



Manufacturing and Producibility



TOPIC LEARNING OBJECTIVES

- Upon successful completion of this topic, the student will be able to:
- 1. Recognize the impact of manufacturing on cost, schedule and performance.
 - 2. Recognize the nine key elements of the Industrial Process.
 - 3. Recognize the magnitude of the fiscal commitment to a program in production and beyond.
 - 4. Identify the methods and objectives of manufacturing that influence system design.
 - 5. Recognize top-level design techniques for a producible product.
 - 6. Distinguish from among the types of tradeoffs that may be required to attain a producible design.
 - 7. Recognize Production, Quality, and Manufacturing as an integrated part of the Systems Engineering Process.

STUDENT PREPARATION

- Student Support Material
- 1. None
- Primary References
- 1. DoDD 5000 (series)
 - 2. Defense Acquisition Guidebook
- Additional References
- 1. DOD Manufacturing Technology (MANTECH) Program website: <https://www.dodmantech.mil>



Overview

- Life-Cycle Cost and fiscal commitments
- Nine key elements of the industrial process
- Systems design
- Production, Quality, Management (PQM) and Systems Engineering



Significance of Manufacturing/Production

- Fastest rate of expenditure
- Increased program visibility/oversight
 - DoD
 - Congress
 - Press
- Upon entering production, the program has committed to significant percentage of Life-Cycle Cost (LCC)
- Complexity of transitioning from design to manufacturing may impact performance
- Production phase frequently experiences schedule slippage and cost growth
- Need to balance ease of manufacturing against operations and maintenance, and tradeoff at appropriate level

**Congress
of the
United States
House of Representatives**

JOHN F. TIERNEY
MASSACHUSETTS
SIXTH DISTRICT

March 19, 2003

The Honorable Donald Rumsfeld
Secretary of Defense
U.S. Department of Defense
Washington, DC 20301-1155

Dear Mr. Secretary:

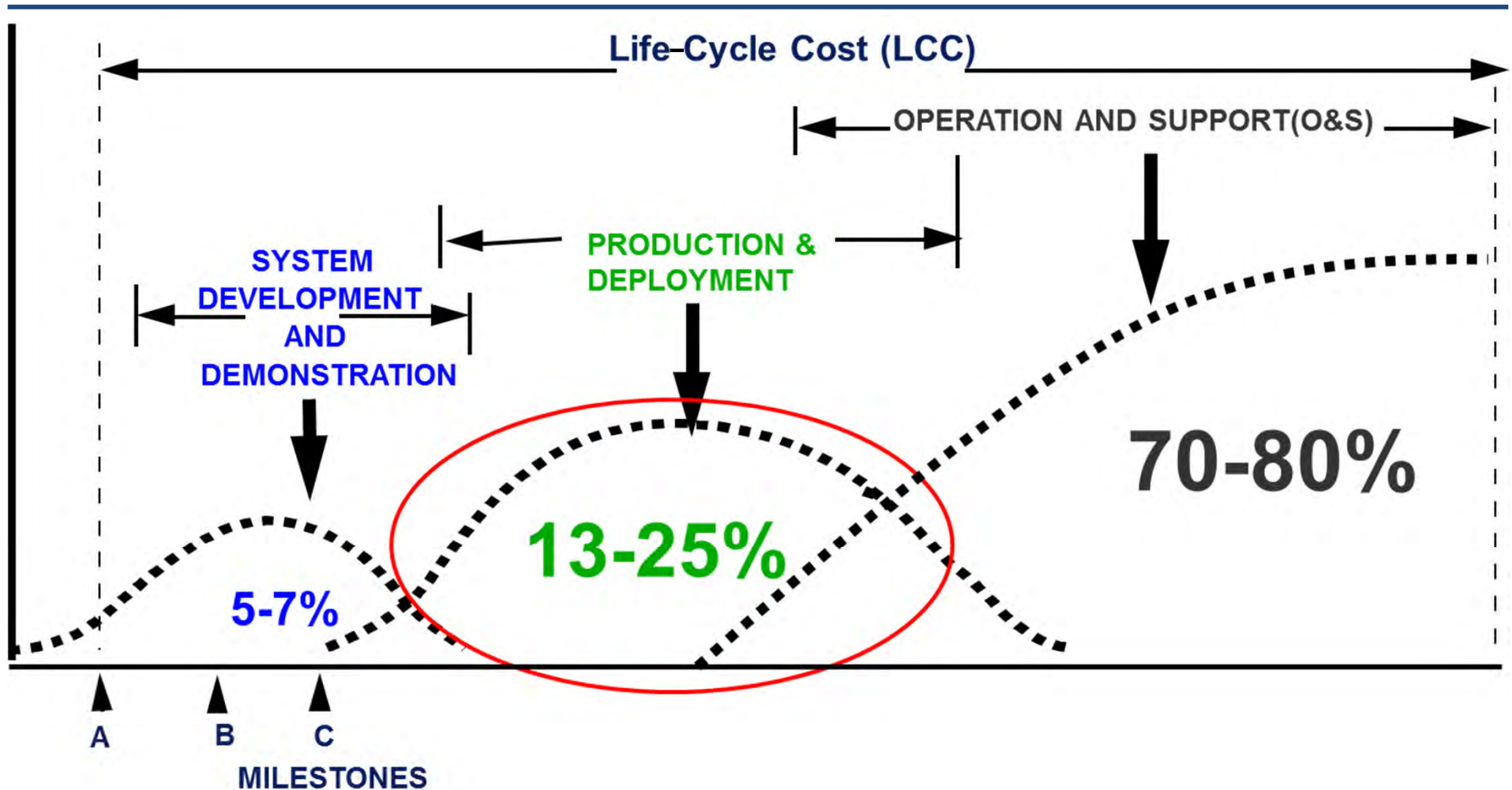
Based on the results of a recent report from the U.S. General Accounting Office (GAO), I am writing to express my disappointment regarding cost overruns in the F/A-22 Raptor program. I am also concerned with GAO's findings that the Defense Department has failed to provide Congress with specific information related to the total estimated cost of the F/A-22 production program or the quantity of aircraft that can be purchased within the cost limitation set by Congress. In anticipation of an upcoming Committee on Government Reform Subcommittee hearing, I request that you provide the specific information requested below.

