



# Systems Engineering Overview



TOPIC LEARNING OBJECTIVES	STUDENT PREPARATION
<p>Upon successful completion of this topic, the student will be able to:</p> <ol style="list-style-type: none"><li>1. Identify the key provisions of Department of Defense policy that relate to systems engineering requirements in the DoD.</li><li>2. Recognize that the following characteristics are included in a good design: Supportability, Mission Performance, Producibility, Testability, Cost Efficiency, Fully Integrated Software, and Technology Transition.</li><li>3. Recognize the most common supporting disciplines in the System Engineering Process.</li><li>4. Recognize which Systems Engineering areas apply to jobs performed by EDOs.</li><li>5. Relate the key tenets of Integrated Product and Process Development to planning and executing an acquisition program.</li><li>6. Recognize that the Systems Engineering Process is a translation and feedback process from operational to system requirements.</li><li>7. Recognize activities, processes, and required planning of the Systems Engineering Process and its visual model.<ol style="list-style-type: none"><li>a. Identify the eight technical processes in Systems Engineering.</li><li>b. Identify the eight technical management processes in Systems Engineering.</li></ol></li><li>8. Trace the maturation of system design information as it evolves through the acquisition life-cycle of a system.</li><li>9. Identify the role of the Systems Engineering Process in the product life-cycle to include balancing cost and performance and its effect on schedule.</li><li>10. Recognize the roles and responsibilities of the Government and contractors in a typical Systems Engineering Process.</li><li>11. Identify the main inputs and outputs of the overall systems engineering process.</li></ol>	<p>Student Support Material</p> <ol style="list-style-type: none"><li>1. None</li></ol> <p>Primary References</p> <ol style="list-style-type: none"><li>1. DoDI 5000.88 “Engineering of Defense Systems”</li><li>2. MIL-STD-499, “Systems Engineering”</li><li>3. MIL-STD-881, “Work Breakdown Structure for Defense Material Items”</li><li>4. DoD Integrated Product and Process Development Handbook August 1998</li></ol> <p>Additional References</p> <ol style="list-style-type: none"><li>1. Program Management Body of Knowledge (PMBOK) <a href="https://www.youtube.com/watch?v=2gmCr40uT4U">https://www.youtube.com/watch?v=2gmCr40uT4U</a></li><li>2. International Council on Systems Engineering <a href="https://www.incose.org/">https://www.incose.org/</a></li><li>3. SEBok <a href="https://sebokwiki.org/">https://sebokwiki.org/</a></li></ol>

TOPIC LEARNING OBJECTIVES	STUDENT PREPARATION
<div>HR</div> <p>Upon successful completion of this topic, the student will be able to:</p> <div><div>12. Recall the development of a Systems Engineering Plan (SEP).</div><div>13. Recognize the role of standards and specifications in the SE Process.</div></div>	<p>Student Support Material</p> <div><div>1. None</div></div> <p>Primary References</p> <div><div>1. DoDI 5000.88 “Engineering of Defense Systems”</div><div>2. MIL-STD-499, “Systems Engineering”</div><div>3. MIL-STD-881, “Work Breakdown Structure for Defense Material Items”</div><div>4. DoD Integrated Product and Process Development Handbook August 1998</div></div> <p>Additional References</p> <div><div>1. Program Management Body of Knowledge (PMBOK) <a href="https://www.youtube.com/watch?v=2gmCr40uT4U">https://www.youtube.com/watch?v=2gmCr40uT4U</a></div><div>2. International Council on Systems Engineering <a href="https://www.incose.org/">https://www.incose.org/</a></div><div>3. SEBok <a href="https://sebokwiki.org/">https://sebokwiki.org/</a></div></div>



# Overview

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- Introduction to Systems Engineering
- The Defense Acquisition Systems Engineering Process
  - System Engineering Plan (SEP)
  - Systems Engineering “V”
  - SE Technical Processes
  - SE Technical Management Processes
- Systems Engineering Process Outputs
  - Specifications
- Government and Contractor Roles



