CHANGING THE CULTURE

The Biggest Task Ahead in Integrated Product/Process Development

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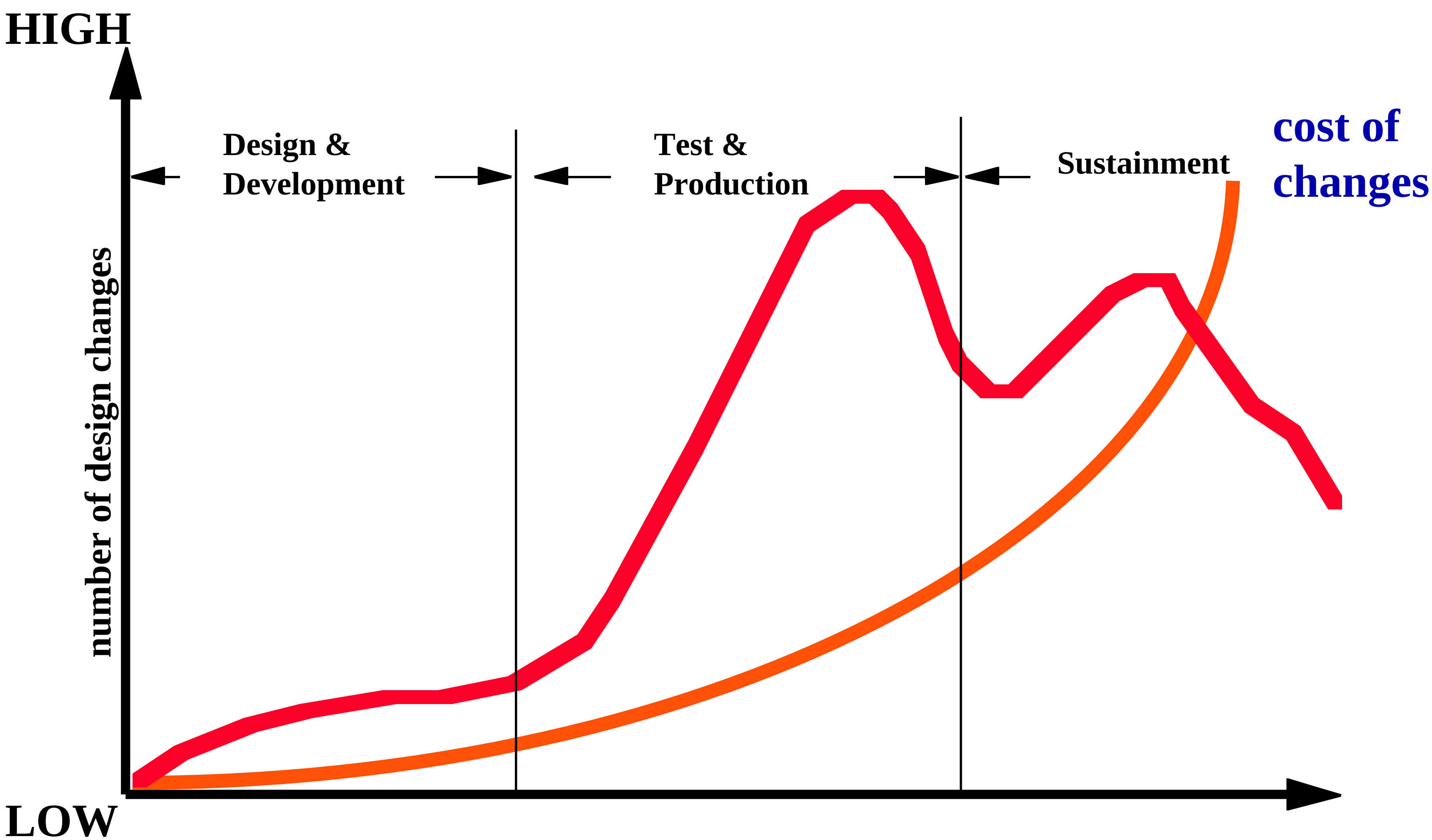
WHY IPPD

- **IPPD IS KEY to:**
  - U.S. Industrial Competitiveness
  - coupling Information Technology & Manufacturing
- **IPPD IS CRITICAL to**:
  - DoD systems where S&T transitions to new systems
  - the Next Step in World Class Quality Evolution

Traditional Serial Approach vs Concurrent Approach



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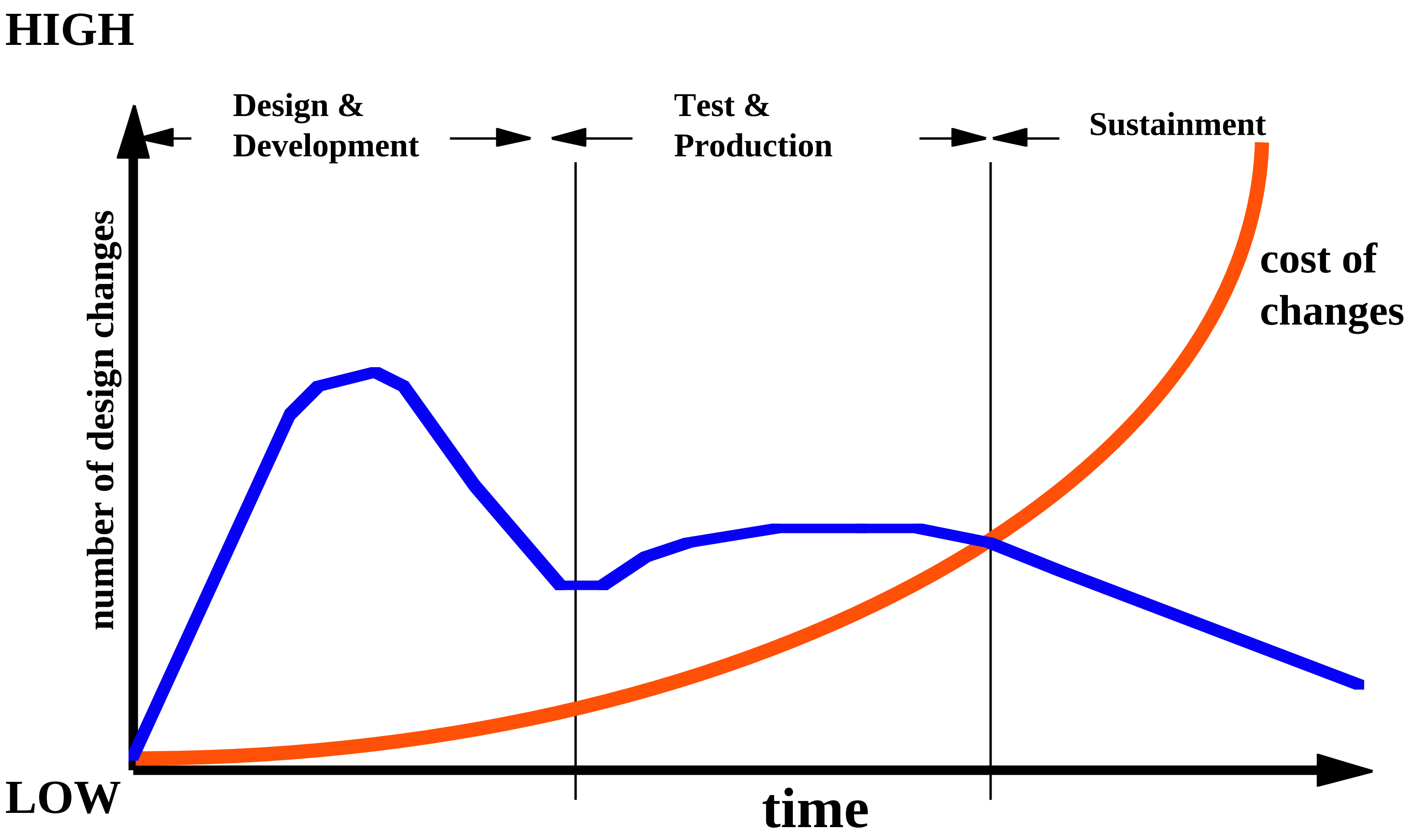

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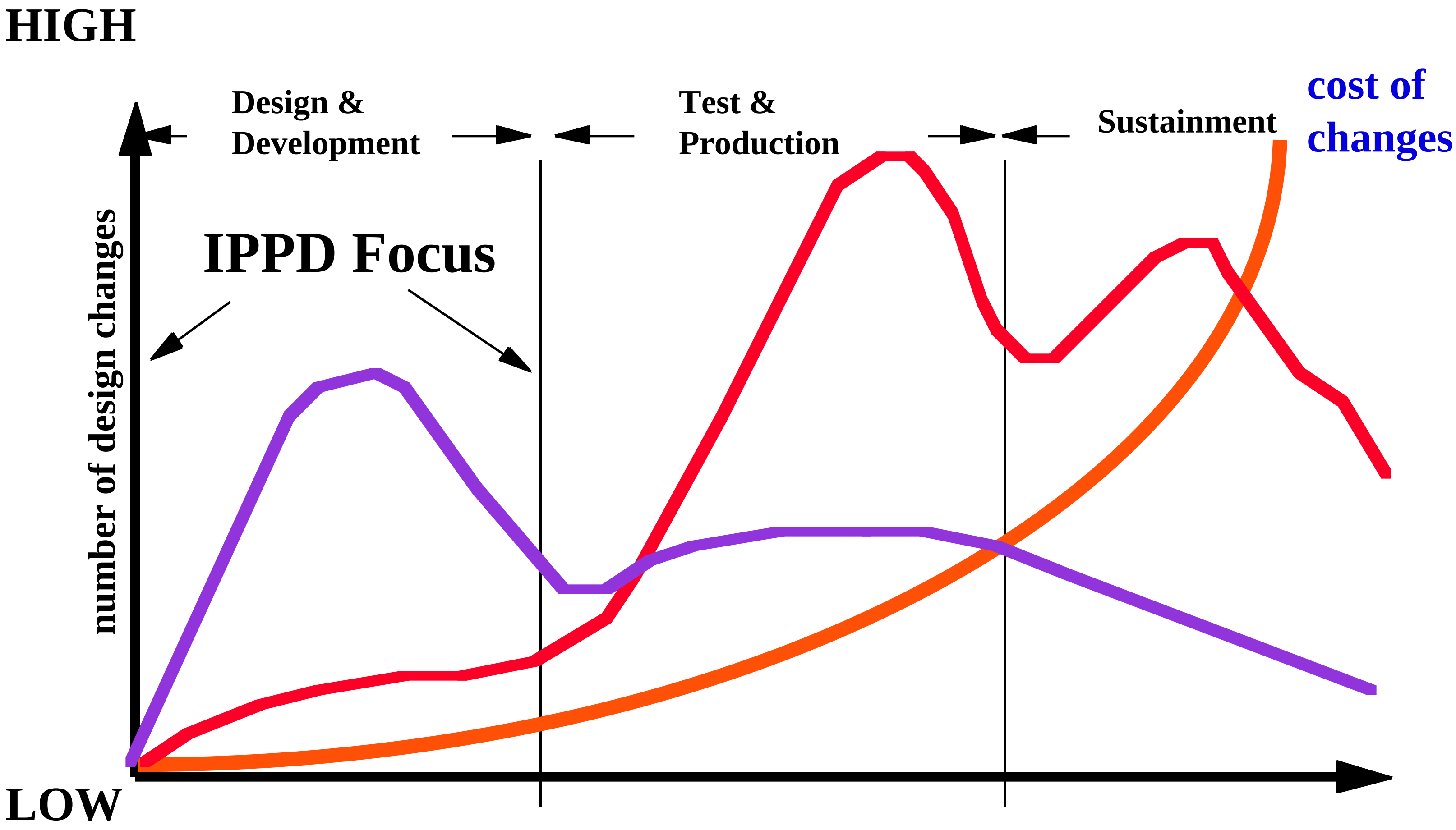


TRANSITIONS REQUIRED for "WORLD CLASS"

PRIOR		FUTURE
• **Design for Performance**	→	**Design for Affordability**
• **Individual Innovation**	→	**Teaming/Workgroup**
• **Min. Customer Involvement**	→	**Customer Team Member**
• **Serial Development**	→	**Concurrent Development**
• **Hardware Prototypes**	→	**Digital Simulation**
• **Paper Documents**	→	**Electronic Database**
• **Incoming Inspections**	→	**Supplier Certification**
• **Lowest Cost Supplier**	→	**Strategic Partnerships**
• **DTUPC Evolution**	→	**Product/Process Cost Model**
• **Design Review**	→	**"Six Sigma"**
• **Product Inspection**	→	**Process Control**
• **New Technology**	→	**Dual Use**
• **Operational Testing**	→	**Simulation/Modeling**
• **Single Program Focus**	→	**Multi/Dual Use**

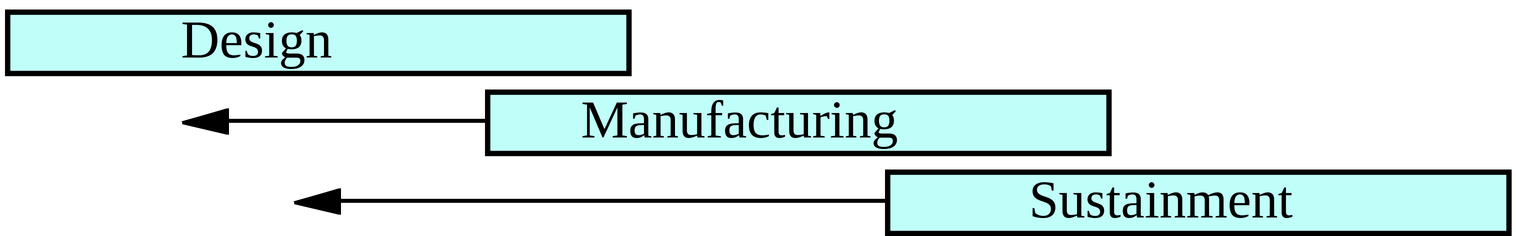
WHAT IS IPPD?

