affordability Management rests on credible cost/performance trade-off analysis conducted in collaborative environments spoken in management vernacular

Our mission is to provide  
collaborative planning,  
cost forecasting  
and budgeting solutions  
that empower clients  
to sustain profitable growth  
through faster, better decisions.

**PRICE**

**FASTER DECISIONS. BETTER DECISIONS.™**



# Additional Material



# Context of Affordability

- Tangible Factors (e.g. investment, performance capability)
- Intangible Factors (e.g. good will, threat deterrence)
- Conflict of capability and affordability objectives
- Limited flexibility in constraints to deal with conflict



# Affordability Implementation Plan

- The document describing how the Affordability Program is defined, managed, and implemented.
- Specifies the processes and procedures for performing ongoing affordability assessments to ensure the satisfaction of requirements within program target cost.
- From Objective Setting to Target Establishment to Trade Studies to Monitoring.

# TOC & DOD LCC

*.... For consistency with past initiatives, Defense Systems TOC is defined as Life Cycle Cost (LCC). LCC (per DoD 5000.4M) includes not only acquisition program direct costs, but also the indirect costs attributable to the acquisition program (i.e., costs that would not occur if the program did not exist)....*

Dr, J. S. Gansler, USD(A&T) Memorandum of November 13, 1998

# TOC Elements

*“The Supplier shall define, maintain, document and deliver TOC estimates on a quarterly basis. The estimates shall represent the sum of all direct and indirect costs associated with the research, development, procurement, construction, operation, logistical support and disposal, including the total supporting infrastructure that plans, manages, and executes that system program over its full life.”*

**Extract from 2003 Weapon System SOW**

# CAIV & TOC Elements

*“The Supplier shall develop and implement throughout the development process an acquisition strategy and philosophy, focused on cost/performance/schedule quality/prioritized-functionality trade-offs in relation to Total Ownership Cost (TOC) of the system. The Supplier CAIV approach shall include the customer in decision-making and requirements trades to meet available budget resources. Supplier shall not only make up-front tradeoffs to balance cost, schedule, and quality, but also make continuing tradeoffs to balance schedule, prioritize functionality, and quality throughout the development process.”*

**Extract from 2003 Weapon System SOW**



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**A Balanced Acquisition Strategy** *tradeoffs but also schedule, prioritize functionality, and quality throughout the development process.”*

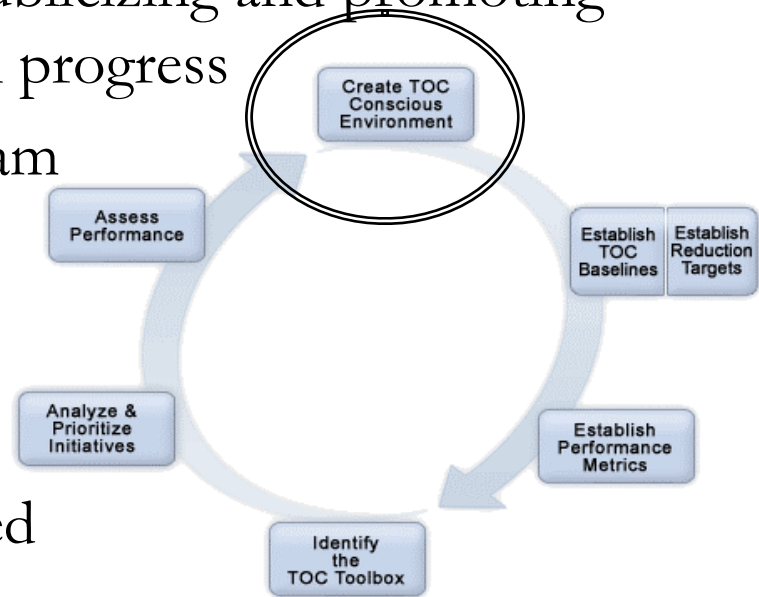
# CAIV & TOC Elements

*“The Supplier shall develop and implement throughout the development process an acquisition strategy and philosophy, focused on cost/performance/schedule quality/prioritized-functionality trade-offs in relation to Total Ownership Cost (TOC) of the system. The Supplier CAIV approach shall **include the customer in decision-making and requirements trades** to meet available budget resources. Supplier shall **make up-front tradeoffs** to balance **make cost** **prioritize** **the development**”*