# Introduction to Systems Engineering

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- Systems Engineering (SE) is an interdisciplinary engineering management process that evolves and verifies an integrated, life-cycle balanced set of system solutions to optimally satisfy customer needs
- SE establishes the technical framework for delivering materiel capabilities to the Warfighter
  - Foundation upon which everything else is built
  - Supports program success
- SE is a methodical and disciplined approach for the specification, design, development, realization, technical management, operations, and retirement of a system
- SE will be used in all EDO jobs throughout the life-cycle of a product

*SE is a process that applies continuously and iteratively throughout the life-cycle*



# DoD Policy on Systems Engineering

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- Defense Acquisition Guide, Chapter 3
  - Systems Engineering (SE) establishes the technical framework for delivering materiel capabilities to the Warfighter
  - SE provides the foundation upon which everything else is built and supports program success
  - SE ensures the effective development and delivery of capability through the implementation of a **balanced approach with respect to cost, schedule, performance, and risk throughout the life-cycle of a program**
  
- DoDI 5000.88 (Engineering of Defense Systems) expounds the use of SE
  - SE comprises a methodical and disciplined approach for the specification, design, development, realization, technical management, operations, and retirement of a system
  - **Systems Engineering Processes** apply critical thinking in a structured multi-disciplined approach to solve problems including the **balance of cost, schedule, and performance while maintaining an acceptable level of risk**



# DoD Policy on Systems Engineering

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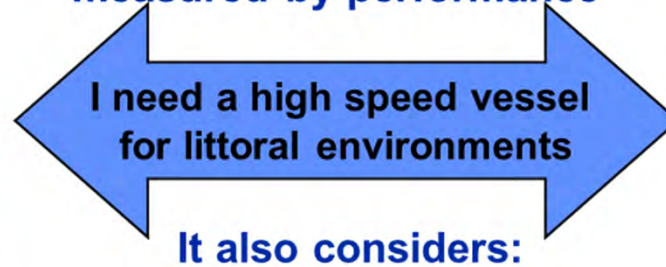
- Military Services, PMs, Lead Systems Engineers (LSEs), and Product Support Managers (PSMs) will implement engineering processes focused on a series of best practices to include:
  - Concept exploration, mission engineering, technical baseline management, engineering technical reviews, peer and independent reviews, test and evaluation, risk and configuration management, and technical decisions, while ensuring the security and integrity of capabilities and services
- The systems engineering and engineering management approach and processes that guide all technical activities of the program will be documented in a **System Engineering Plan (SEP)**
  - The SEP is highly specific for each program and will be updated as needed to reflect the program's evolving systems engineering approach, plans, and current status



# Performance is Not the Only Indicator of Good Design



Good system design is not just measured by performance



- **Supportability** – Can the hardware and software be supported throughout the life-cycle?
- **Mission performance** – Will it meet performance requirements?
- **Producibility** – Can it be manufactured efficiently?
- **Testability** – Can the requirements be verified?
- **Cost efficiency** – Can it be designed to reduce total cost of ownership?
- **Fully integrated software** – Will the SW and HW be fully integrated?
- **Technology transition** – Will the system take advantage of technology transition and refresh?



# Integrated Product Process Development (IPPD)

- IPPD is a management process that simultaneously integrates all essential acquisition activities using multi-disciplinary teams to optimize the design, manufacturing, business, and supportability processes
- Integrated Product Teams (IPTs) are core to IPPD
  - Plan, execute, and implement life-cycle decisions
- Key Tenants of the IPPD
  - Customer focus, concurrent development of products and processes, early and continuous life-cycle planning, maximize flexibility for optimization and use of contractor approach, encourage robust design and improved process capability, event driven scheduling, multi-disciplinary teamwork, empowerment, seamless management tools, proactive identification and management of risk
- SE is responsible for integrating effort of various disciplines
  - Including business, managerial, and technical components

*IPPD ensures program cost and performance objectives are met from product concept through production and field support*



# Systems Engineering Disciplines

- Common disciplines support the Systems Engineering process:
  1. Systems Engineering (PMO, WC, Labs, TR, SY, SUPSHIP, RMC)
  2. Test and Evaluation (PMO, WC and INSURV)
  3. Life-cycle Logistics (PMO, SYSCOM 04, WC)
  4. Science and Technology (WFC, Labs)
  5. Production, Quality and Manufacturing (SY, SUPSHIP, RMC)
  6. Hardware/Software Engineering (PMO)
  7. Cybersecurity (PMO, Labs)