- **"...management methodology** that incorporates a systematic approach to the ***early integration*** **and** ***concurrent application*** **of all the disciplines** that play a part **throughout a system's life cycle."**
  Industry Task Force, 1992

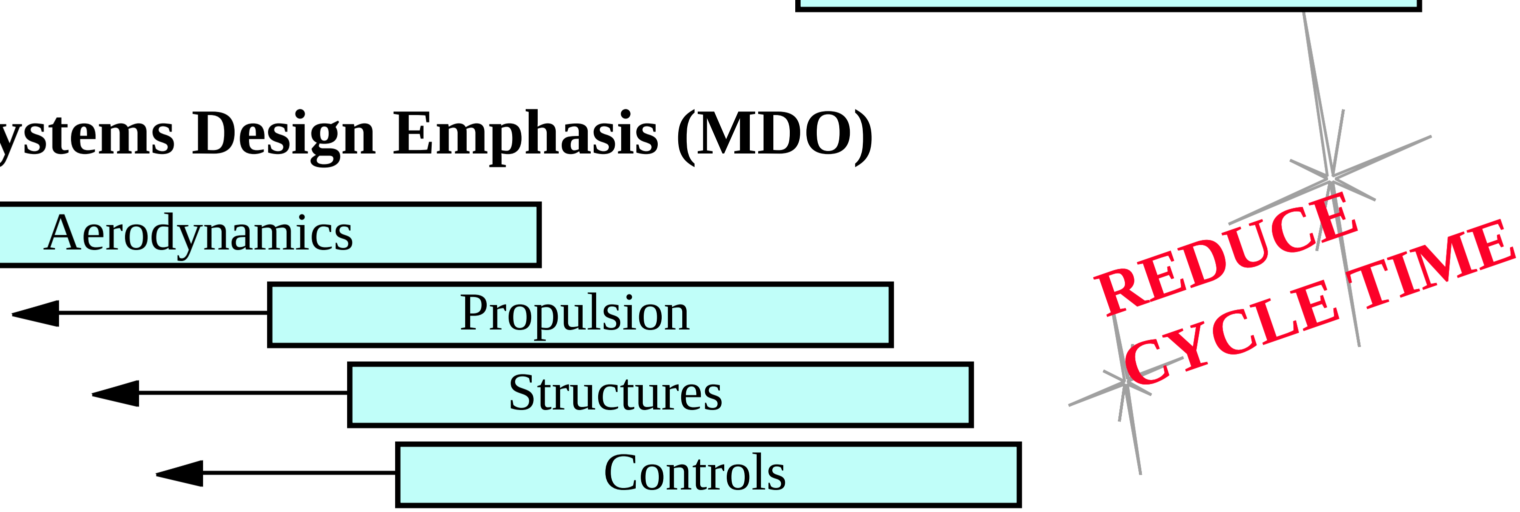
- **"...a management technique** that simultaneously integrates ***all essential acquisition activities*** through the use of **multidisciplinary teams to optimize the design, manufacturing, business and supportability processes"**
  DoD Guide to IPPD, 1996

Concurrent Engineering & Multi Disciplinary Optimization

- **Life Cycle Emphasis (Concurrent Engineering)**



- **Systems Design Emphasis (MDO)**



Unlearning the Past

Learning Curve vs Forgetting Curve

- What New Warfighter Benefit To Provide
- What New Competencies Will We Need
- How to Reconfigure

Culture Change Formula

- **Education (Mid Term)**
  - **Functional Disciplines**
  - **Integration in Basics**
- **Research (Long Term)**
  - **Simulation**
  - **Modeling**
  - **In Situ Testing**
- **Training (Short Term)**
  - **Awareness**
  - **Tools**
  - **Methods**

Awareness & Training

- **All Senior Leadership on Same Wavelength**
  - Policy Continuously Reinforced
  - Trickle-Down Time Recognized
  - No “Reactive Policy” to Mistakes
- **All Workforce on Same Wavelength**
  - Toolkit Training
  - “Who Did It Well - Where are the Blind Alleys”
  - Methodology

Entrance Criteria

Customer Requirements

- Multi Use
- Top Level

State-of-Art Technology Assessment

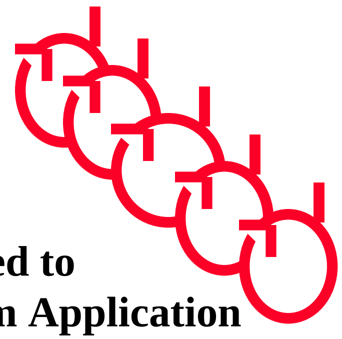
- Sub-systems
- Components
- Material
- Processes

Identify Hi Risk/
Hi Payoff Tech Needs

Estimate Success Metrics

Advanced Development

Define Gated Process Steps



Needs tailored to System Application based on Business, Industry, & Risk

IPPD Management System

IPPD Team
IPPD Process (Methodology)
IPPD Tools

Exit Criteria

Generic Technologies ready to Integrate in new products

- Suitable for buildable prototype
- Mfctd w/ prod eqpt
- Test (Real &Sim)

Product/Process Characteristics

- Cp/Cpk Goals
- Life Cycle Cost
- R&M Goals

Material Characterized

Alternative Design Trades conducted, eval'd, prioritized

Where Competition is Determined Today

Cost Advantage

Cheap Labor
Hi Volume, Lo Mix production

Quality

Statistical Process Control
Variability Reduction
Customer Satisfaction

Time to Market

Cycle Time Comparison (JIT)
IPPD
Product/Process Simulation
Hi Skill/Adaptable Workforce

Manufacturing Enterprise Flexibility

Product Variety

Cost Independent of Volume
Agility
Commercial/Military Integration
Virtual Companies

Company Goodness

Environment

'60 '70 '80 '90 '00

An Integrated Strategy for Cost Reduction

ACQUISITION REFORM
- MilSpec Relief
- Reduced Oversight
- New DAB Process
- Streamlined Procurement
- Reqmt & Resources
- Training & Education

Best Commercial Business Practices & Acquisition Process Re-Engineering

Affordable Product & Process Technology

Lean Weapons Systems Dev't, Production & Spt
- **IPPD**
- **Decouple Cost/Qty**

AFFORDABLE SUPPORTABLE DEFENSE SYSTEMS

S&T
- Process Maturity
- New "M" Mantech
- New Acq Interface
- IPPD

Affordable "Parts"

INDUSTRIAL BASE
- Dual Use Suppliers
- Defense Essential
- Commercial Characteristics

Introduction to an IPPD Methodology

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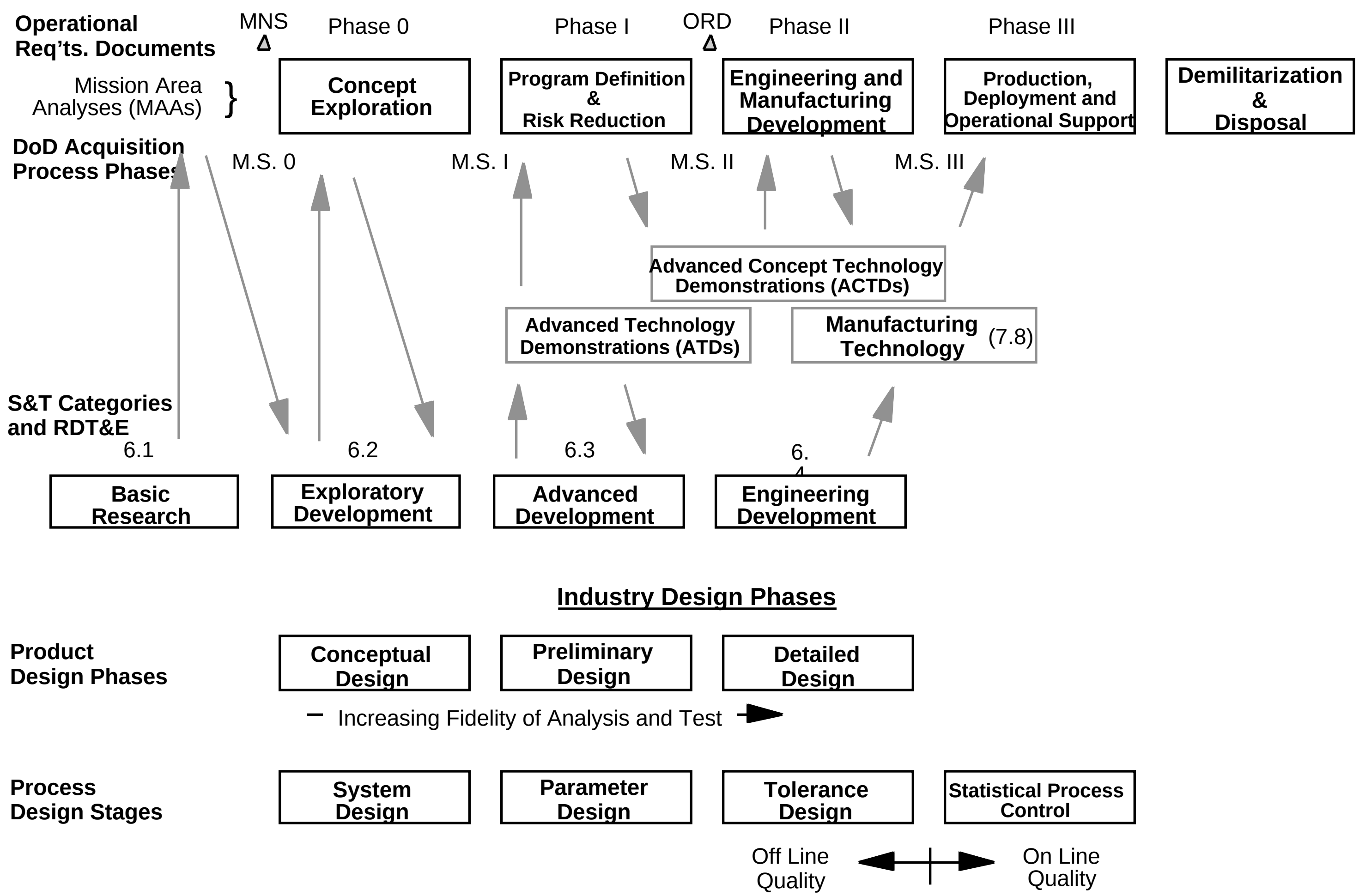
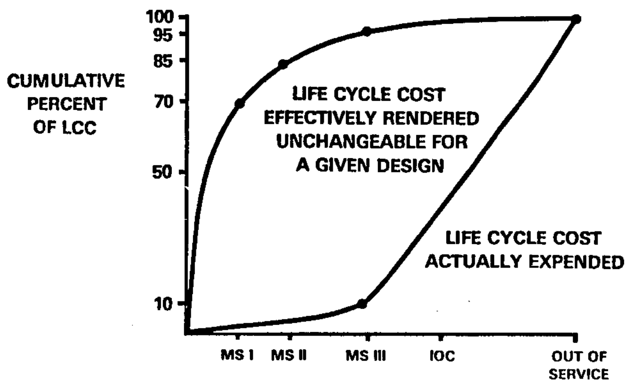
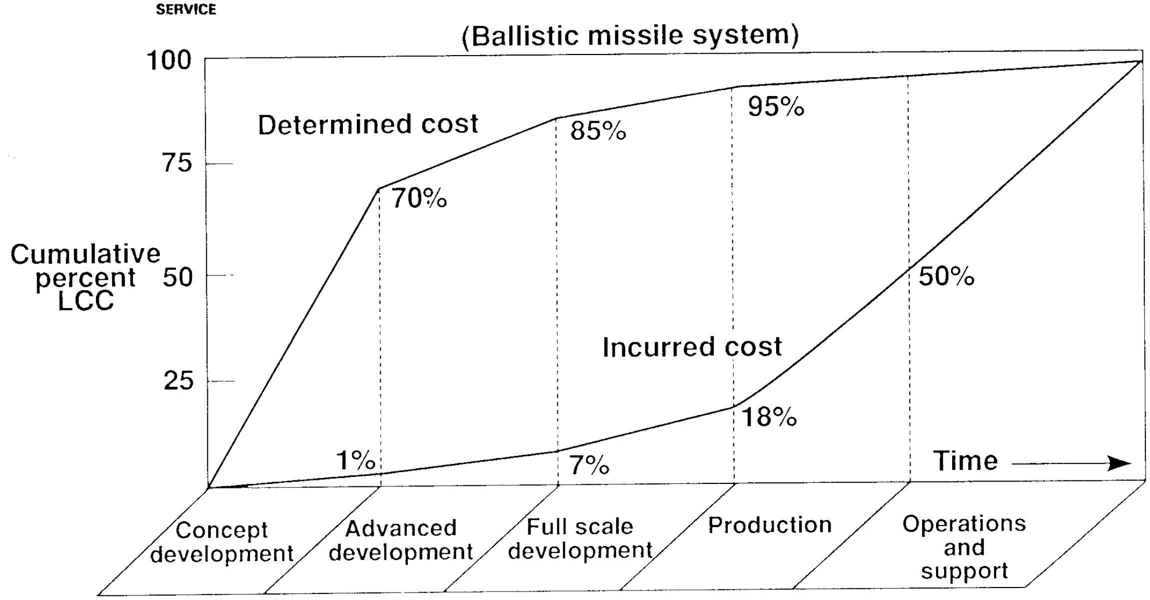
The DoD Acquisition Process and Its Interfaces