As we reported in April 2003, cost increases have been a factor in the Air Force substantially decreasing the number of F/A-22 Raptors to be purchased—from 648 to 276.¹³ Moreover, current budget estimates, which exceed mandated cost limitations, are dependent on billions of dollars of cost offset initiatives which, if not achieved as planned, will further increase program costs. In addition, GAO considers continued acquisition of this aircraft at increasing annual rates before adequate testing is completed to be a high-risk strategy that could further increase production costs.

Good manufacturing practices result in a design that is cheaper and easier to build and a more stable, higher quality product



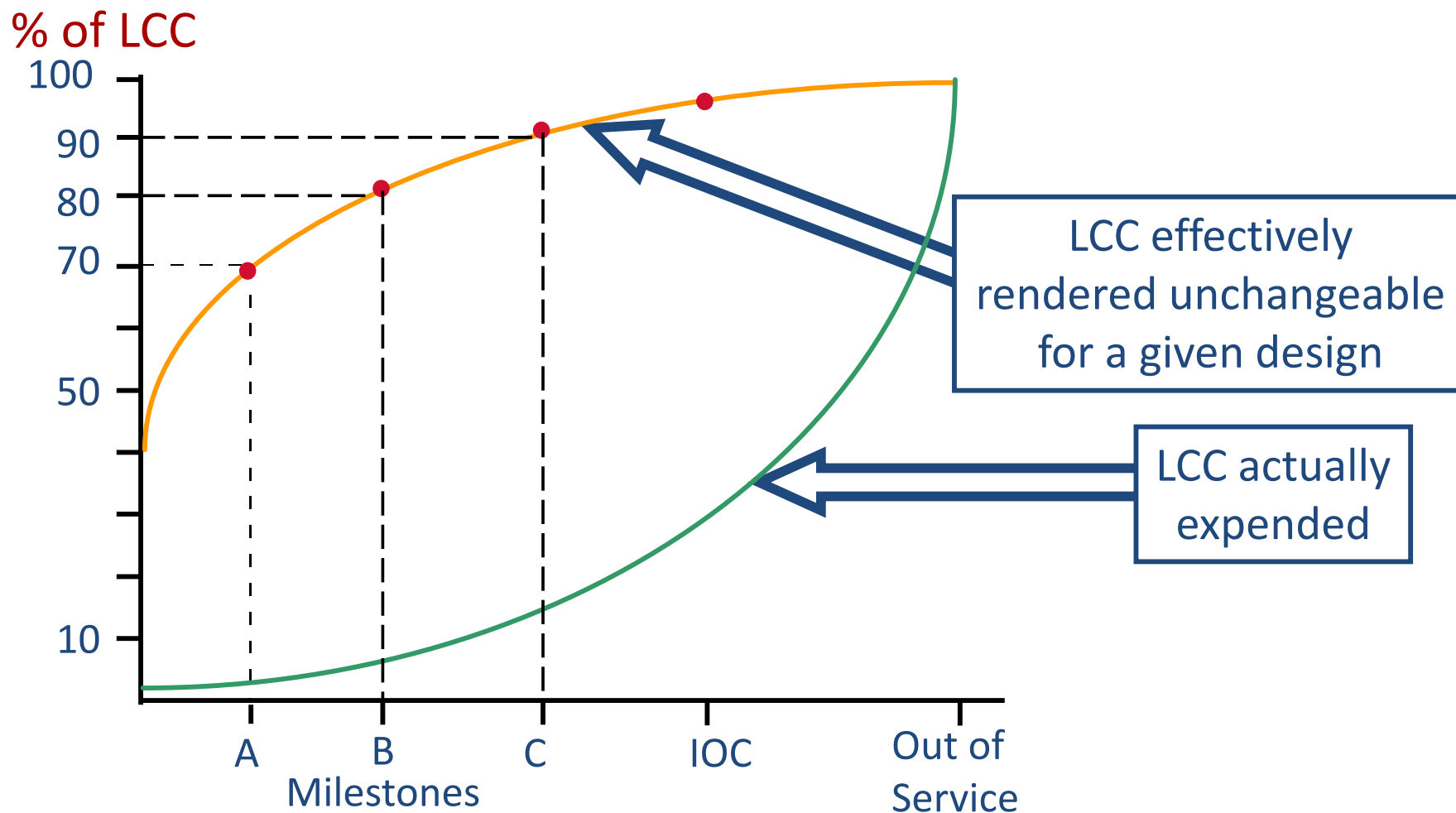
Life-Cycle Cost (LCC)



Production and Deployment phase has increased program visibility with fastest program expenditure rate



Financial Commitments



Early decisions affect Life-Cycle Cost (LCC) - About 90% of LCC “commitment” is unchangeable going into Production at Milestone C



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Nine Key Elements of the Industrial Process

- **Easily influenced by Program Manager (PM)**
 - Design – requires an analysis of the degree to which the identified, evolving or systems design will meet user requirements and the degree to which the design is new and unproven
 - Materials – requires an analysis of the risks associated with materials including basic/raw materials, components, parts, and subassemblies
 - Cost and funding – requires an analysis of the risk that the system development and deployment will not meet the DoD cost and funding goals
 - Process capability and control – requires an analysis of the risk that the manufacturing processes may not be able to reflect the design intent repeatedly and affordably
 - Quality Management – requires an analysis of the risk and management efforts to control quality and foster continuous quality improvement
 - Manufacturing planning, scheduling and control – requires an analysis of the orchestration of all elements needed to translate the design into an integrated and fielded system



Nine Key Elements of the Industrial Process

- **No direct control by PM**

- Technology and industrial base – if the assessment reveals significant concerns in these areas, the PM can budget/buy the tech data specs, the facilities, and the people to provide "uninterrupted maintenance support of the system and eventual disposal
- Facilities – requires an analysis of facility and infrastructure capabilities and capacity of Prime Contractor, Subcontractors, and suppliers
- Personnel – requires the assessment of the required skills and availability in required numbers of personnel to support the manufacturing effort

Acquisition Programs assess and manage the risk of the nine key elements to balance cost, schedule, and performance objectives