*SY: Shipyard  
WC: Warfare Center  
RMC: Regional Maintenance Center  
PMO: Program Management Office  
SUPSHIP: Supervisor of Shipbuilding  
SYSCOM: Systems Command  
TR: Tech Rep*

*EDOs perform jobs in all of these disciplines*



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# System Engineering Plan (SEP)

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- Program Office personnel, including the program engineers, develop a Systems Engineering Plan (SEP) to assist PMs in communicating and managing the overall SE approach that guides all technical activities of the program
- The systems engineering and engineering management approach and processes that guide all technical activities of the program will be documented in a SEP. The SEP describes key technical risks, processes, resources, metrics, engineering products, organizations, and design considerations. The SEP is highly specific for each program and will be updated as needed to reflect the program's evolving systems engineering approach, plans, and current status
- The SEP should define the “who, what, where, when, why and how” of the SE approach
  - Multiple activities across organizations must be planned and budgeted
  - Roles and responsibilities must be assigned
  - Program specific processes must be defined
  - SE events must be defined (e.g., technical reviews)
  - Rationale for balancing requirements and trade-offs should be defined
  - Entry and exit criteria for reviews should be defined
  - SE support tools should be discussed



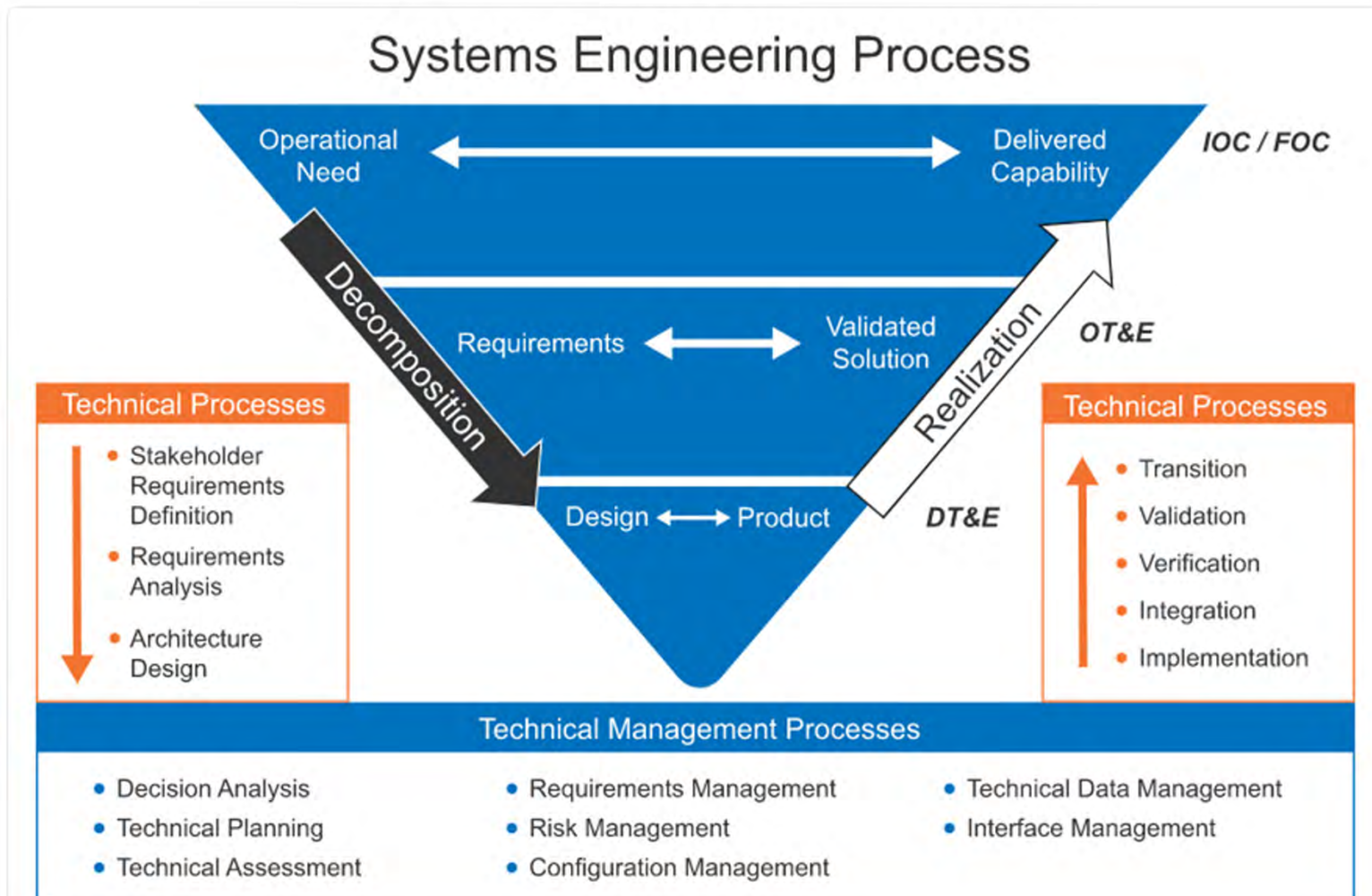
# System Engineering Plan (cont.)