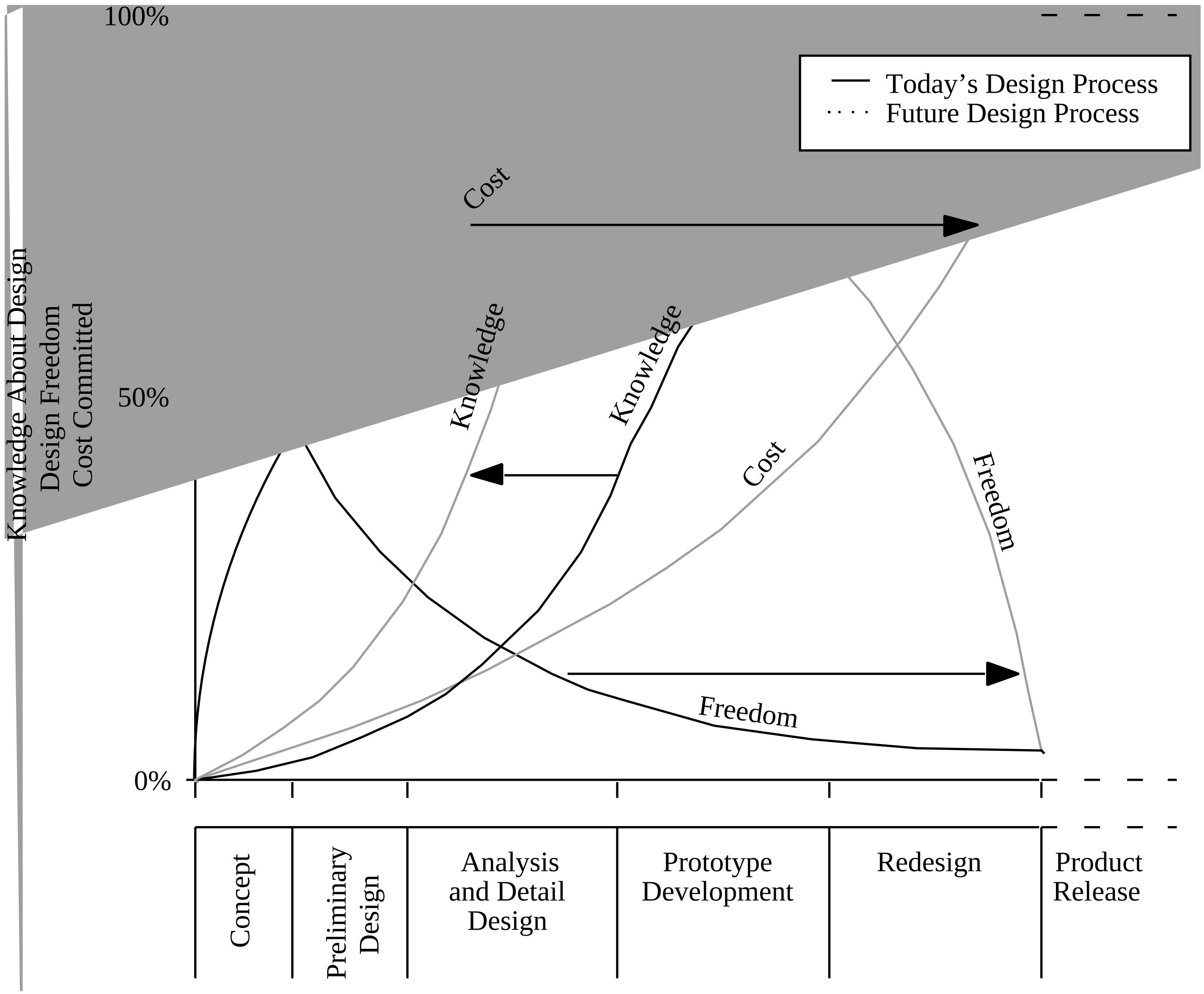
Life Cycle Costs Get Locked in Early for Complex Systems





Source: Boeing Company

Desired Paradigm Shift From IPPD



Cost As an Independent Variable (CAIV)

- An acquisition management concept wherein cost goals are achieved through tradeoffs between cost, schedule, and performance. Cost, as an independent parameter, is addressed as part of the acquisition process. Sample CAIV goals are:
- Design to Unit Production Cost (DTUPC) goal:

  Achieve the delivered unit production cost goal.

  Life Cycle Cost (LCC) goal:

  Minimize the total cost for the customer to acquire, operate, support, and dispose of the system.
- Making design converge on cost rather than allowing cost to converge on design; and, ...where cost is elevated to the same level of concern as performance and schedule.
- (Albert, N., 18th ISPA Conf.)

Cost As an Independent Variable (CAIV) Government Perspective

- **Guidance**

  - USD(A) policy memo requires that the acquisition process must consider both performance requirements and fiscal constraints

  - Cost must be an independent variable in programmatic decisions, with responsible cost objectives set for each program phase

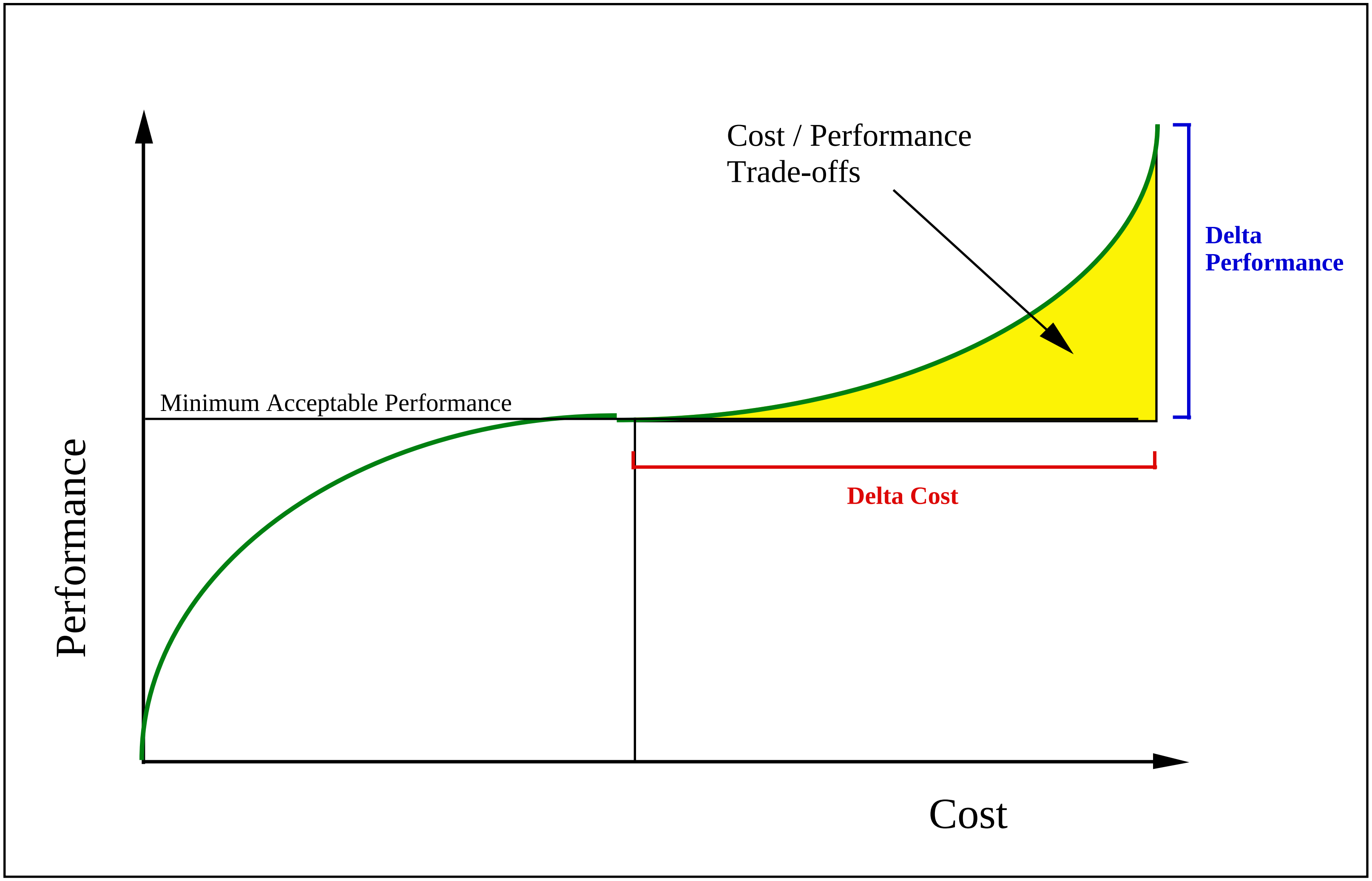
- **Considerations**

  - System performance and objective cost are decided on basis of cost-performance trade-offs.

  - Cost performance trade-offs and requirements trade-offs will impact operational capability requirements documents.

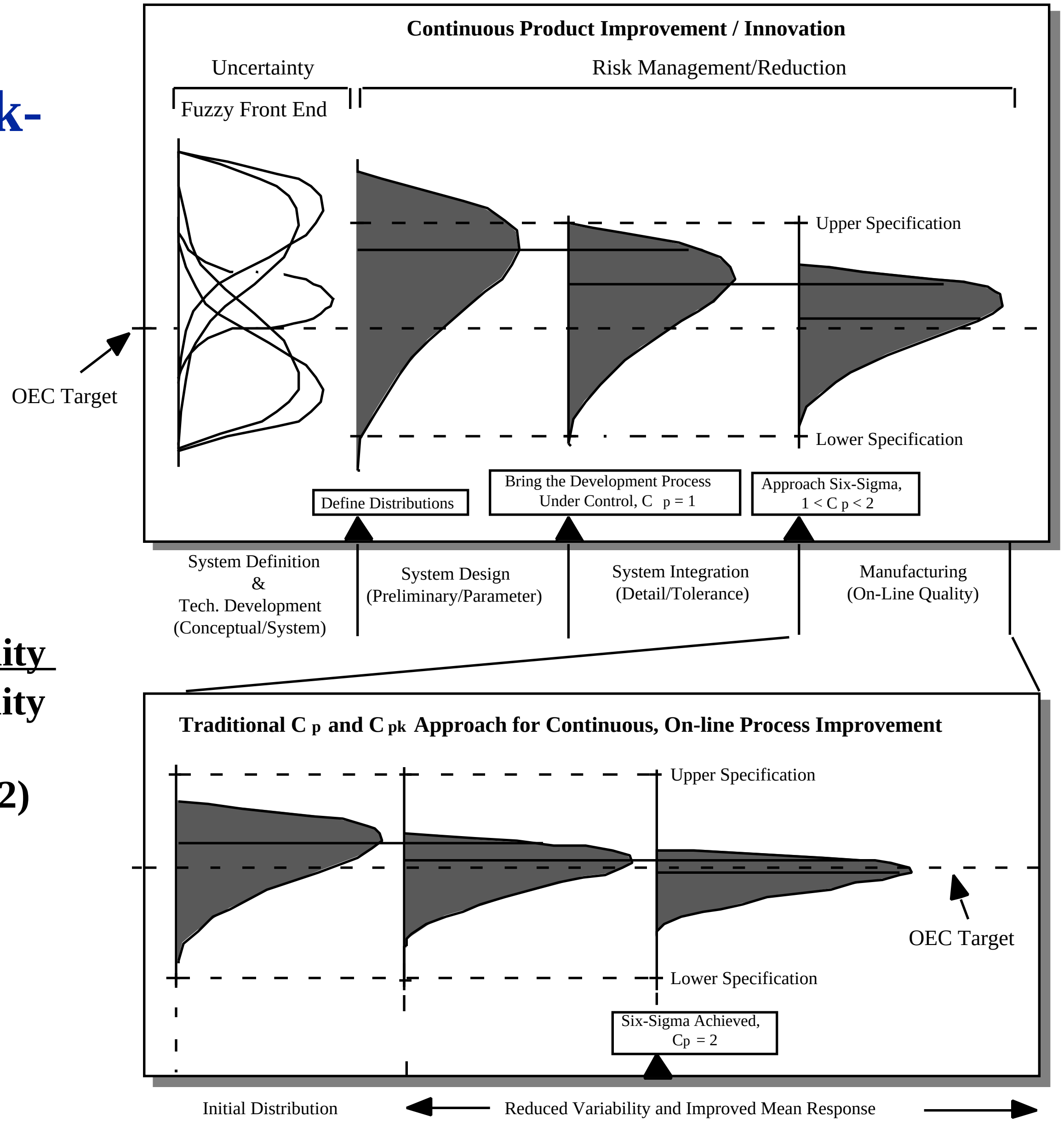
  - Cost performance trade-offs and requirements trade-offs will impact analysis of alternatives.

Affordability is Benefit-Cost Tradeoff, *Not* Just Cost Reduction



Uncertainty and Risk-

Variation Reduction along the Design Timeline



C_P = ratio of $\dfrac{\text{product capability}}{\text{process capability}}$

(e.g. Six-Sigma indicates C_P = 2)

Robust Design

A robust design is capable of operating efficiently in a wide variety of environments, not just a single design-point situation.

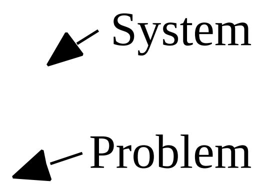
- A robust design is a design with minimal variance due to external noise factors that are beyond the designer's control
- A robust design is one that is well balanced and capable of performing well in all environments.
- For one example, a robust airliner design is insensitive to changes in economic noise parameters such as the cost of fuel.

Open Systems

- Keeping a system open so that it can be flexibly manufactured and upgraded for a variety of customers requires direct involvement of the early RD&A community.
- Instead of designing point optimal solutions, satisficing solutions are sought which are easily tailored for a variety of products with different levels of technology.
- Open systems require robust design techniques where designers and technologists set specification limits and technology goals that allow variability when uncertainty and risk are highest. This keeps the design freedom open.