A Collaborative  
Action

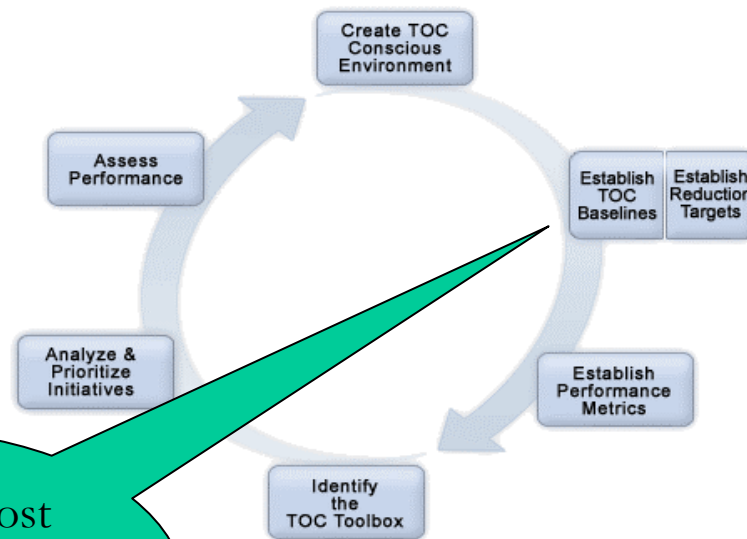
# Create TOC Consciousness

- Establish and publicize top-level program goals for TOC savings/avoidance
- Create guidelines and templates for TOC evaluation
- Develop a mechanism for publicizing and promoting TOC achievements and total progress
- Incentivize and recognize team members for TOC achievements
- Capture and disseminate TOC program lessons learned



# R-TOC Process

## Establishing a Baseline & Goals



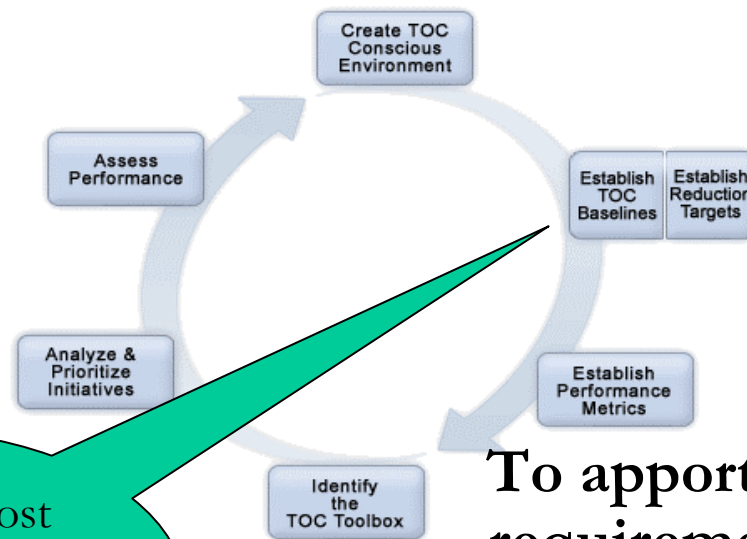
What are the cost baselines, reduction targets, and program success measures?

# Establishing Goals

- Step 1 in establishing reduction targets is to set top-level program goals
- Goals are the stimuli and incentives to drive to affordability
- Goals should be challenging and realistic
- Variable or uniform allocation over time and program elements
- Goals: Percent reduction from a baseline value of the life cycle cost of all pertinent products
- Targets: Stated in absolute terms (as dollars, wan, etc.) as either a unit cost or cost per function

# Affordability Process

## Allocate TOC Baseline

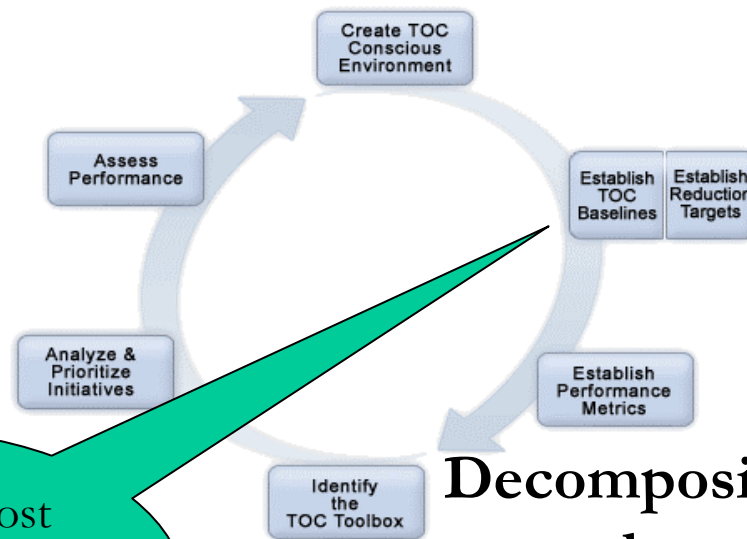


What are the cost baselines, reduction targets, and program success measures?