- According to DoDI 5000.88, PMs will prepare a SEP as a management tool to guide the system engineering activities on the program
- The SEP will be:
  - Submitted for approval for each milestone review, beginning with M/S A
  - Describe program's overall technical approach including key technical risks, processes, resources, organization, metric, and design considerations
  - Detail the timing and criteria for the conduct of technical reviews
  - Address system integration with existing and approved architectures and capabilities
- The PM will use the SEP outline, which identifies the minimum expected content to be addressed in the SEP (includes embedded notes/guidance on expectations for each section)

*PM documents the Program's integrated approach in the SEP, which the MDA must approve*



# Systems Engineering Process Model



*The Systems Engineering Process Model consists of 8 Technical Management Processes and 8 Technical Processes (3 Decomposition Processes & 5 Realization Processes)*



# Systems Engineering “V”

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- The SE processes are not meant to be performed in a particular time-dependent order or serial sequence
  - Apply iteratively, recursively, and in parallel (as applicable) throughout the life-cycle
- The 8 Technical Management Processes provide a tool kit of management tools that help keep the Technical Processes flowing and under control
- The 8 Technical Processes define the flow of SE from understanding the Warfighter’s requirements to transitioning the completed system to the field
  - The left side depicts the decomposition processes
  - The right side depicts the realization processes (fabrication, integration, and test)



# 8 Technical Processes

## Decomposition Processes

### Stakeholder Requirements Definition

The lead Service, Component, or designated program office receives requirements from relevant stakeholders and translates them into technical requirements

### Requirements Analysis

Involves the decomposition of user needs into clear, achievable, and verifiable high-level requirements and system functions

### Architecture Design

Allows the Program Manager and Systems Engineer to translate the outputs of the Stakeholder Requirements Definition and Requirements Analysis processes into alternative design solutions and establishes the architectural design of candidate solutions that may be found in a system model



## 8 Technical Processes (cont.)

Realization Processes	
<b>Implementation</b>	Outputs of this process include the detailed design down to the lowest level of system elements in the system architecture, and the fabrication/production procedures of forming, joining, and finishing or coding the software
<b>Integration</b>	Used to systematically assemble lower-level system elements into successively higher-level system elements until the system itself emerges
<b>Verification</b>	Provides evidence that the system or system element performs its intended functions and meets all performance requirements listed in the system performance specification and functional and allocated baselines; involves developmental testing of the system
<b>Validation</b>	Provides objective evidence that the capability provided by the system complies with stakeholder performance requirements in its intended environment; consists of evaluating operational effectiveness, operational suitability, sustainability, and survivability
<b>Transition</b>	The process applied to move any system element to the next level in the physical architecture; for the end-item system, it is to field the system to the user in the operational environment



# 8 Technical Management Processes

Technical Management Processes	
<b>Technical Planning</b>	Process includes defining the scope of the technical effort required to develop, field, and sustain the system as well as providing critical quantitative inputs to program planning and life-cycle cost estimates
<b>Decision Analysis</b>	Transforms a broadly stated decision opportunity into a traceable, defensible, and actionable plan
<b>Technical Assessment</b>	Allows the Systems Engineer to compare achieved results against defined criteria to provide an understanding of the current level of technical maturity, program status, and technical risk. Provides better understanding of the health and maturity of the program, giving the PM a sound technical basis upon which to make program decisions
<b>Requirements Management</b>	Through this process, the Systems Engineer tracks requirements changes and maintains traceability of end-user needs to the system performance specifications and ultimately the delivered capability. Helps ensure delivery of capability that meets intended mission performance to the operational end user