Solution Strategies

Traditional Approach:



Optimal Solution

Problem Deviation

Solution Becomes Invalid

Satisficing Approach:

Satisficing Solution

Problem Deviation

Solution Remains Valid

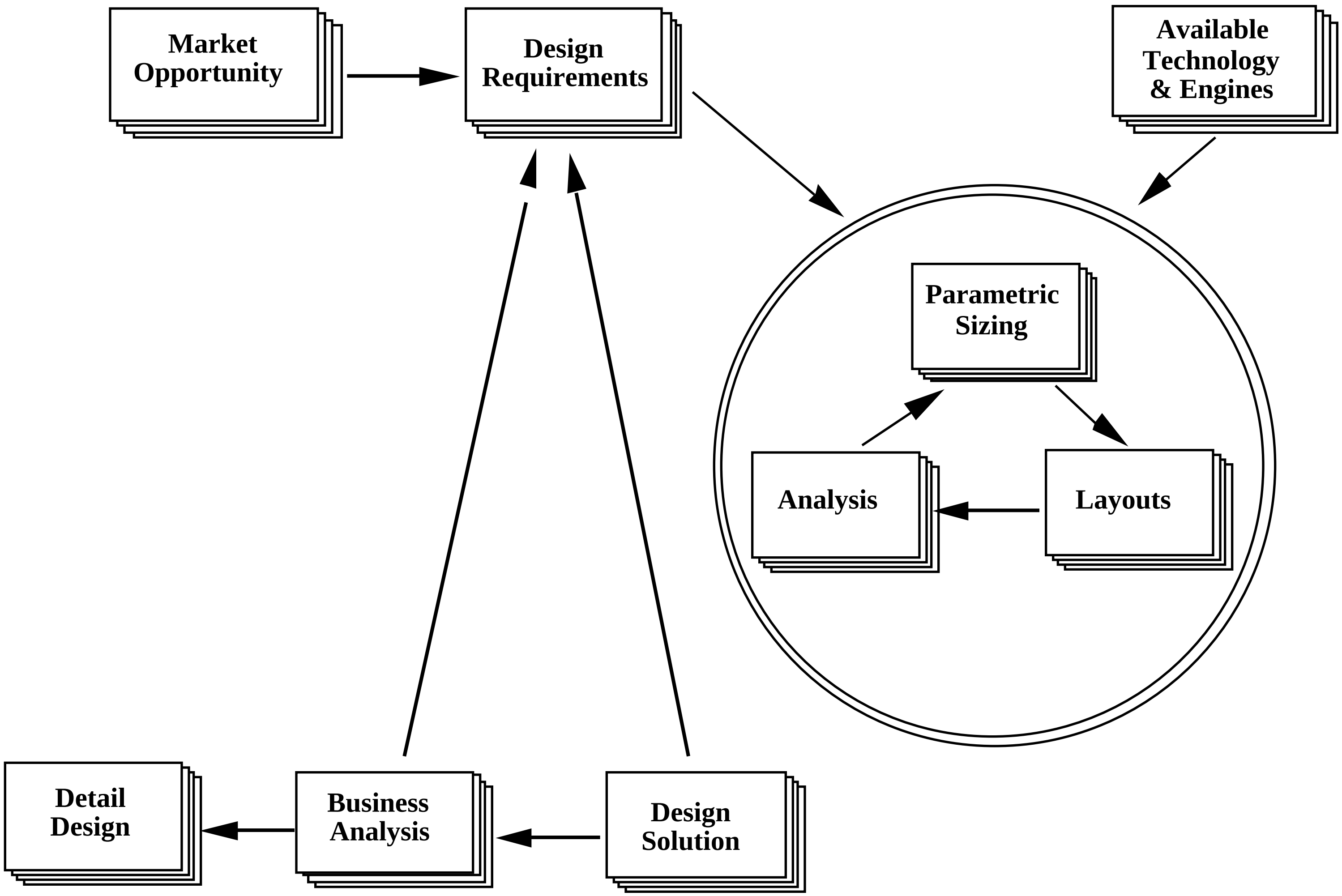
Solutions Along a Timeline

Satisficing Approach Earlier...

..becomes Traditional Approach Later.

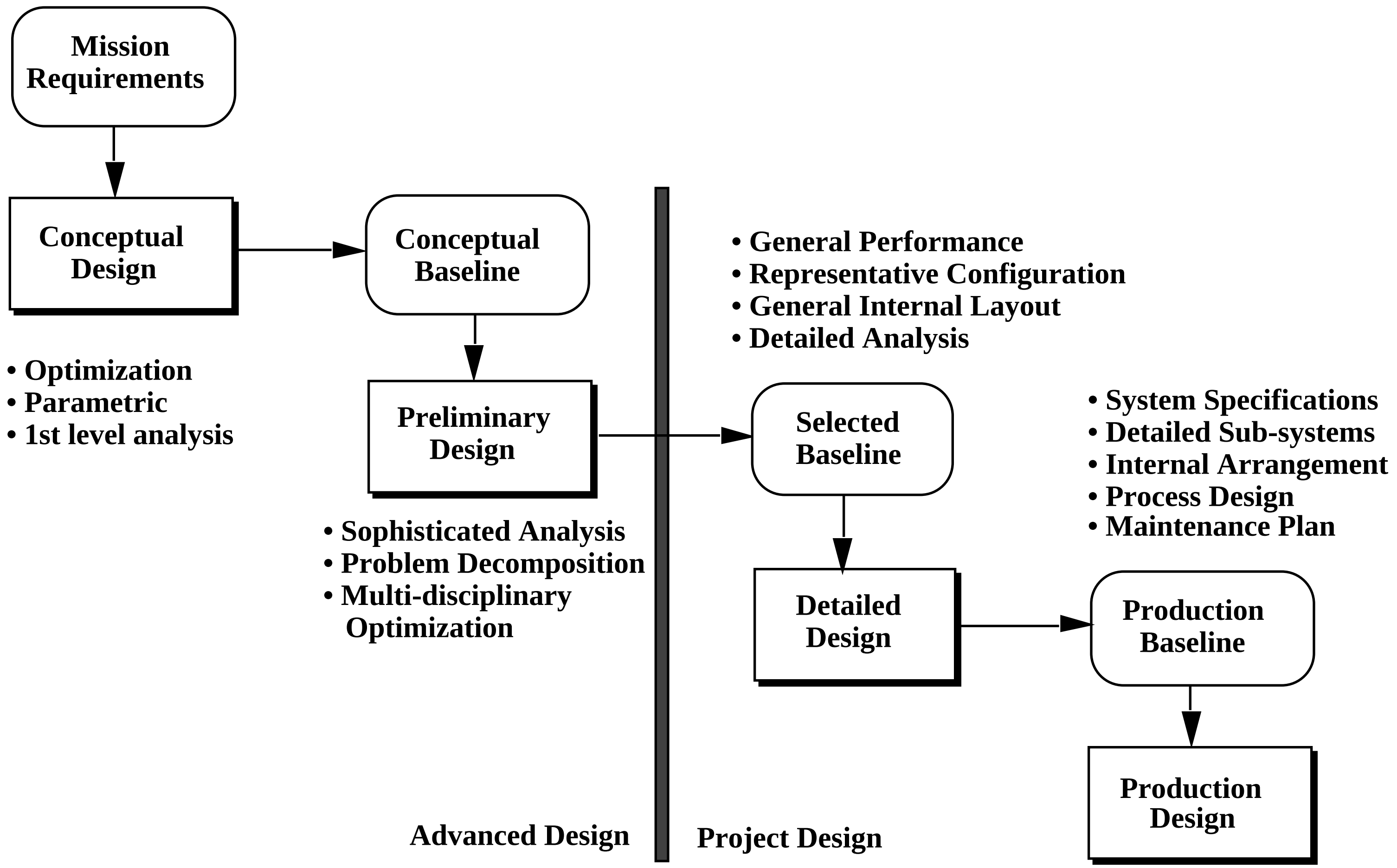
Commercial System

Conceptual and Preliminary Design Process



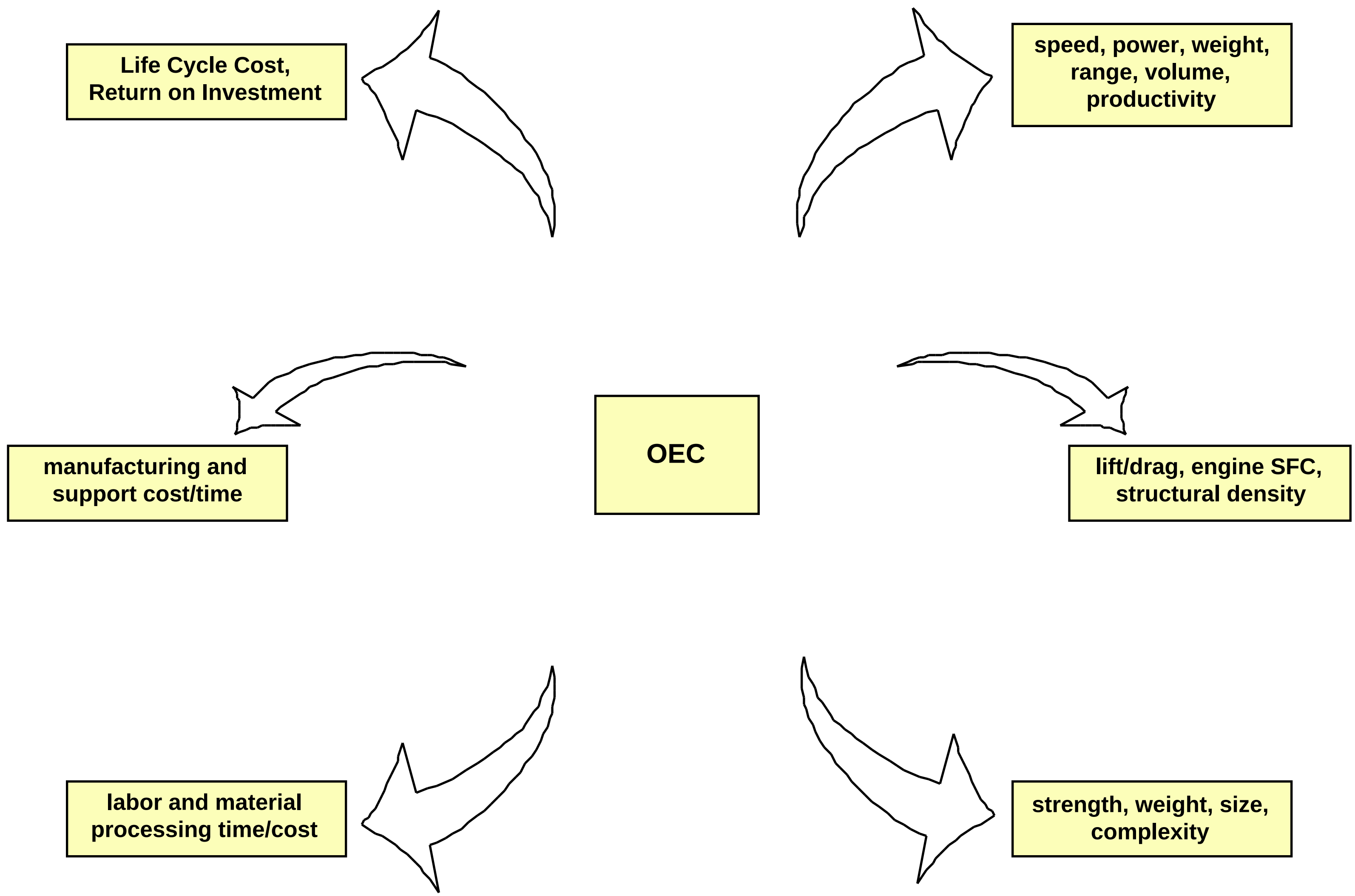
Traditional Development Process

Using Systems Engineering *Only*



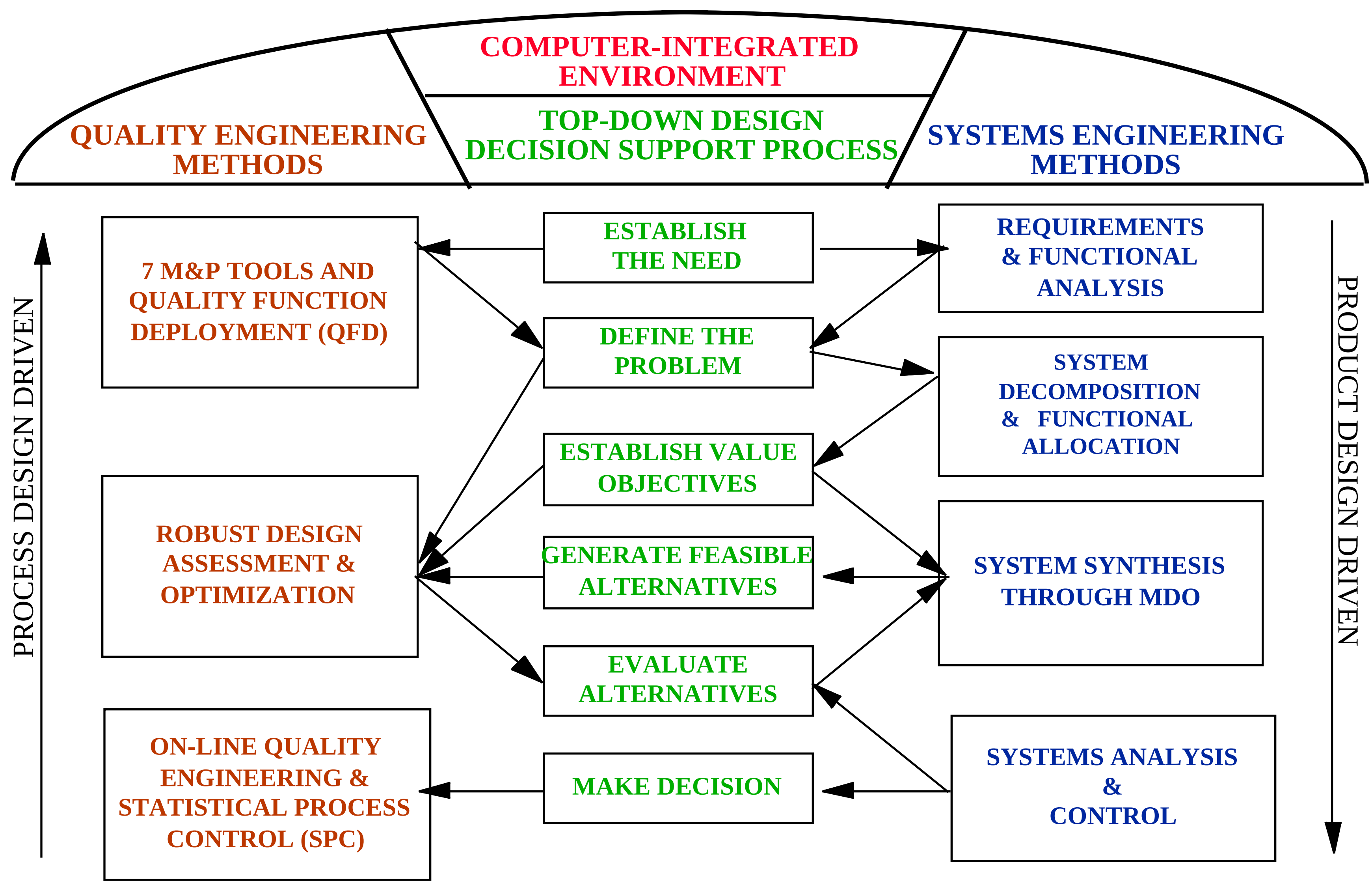
IPPD As the Integrating Function during Decomposition and Recomposition

Product/Process Metrics for Design Trade-Offs at Various Levels of Decomposition and Recomposition



National Center for Advanced Technologies

A Generic IPPD Methodology



Georgia Institute Of Technology Texas Instruments

What Methods and Tools are Required for Use in an IPPD Methodology ?