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Manufacturing Objectives and Design Influence

- **Producibility**
 - Degree to which the design of the system facilitates the timely, affordable, and optimum-quality manufacture, assembly, and delivery of the system to the customer
 - Development priority
- **Systems Engineering design objectives for manufacturing**
 - **Design:** Develop producible and testable designs
 - **Process:** Design and develop capable manufacturing processes
 - **Process Control:** Develop necessary process controls to satisfy requirements and minimize manufacturing costs
- These objectives should produce the following **conditions** to support successful **Full Rate Production Decision Review (FRPDR)**
 - Stable design
 - Proven manufacturing processes
 - Available production facilities and equipment



Design for Producibility

- A balanced design must take into consideration the inevitable tradeoffs that must be made among various functional areas. Some considerations include:
 - Changes made late in the development process or early in the production process are usually the most expensive
 - The **highest risk of failure** is most likely to occur in the **transition from system development to production**
 - A product can usually be produced by different methods, each with its own set of costs, and the optimum method should be determined early in the design process
 - Most costs associated with manufacturing are inherent in the design
 - An additional major cost driver is the logistics of obtaining materials. Material Unit Cost (MUC) rates have doubled between FY22-25



Methods/Techniques for Producibility

- The following methods are top level design techniques that may be used to achieve a producible design:
 - Use standard components
 - Use parts designed for ease of fabrication
 - Use multifunctional parts
 - Use a modular approach
 - Minimize assembly and fabrication requirements
 - Minimize total number of parts

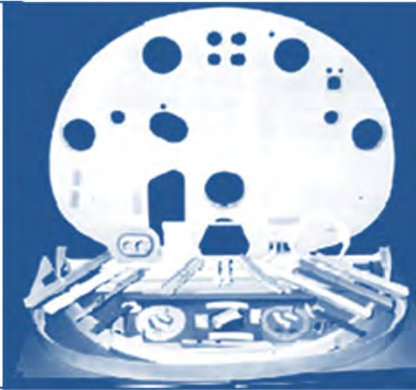


Applied Techniques for Producibility

Before:

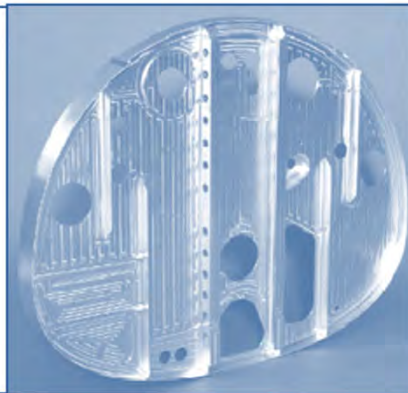
F/A-18 Example

Fab & Assy:	115.3 hrs
Part Count:	100
Tools Req'd:	95
Fastener count:	483
Weight:	16.5 lbs
Non-recurring costs:	\$1.3M
Recurring costs:	\$15k



After:

Fab & Assy:	39.5 hrs
Part Count:	56
Tools Req'd:	19
Fastener count:	~40
Weight:	13.8 lbs
Non-recurring costs:	\$0.3M
Recurring costs:	\$7k



- Another aircraft study:
 - > 50% of fasteners used < 20 times (with 44% used <10 times)
 - 12,000 bins required for production
- Destroyer example:
 - Fastener standardization on DDG-51 saves \$1.1M/ship
- Submarine example:
 - VIRGINIA class modular design and unified build strategy - \$2B per submarine

Reduced complexity saves money



Design Questions

- Are there requirements for producibility or sustainment that are measurable and enforceable?
- How are the design contract and contractual incentives structured to incentivize a producible and sustainable design?
- How are ship construction and sustainment teams incorporated into design at the Contractor/at the Government?
- How are the Contractor and Government design teams organized to get construction and sustainment expertise?