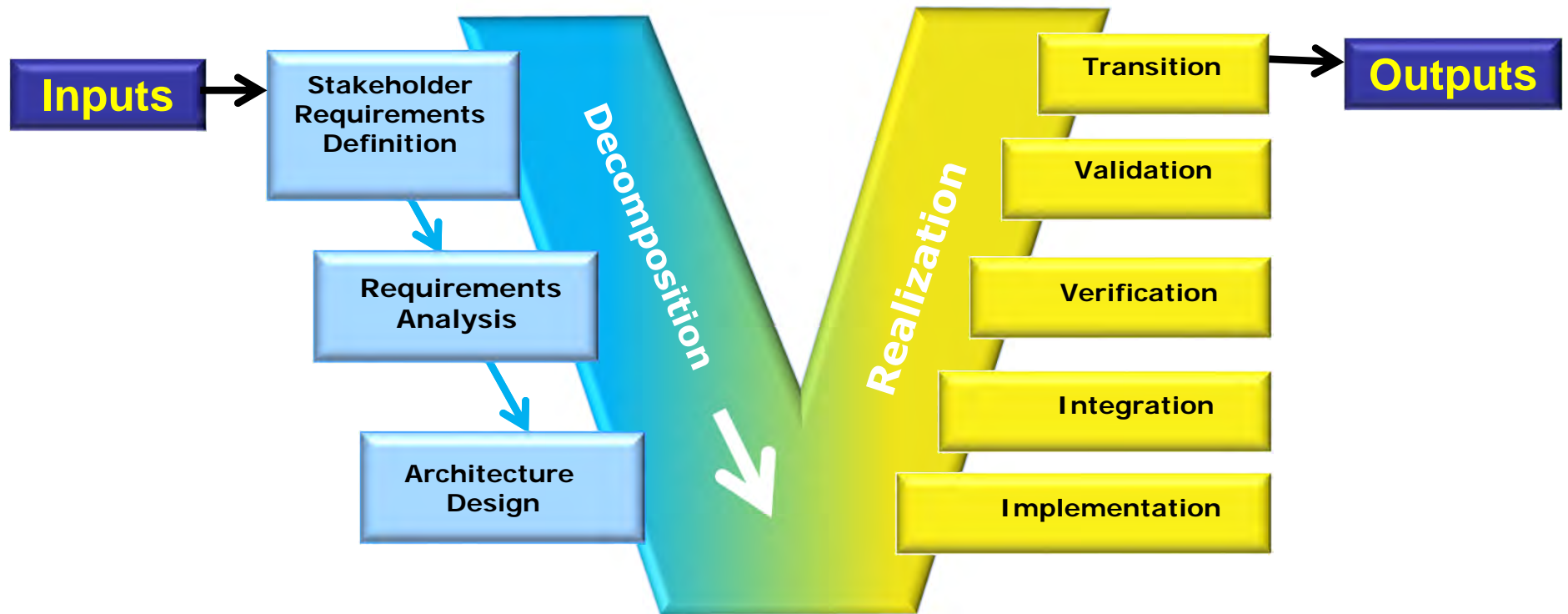


## 8 Technical Management Processes (cont.)

Technical Management Processes, cont.	
<b>Risk Management</b>	The overarching process that encompasses identification, analysis, mitigation and monitoring of program risks. Primary method of mitigating program uncertainties and it critical to achieving cost, schedule, and performance goals at every stage of the life-cycle
<b>Configuration Management</b>	Facilitates the orderly development of a system through establishment of the technical baseline (including the functional, allocated, and product baselines), and their assessment and approval at various technical reviews and audits. Through this process, the program identifies, controls, and tracks changes to system baselines
<b>Technical Data Management</b>	Used to identify, acquire, manage, maintain and ensure access to the technical data and computer software required to manage and support a system throughout the acquisition life-cycle
<b>Interface Management</b>	Process assists the Program Manager in ensuring interface definition and compliance among the system elements, as well as with other systems