- **Systems Engineering** methods and tools because they provide *system decomposition* through functional analysis and synthesis, along with system analysis and control
- **Quality Engineering** methods and tools because they provide *system recomposition* through statistical process control, robust design assessment & optimization, and adherence to the "voice of the customer"
- **Top Down Design Decision Support** methods and tools because they provide a flow path for cost-performance trades, the heart of what IPPD is meant to accomplish
- **Computer Integrated Environment** to provide the framework for integration of the other methods and tools in a timely manner through the use of advances in information-based technologies

The Decision Support Process

Establish The Need

Does a problem exist? Is a decision needed?
Is a decision possible?

↓

Define The Problem

Who are the customers? What are the requirements?
What is the scope? What is the environment?
Who is the decision maker? What are the resources?

↓

Establish Value Objectives

What design constraints and factors are to be considered?
- a. Feasibility (yes/no)
- b. Criterion Function

↓

Generate Feasible Alternatives

Accomplish functionality while considering feasibility criteria, including manufacture, support, operations, society, ethics, environment, legalities, and safety.

↓

Evaluate Alternatives

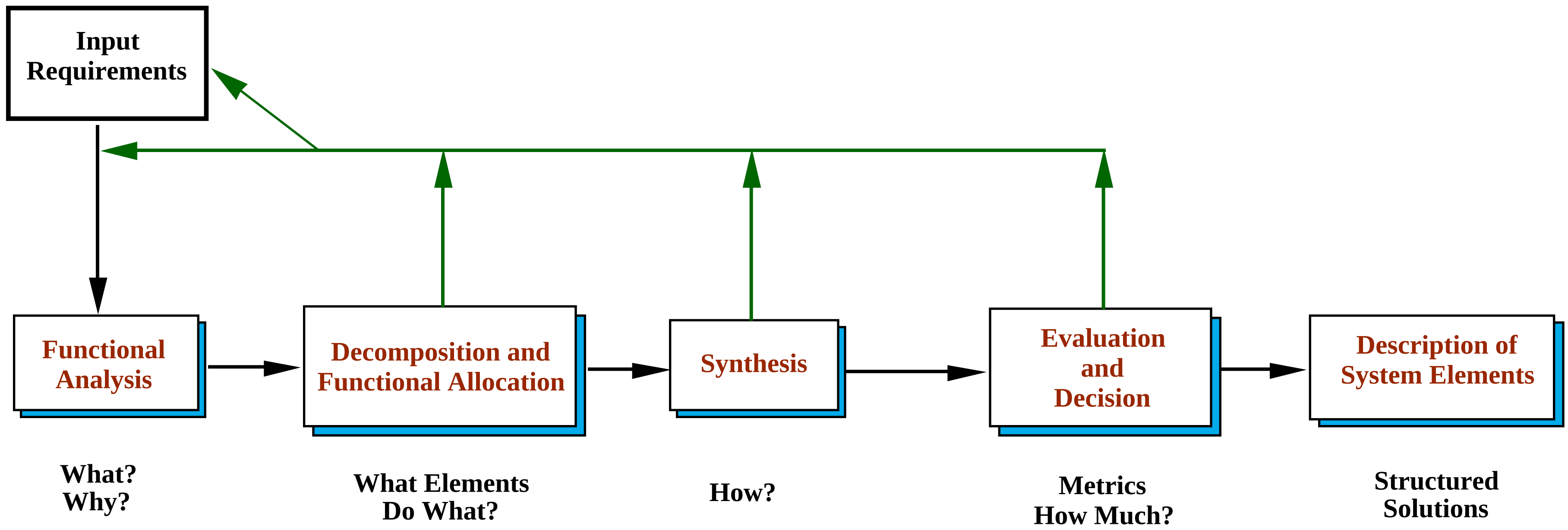
Apply the criterion function, including both objective measures and subjective factors.

↓

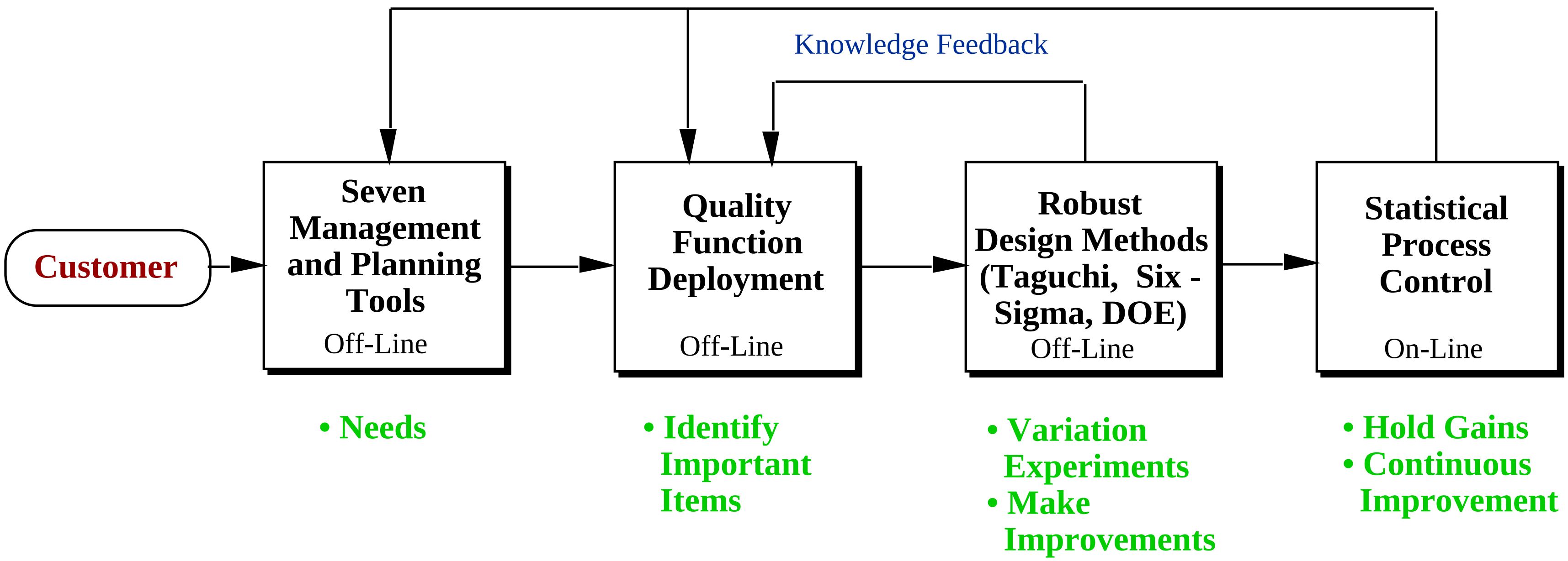
Make Decision

Choose the "Best" alternative and doccument the decision by describing why it is superior, what alternatives were considered, and what metrics were used.

The Systems Engineering Process



The Quality Engineering Process

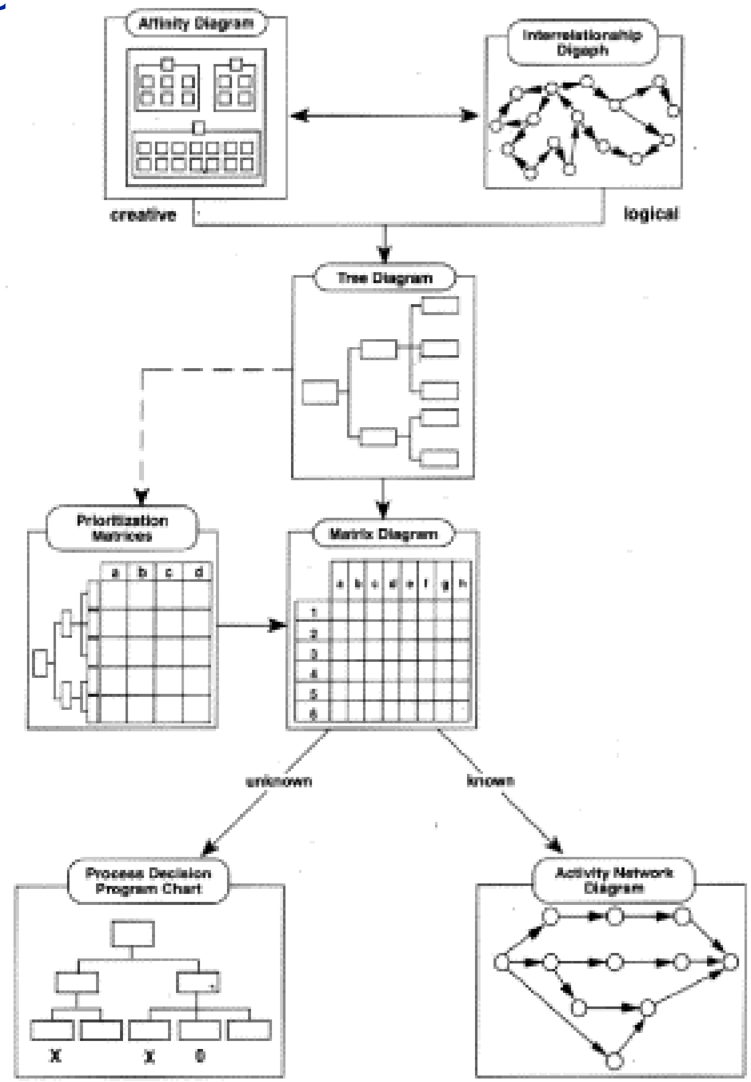


Flow Of the Seven Management And Planning Tools.