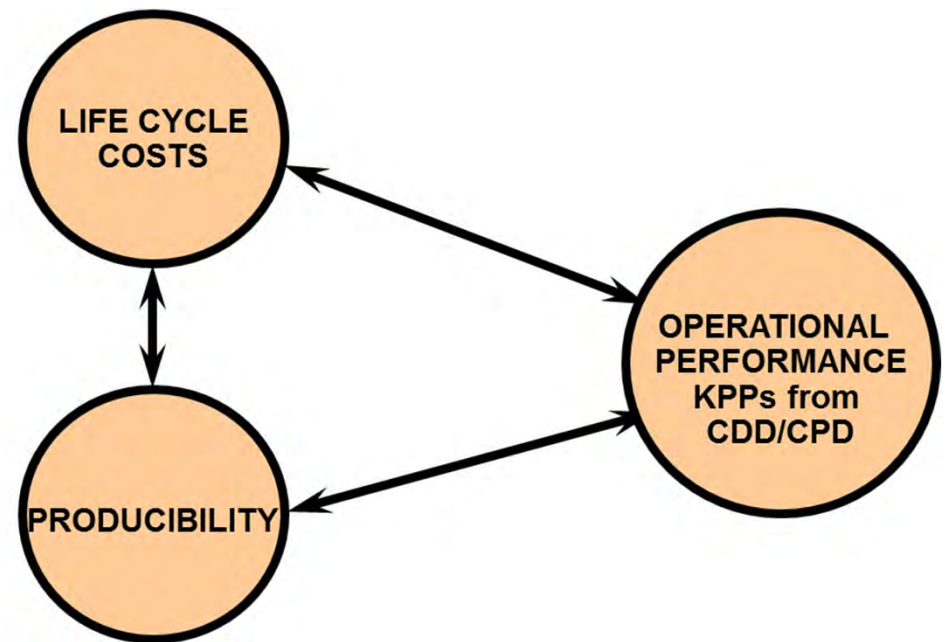
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Tradeoff Considerations

- Can operational performance be reduced to make a more producible design?
- Is technology available to provide the needed operational performance while reducing design complexity?
- Is the industrial base capable of producing the design repeatedly with acceptable quality?
- Is the design producible, yet able to support simplified maintenance procedures and sustainability?



A balanced design will satisfy all operational requirements, maximize producibility, and remain within cost thresholds



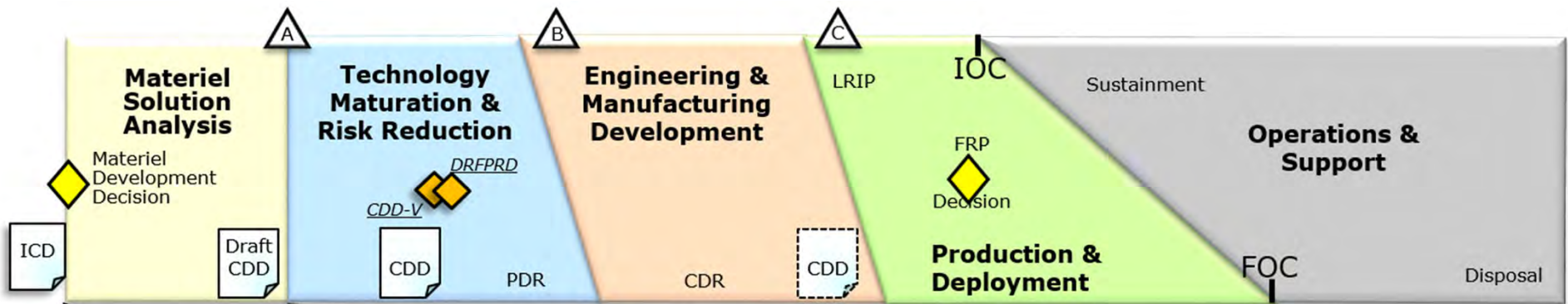
PQM and the SE Process

- The systems engineering process is a common thread that ties manufacturing to the technical acquisition disciplines:
 - Manufacturing provides important design influence for producibility as input to the process
 - In turn, a producible design is the output of the systems engineering process, which drives manufacturing
 - Inputs: Customer requirements and constraints
 - Delivery schedule
 - Industrial base
 - Technology base
 - Outputs: Product baseline requirements
 - Manufacturing plan
 - Manufacturing processes
 - Materials

PQM is integrated into the SE process by influencing the design process, preparing for production, and executing the manufacturing plan