To apportion top-level requirements to lower indenture levels and make baseline cost allocations to functional groups or IPT's

# R-TOC Process

## Establish Reduction Targets



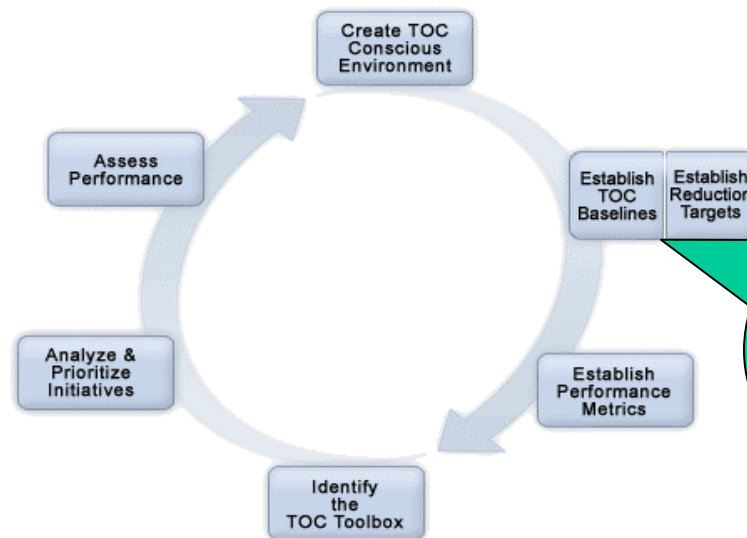
What are the cost baselines, reduction targets, and program success measures?

Decomposition of cost targets to product pieces often needed in order to relate them to meaningful design parameters – especially for acquisition costs

# R-TOC Process

## Cost Driver Identification

### How is this done?



What are the program cost drivers and cost reduction opportunities?

# Cost Drivers

- Cost Drivers are:
  - Factors that have major impact on total ownership cost
  - In aggregate, influence most of the cost of an item
  - Identifiers of the greatest opportunities for cost reduction
  - Determined by investigating for root causes
- Cost Drivers are not:
  - High-level, high-cost WBS items such as maintenance, manpower, or training
- Examples
  - A cost driver for manpower may be the need to provide an operator whenever an item is operating
  - A cost driver for maintenance may be the need for unique support equipment



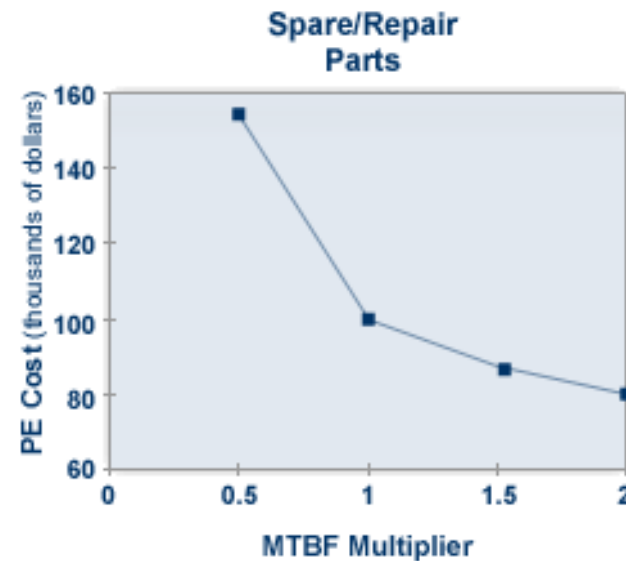
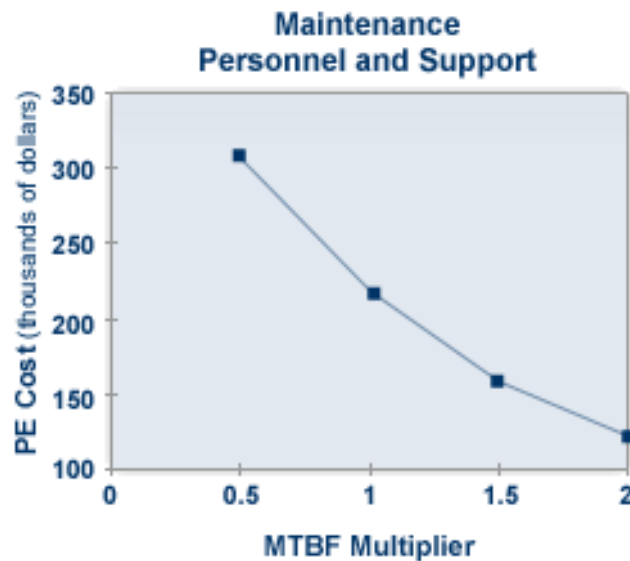


# Identifying Cost Drivers

- Develop a cost summary
- Identify the high-cost contributors
- Determine "cause and effect" relationships
- Identify the causes for high cost areas
- Conduct sensitivity analysis to determine the effect of input factors on the analysis results
- Identify high-risk areas

# Cause and Effect Relationships

- What are the drivers of the cost contributors?
- How do drivers influence cost?



# Cause and Effect Relationships

- Cost Driver insight requires understanding of product type
  - Drivers will differ from a ship to a airplane to a software development, for example
  - Candidate drivers might be armament and level of manning for a ship, speed and range for an airplane, and number of components and processing function for software
- Capturing Cost Driver effect on cost requires understanding of cost modeling
  - Regression Analysis captures response of cost to changing parameters, yielding CERs
  - Known as Parametric Estimating