Brainstorming

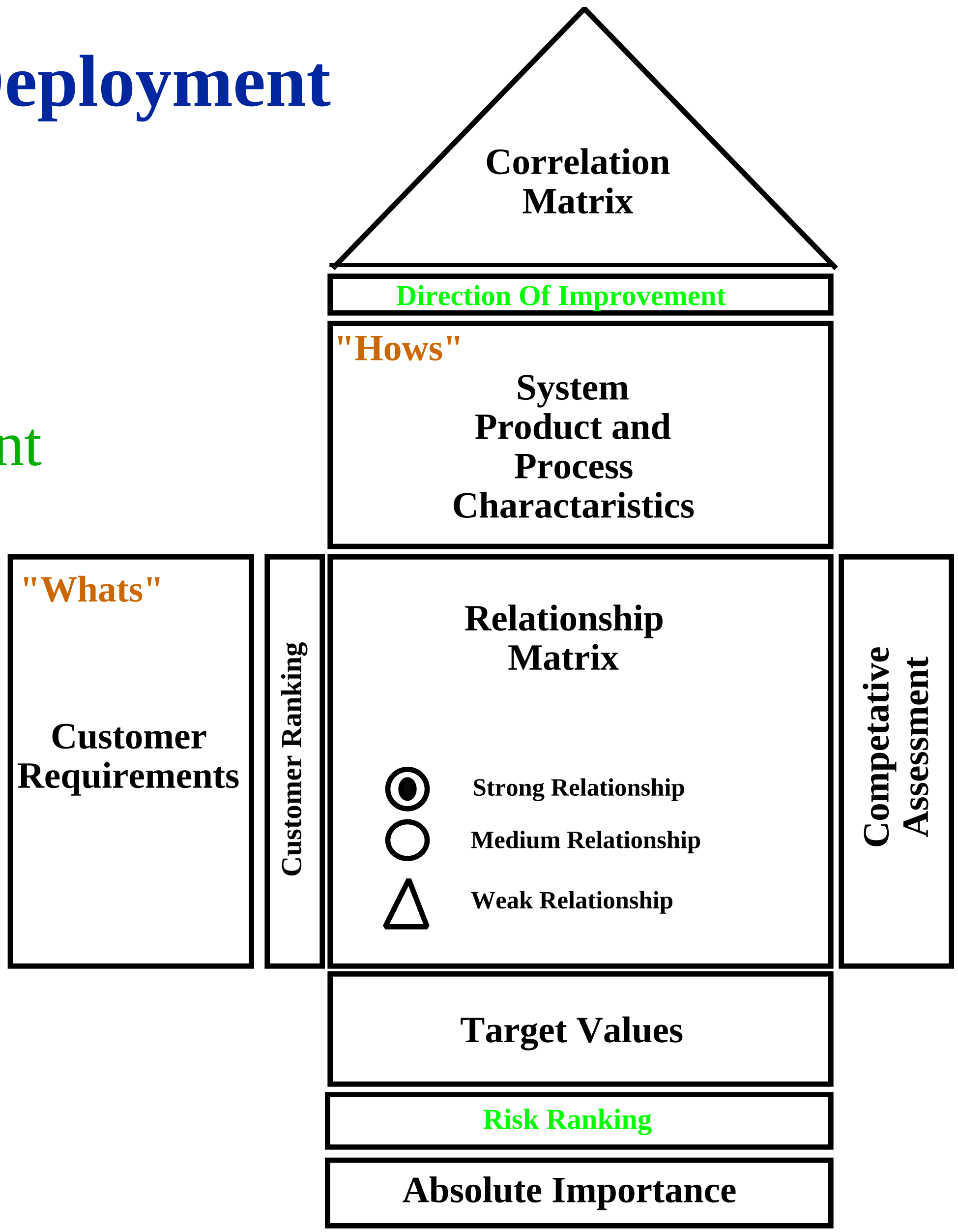
Organization & Ranking

Implementation & Process



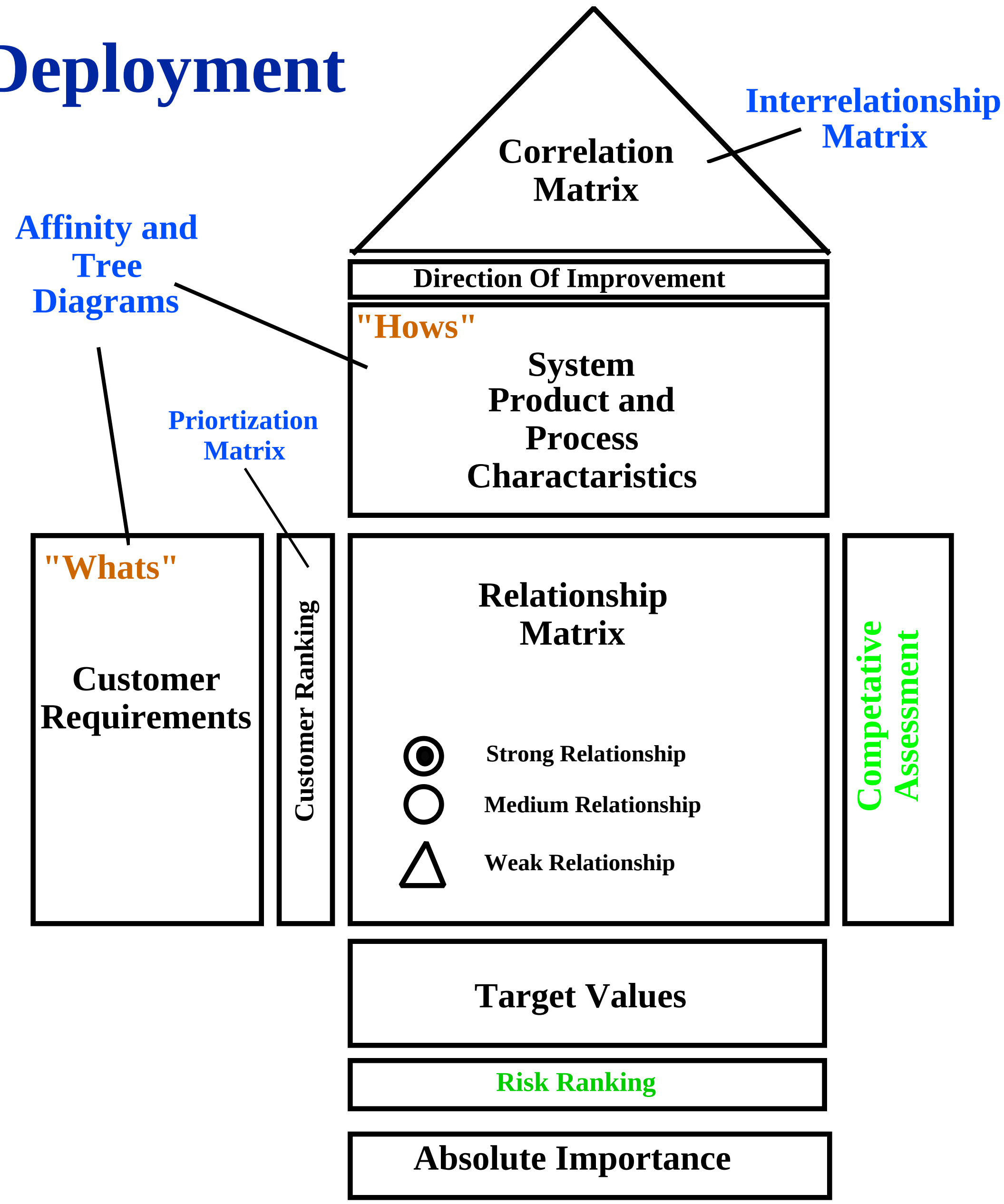
Quality Function Deployment

The Elements Of A Quality Function Deployment Matrix



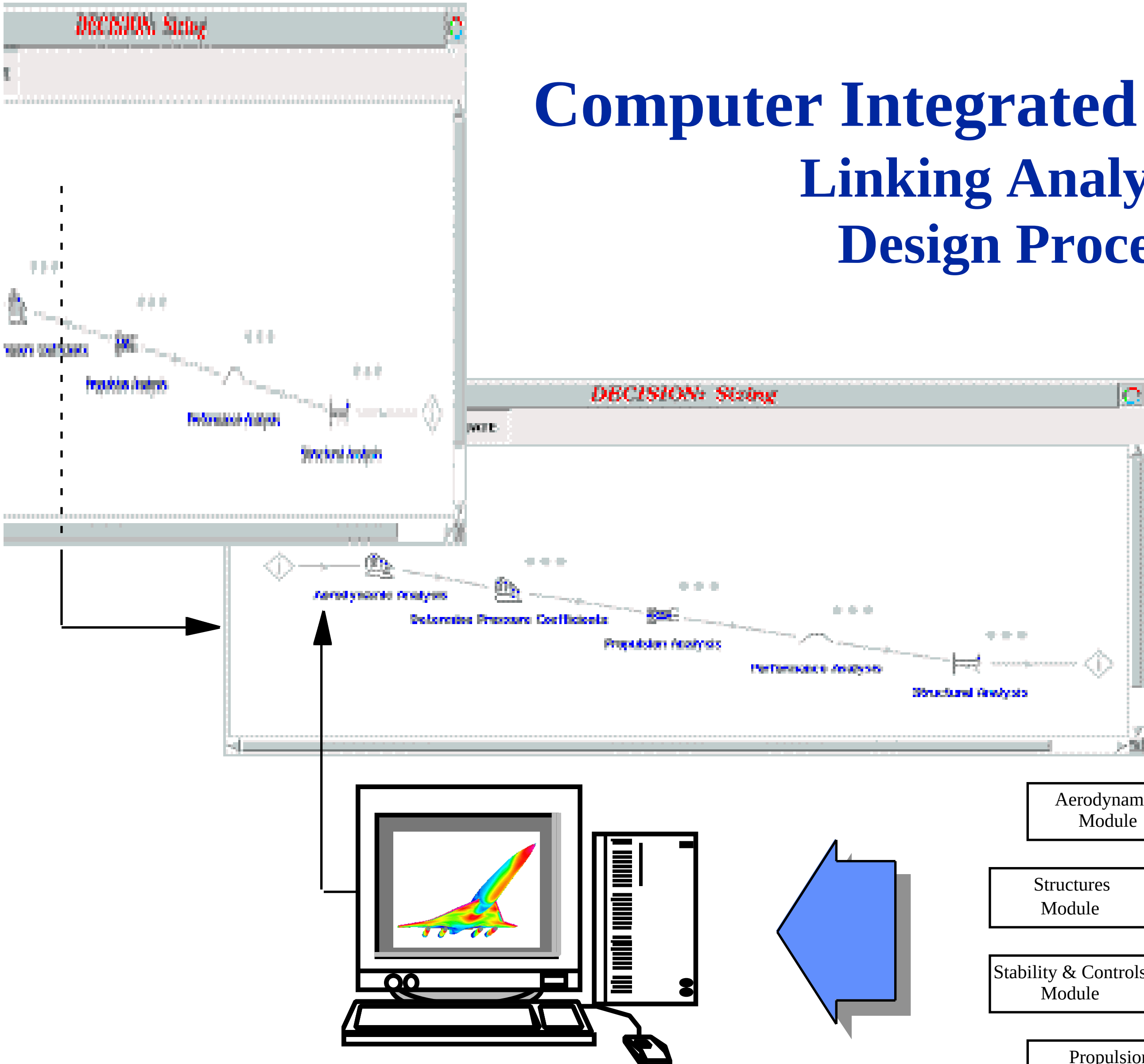
Quality Function Deployment

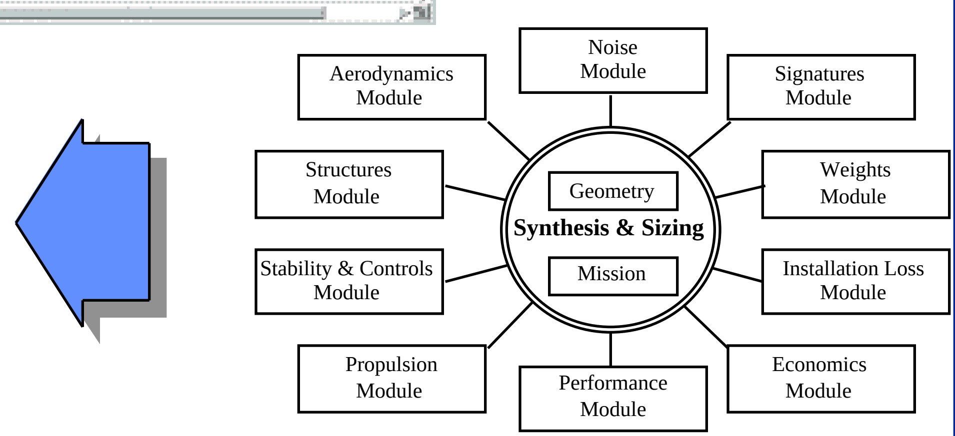
The Flow Of The
7 M & P Tools
Into a QFD matrix



Computer Integrated Environment:

Linking Analyses to Design Processes





Conclusions and Summary

- **Reinvention of the DoD Acquisition Process**
  - **DoD 5000.1 and DoD 5000.2**
  - **rewritten to provide flexibility for implementation**
- **IPTs practicing an IPPD Methodology**
  - **major document themes such as Teamwork, Tailoring, Empowerment, Commercial Products and Best Practices**
- **IPPD as the "integrating function"**
  - **required for successful execution with inclusion of various engineering and management initiatives (Six Sigma, CAIV,...)**
  - **must be implemented as early as possible in the acquisition process.**

Six Sigma

A Design Method for Integrated Product and Process Development

Mr. Ron Randall
Texas Instruments, Inc.
The Six Sigma Academy

Acknowledgment:

This presentation applies *Six Sigma* concepts developed by Motorola, Inc. These concepts include associating an equivalent *sigma* with a given defect level, a measurement of customer perceived quality using defects per unit (DPU), and the Six Steps to Six Sigma.

What is Six Sigma?

Six Sigma is a:

- **method**
- **metric**
- **benchmark**
- **stretch goal**

Six Sigma has become a metaphor for

World-class Quality

Definitions for Six Sigma

- Six Sigma is a way to measure the probability that a product being developed will have almost no risk.
- The probability of success is > 99.99966 % for each six sigma product characteristic.

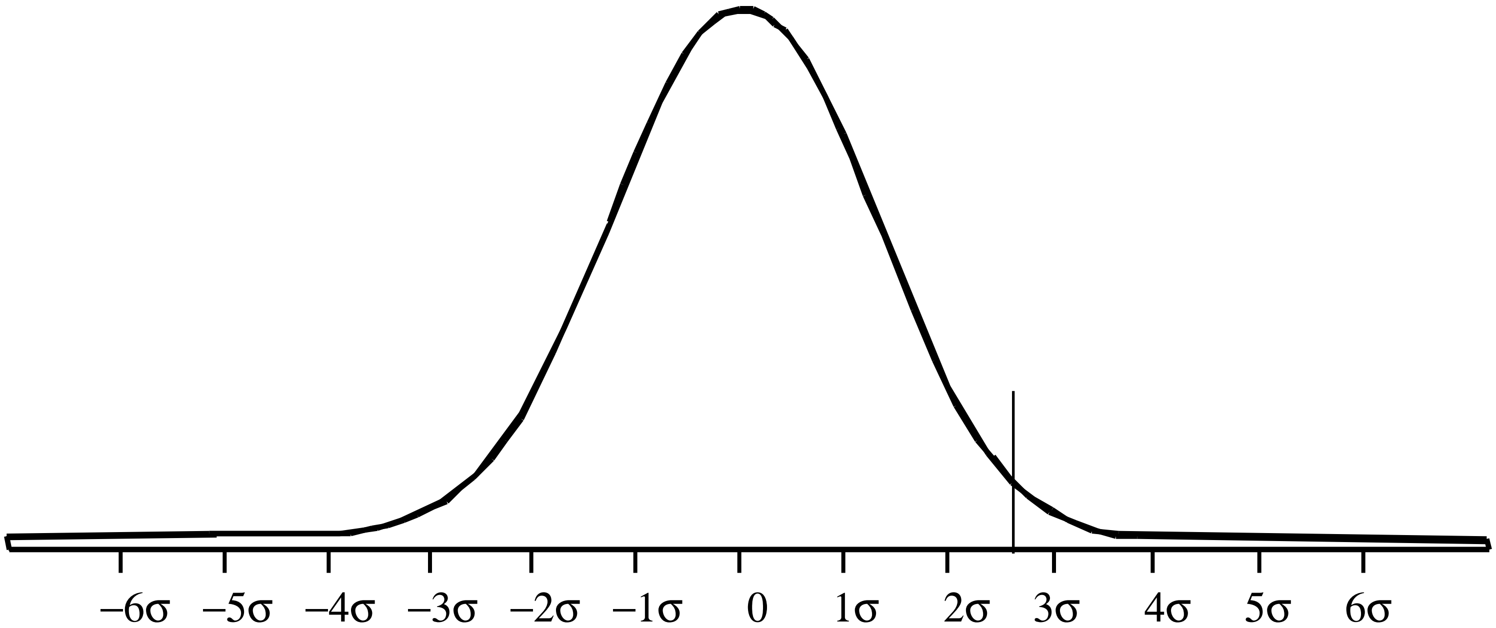
Definitions for Six Sigma

- Six Sigma is a way to measure the chance that a unit of product or a work process can be manufactured or performed with virtually zero defects.
- For variables, Six Sigma is $Cp \geq 2$ AND $Cpk \geq 1.5$
- For attributes, Six Sigma is no more than 3.4 defects per million.