Material Solution Analysis



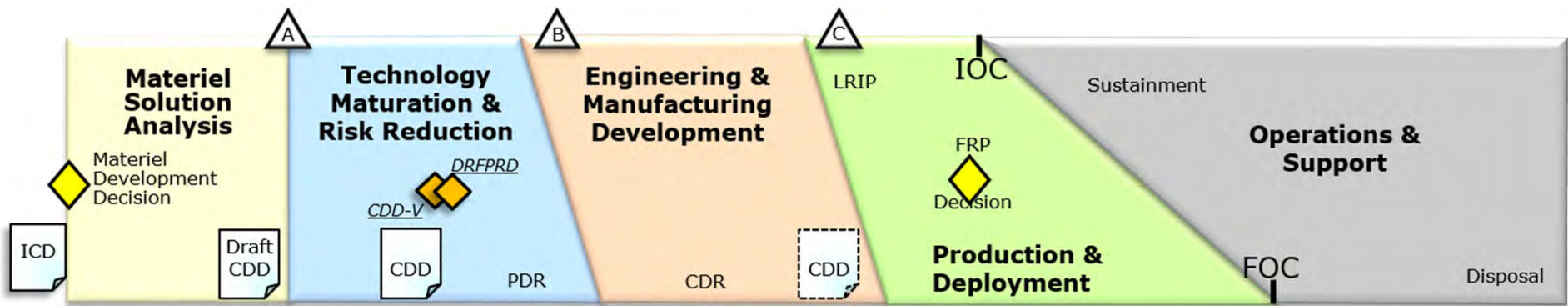
- Evaluate production feasibility
- Evaluate material/process capabilities
- Estimate manufacturing costs
- Evaluate production strategy
- Assess production risk

SE Process is an iterative process applied throughout the life-cycle necessary to balance cost and performance

Schedule is indirectly balanced as a result of good design



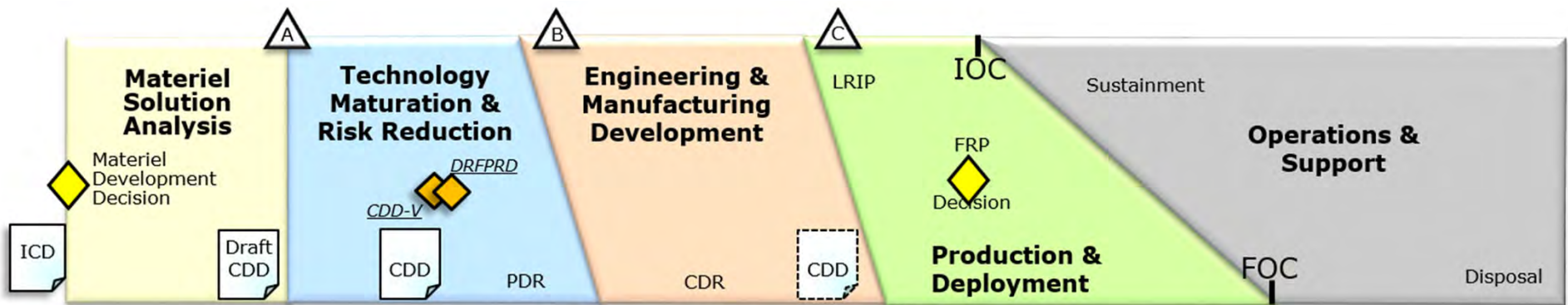
Technology Maturation and Risk Reduction



- Conduct producibility assessments
- Conduct material/process tradeoffs
- Significantly influence the design process
- Develop preliminary Manufacturing Plan
- Initiate Quality Assurance planning
- Resolve production risk