Why Six Sigma?

- The application of Six Sigma concepts to advanced technology projects increases the predictability of the result.
- The Six Sigma metrics allow us to assess the risk associated with prototype development and with production based on that prototype.
- Risk reduction helps us more effectively invest increasingly scarce development resources in a rapidly changing and competitive environment.

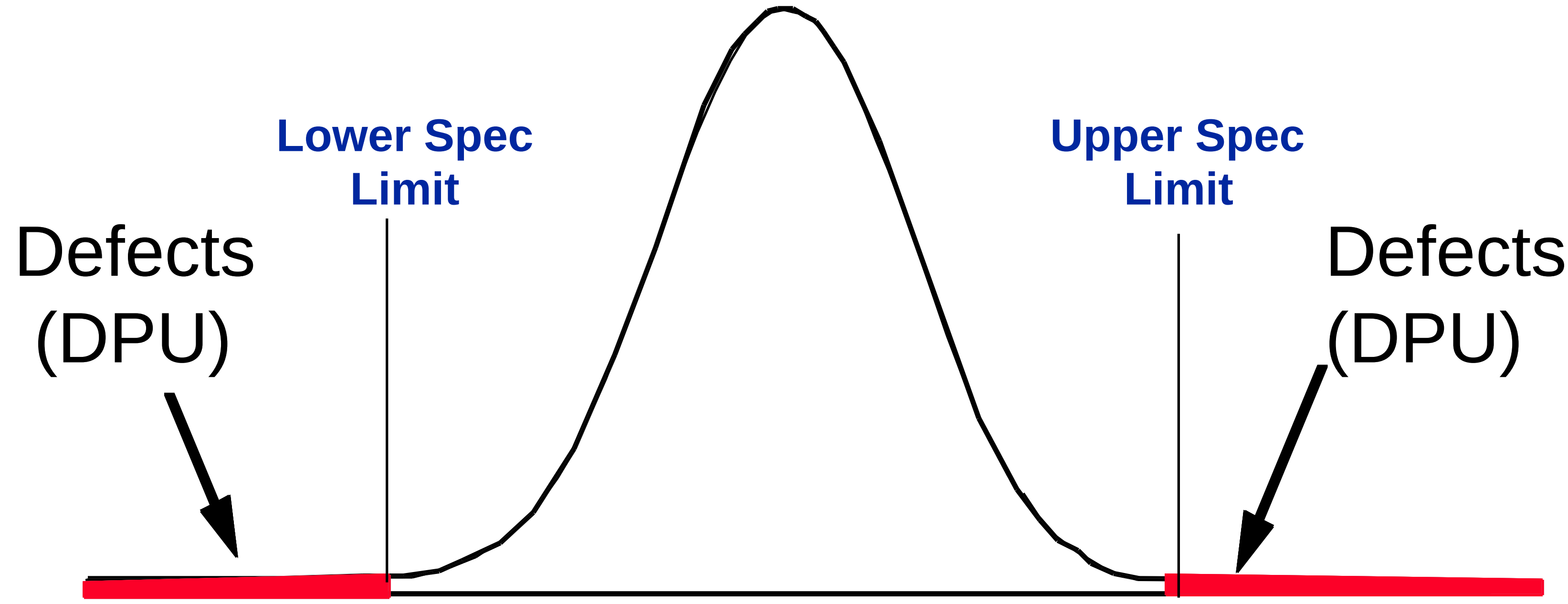
The normal distribution is used to estimate the probability of exceeding a value.



Probabilities for the normal distribution are found in Z tables.

What Causes Defects ?

The Capability does not meet the Requirement !



Process Capability Index

Cp

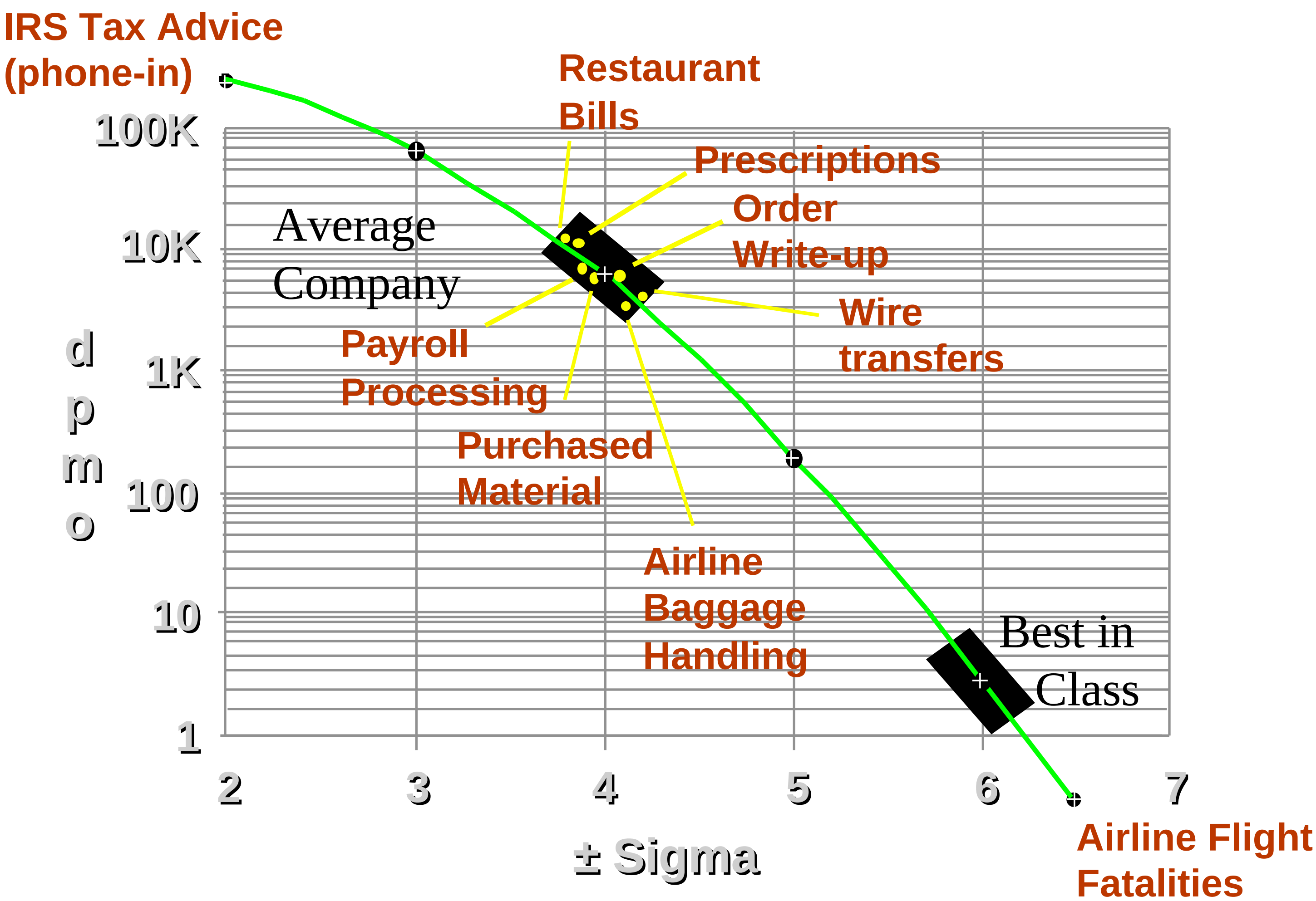
By Definition:

$$C_p = \frac{\text{Spec Width (road)}}{\text{Mfg Capability (car)}} = \frac{\text{USL - LSL}}{\pm 3\sigma}$$

Concurrent Engineering Index

Design / Manufacturing

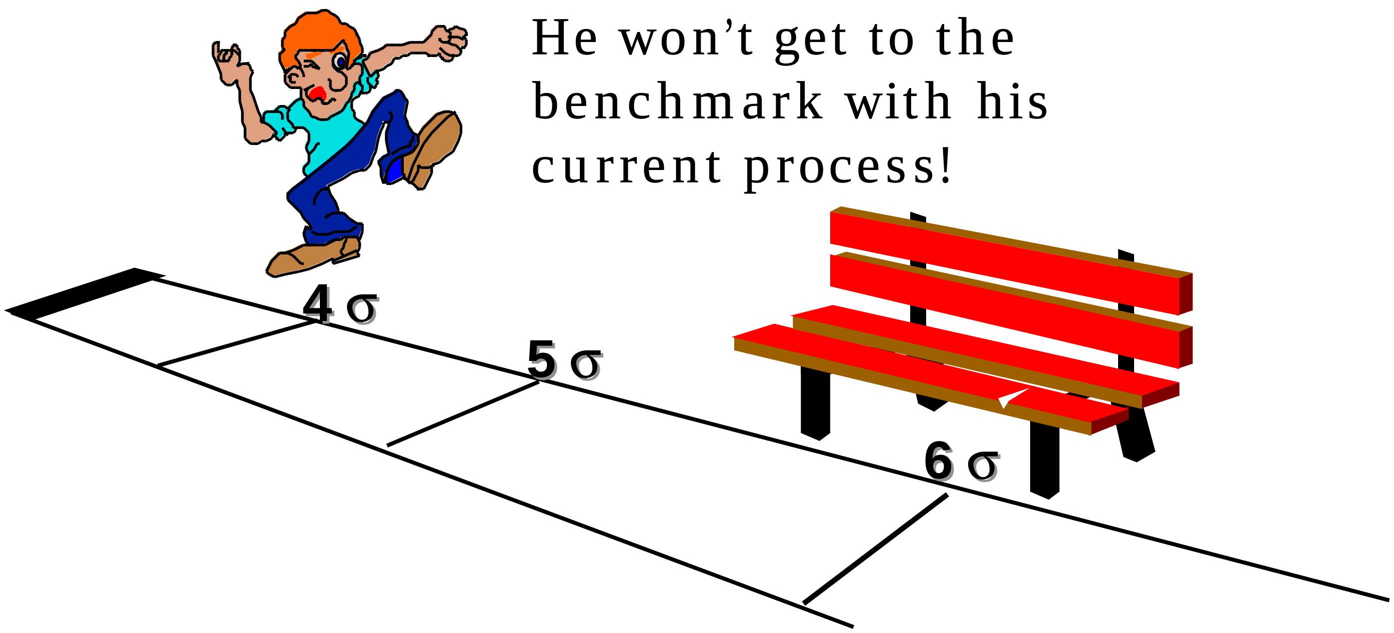
Benchmarking Different Services



Acknowledgement: Motorola

A Stretch Goal

- Six Sigma, the metric, quantifies the benchmark: “world class” quality
- Six Sigma, the method, is a set of principles to get to “world class”



Six Steps

For Integrated Product/Process Development Teams

1. Identify the customer’s physical and functional requirements.
2. Determine the product characteristics critical to each requirement.
3. Determine if the characteristic is controlled by the part, the process, or both.
4. Determine the target nominal and maximum tolerance allowable for each characteristic.
5. Determine the process capability for each critical characteristic.
6. If Cp< 2 OR Cpk< 1.5, redesign the product or process as required.

± 6 Sigma Spec Width

Shifted Mean

Cp = 2

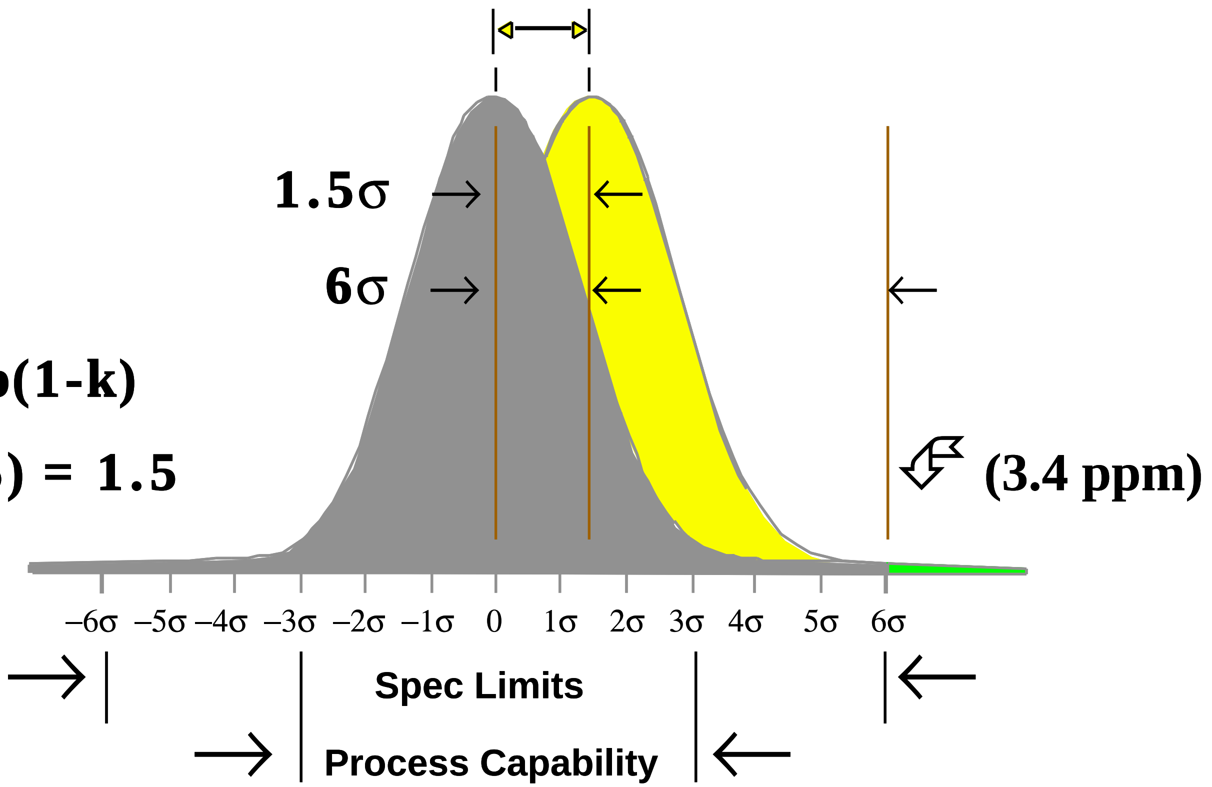
k = $^{a}/_{b}$

a =

b =

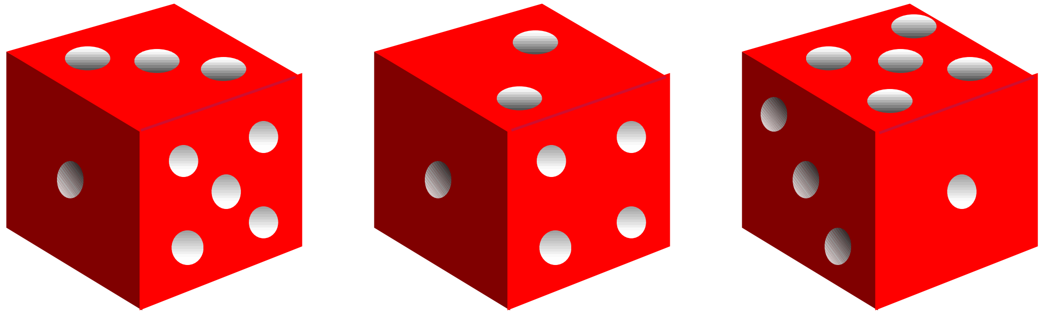
Cpk = Cp(1-k)

= 2(1-.25) = 1.5



Combined Probability of Independent Events

Probability of not throwing a 1 on any of 3 die:

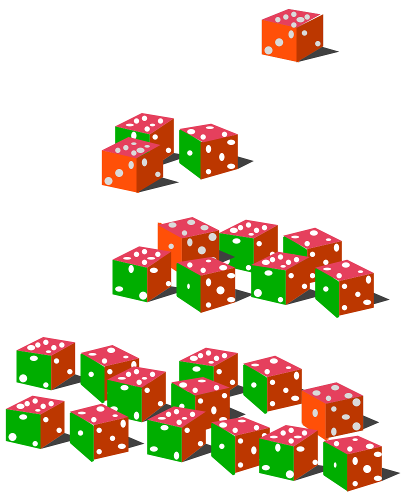


$$\frac{5}{6} \times \frac{5}{6} \times \frac{5}{6} =$$

57.87% =

Rolled Yield

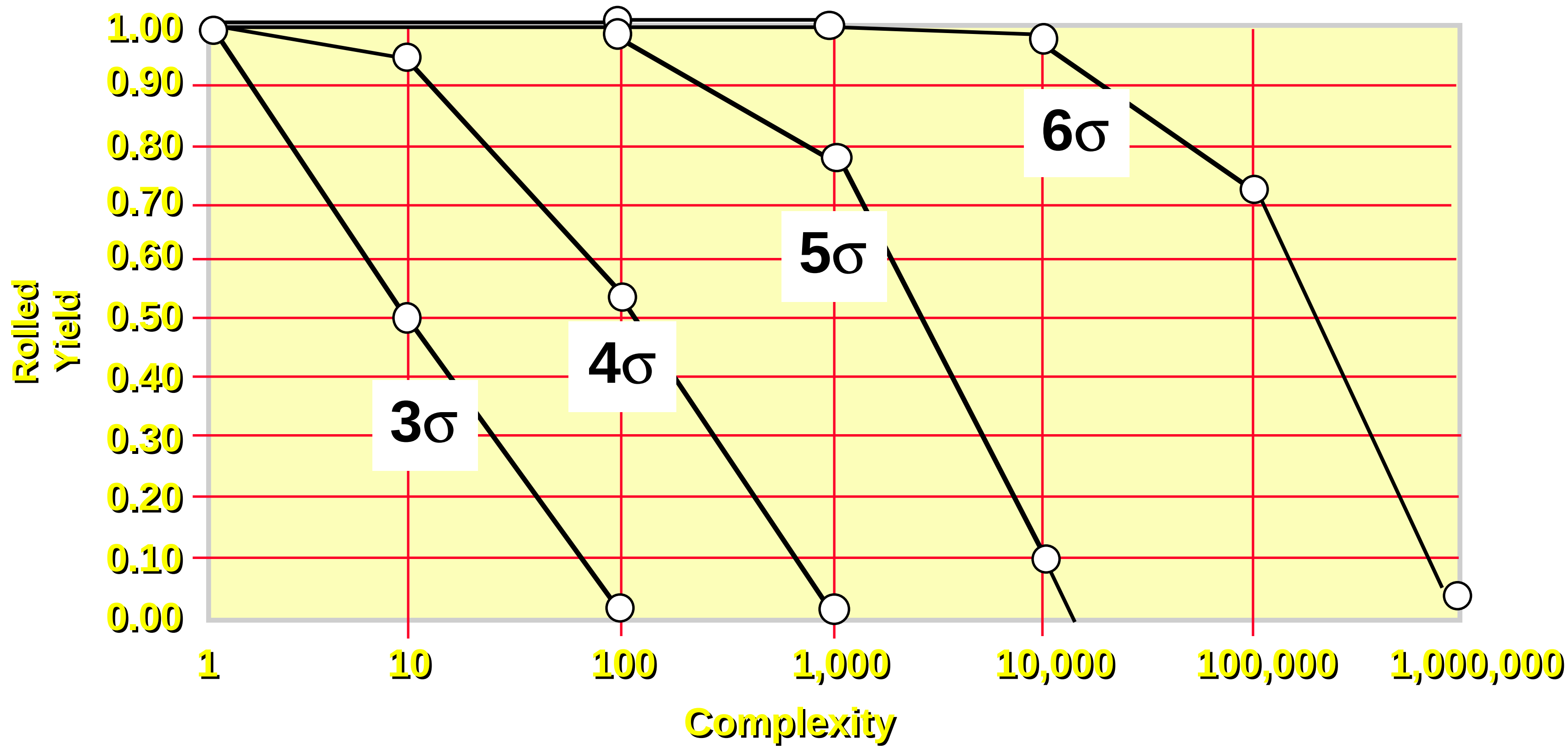
Probability of Not Rolling a One



# of dice (x)	$RY = Y_1^x$
1	83.33%
3	57.87%
10	16.15%
30	.42%
50	.01%
100	--

Yield and Complexity

(Distribution Shifted ± 1.5 σ)



Long-Term Performance

Scorecard Concept

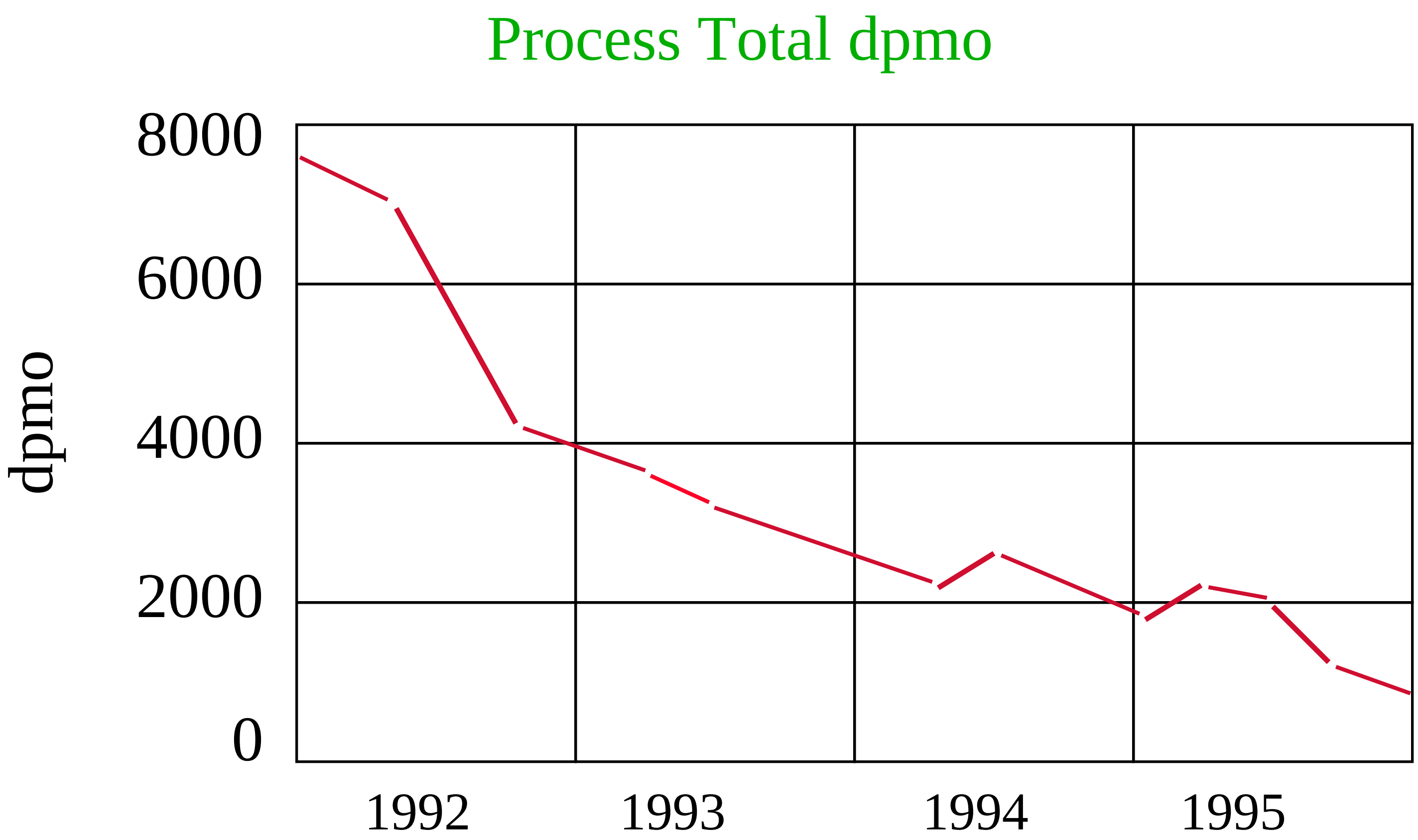
PROCESS | **PERFORMANCE** | **SOFTWARE**

Defects in Fabrication and Assembly

Defects in Test

Defects in Software

The Results


Process Total dpmo
dpmo
8000
6000
4000
2000
0
1992
1993
1994
1995

Why Six Sigma?

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IPPD Case Studies

A Collection Of Lessons-Learned From Defense Programs Utilizing IPPD

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Case Studies For IPPD

- The objective of this presentation is to present *Lessons Learned* from several defense programs that have utilized IPPD in the design and development of a complex system.
- For each program, the use of one or more IPPD tools will be focused upon.
- The following are Case Studies for the implementation of IPPD Principles and IPPD Tools:
  - Next Generation Soldier (ATD)
  - New Attack Submarine
  - Low Cost Interferometric Fiber Optic Gyro
  - Tier II UAV (Global Hawk)
  - Autonomous Scout Rotorcraft Testbed (TD)

IPPD Principles Used

- **Next Generation Soldier**
  - Excellent Implementation of Integrated Product Teams
- **New Attack Submarine**
  - Seamless application of Modeling and Simulation, including Manufacture and Support
- **Low Cost IFOG**
  - Continuous Improvement of Process Using Six Sigma Process Capability Characteristics.
- **Global Hawk**
  - Streamlined the contracting process using *Other Transaction Authority* to reduce cost and time.

Conclusions

- An IPPD methodology creates an early attention to process design, and an evaluation of the capability to manufacture and support a particular design, *before it's finished*.
- Pulling the integration efforts forward into the design stage allows incremental development and thus *evaluation by the user*, before it's too costly to change.
- Customization of the IPPD process with methods and tools to attain a central decision flow supports different program goals for affordability. IPPD is Descriptive not Prescriptive!
- Creating a team structure with distributed responsibility but effective leadership is still an art. Build On Success!

Recommendations

- Universal recommendations include:
  - Train as a team in all IPPD tools.
  - Build trust between government and contractor teams, so that innovative contracting mechanisms can be used smoothly.
  - Use process metrics such as Cp in the design stage.
  - Simulation can significantly lower cost and time, by reducing reliance on hardware prototypes.
  - Allow more time early in the program for IPTs and support system development.
  - Electronic connectivity and data sharing will become THE enabling technology for integrated development.