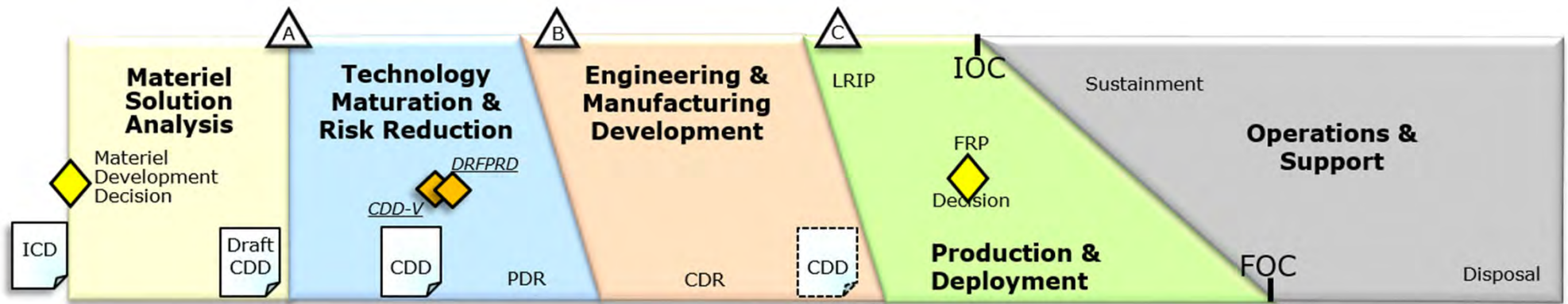
Engineering & Manufacturing Development



- Perform process proofing
- Start long lead-time material procurement
- Identify LRIP quantities
- Develop final Manufacturing Plan
- Start conversion of engineering drawings to manufacturing drawings



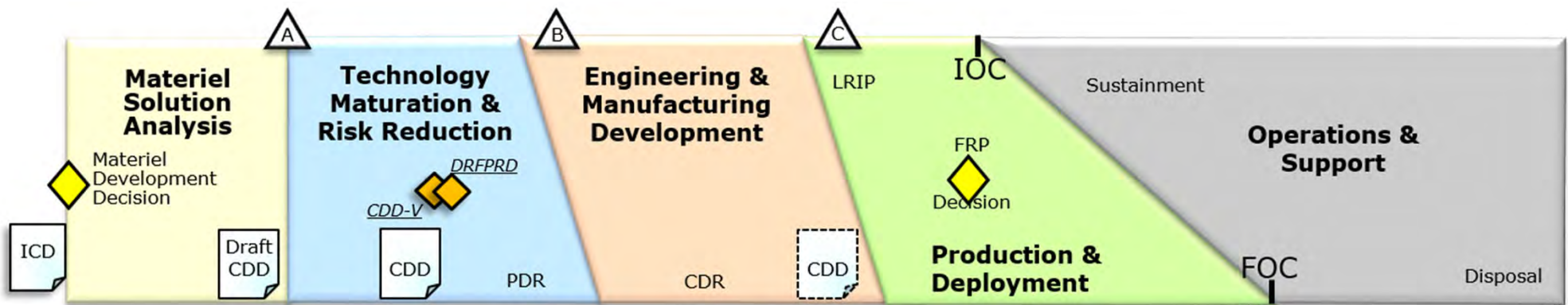
Production & Deployment



- Monitor and control manufacturing processes
- Implement continuous process improvement
- Complete manufacturing development during LRIP
- Prepare for orderly increase to full-rate production
- Execute the Manufacturing Plan



Operations & Support



- Monitor post-production support risk
- Execute pre-planned product improvement (P3I) plan



Common Issues

- Production issues are integrated through the Systems Engineering process. During the production process, various problems may arise that will adversely affect the acquisition process. There are five major causes of these production problems:
 - Unstable rates and quantities
 - Design instability
 - Undue emphasis on schedule
 - Inadequate Configuration Management System
 - Inattention to environmental impact
- It is important to understand these warning flags so that an IPT can be sensitive to the impact of such factors. IPT members should recognize and assess the effect these factors have on cost, schedule, and performance





Summary

- What are the nine key elements of the industrial process?
 - Easily influenced by PM

 - No direct control



Summary

- What percentage of total life-cycle cost is expended in the production and deployment phase?
- What percentage of total life-cycle cost is expended in the operations and support phase?
- What percentage of total life-cycle cost has been committed once the design is released for production (M/S C)?
- What are the Systems Engineering design objectives for manufacturing?
- What are the manufacturing conditions that support a full-rate production decision?



Summary

- What are the design techniques for a producible product?
- What are the tradeoffs for a producible design?
- How is PQM integrated in the SE process?