# Systems Engineering Process



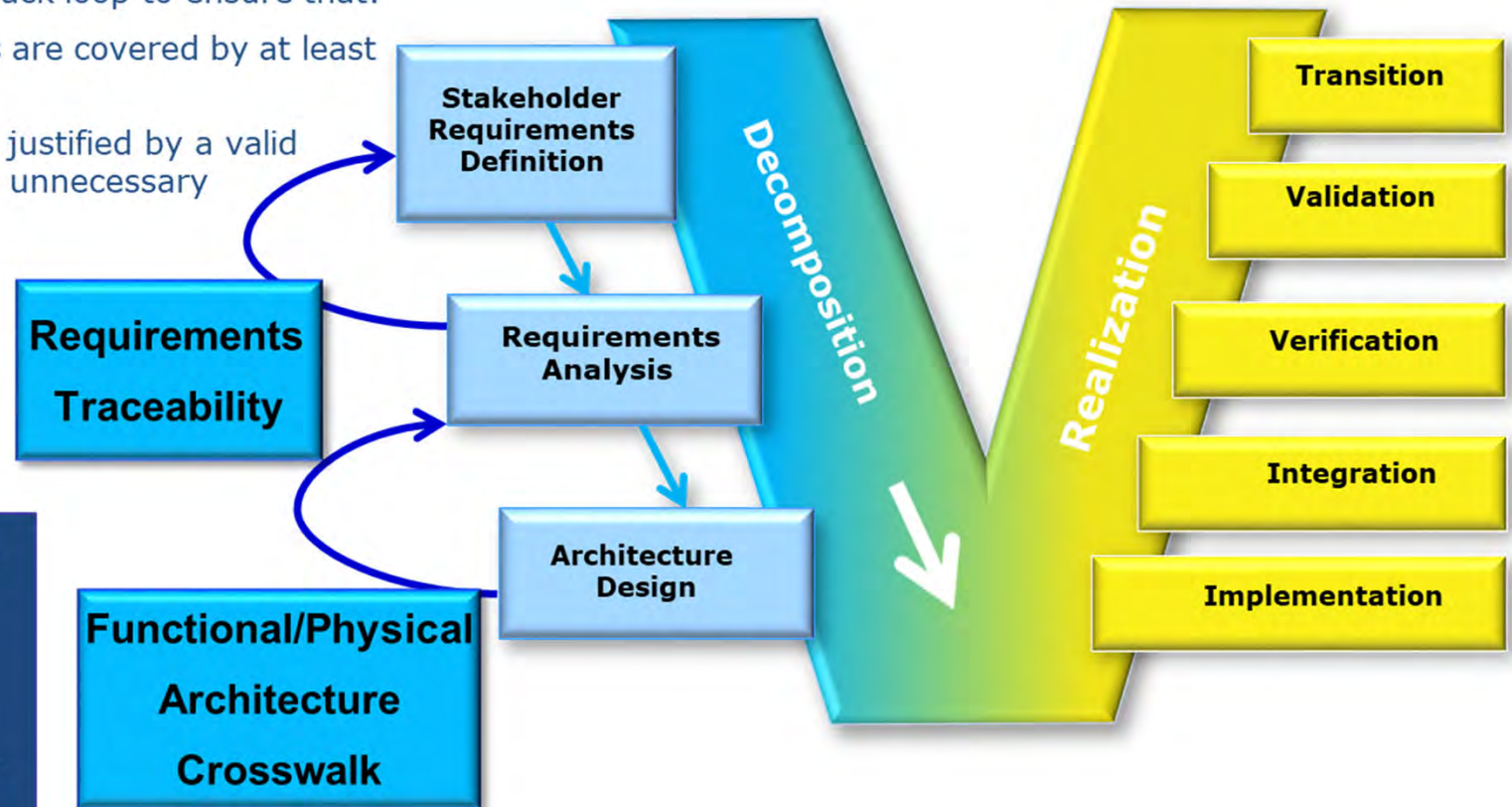
- The Systems Engineering Process is
  - A *translation and feedback process* of operational needs to system requirements
  - Allows development of effective and suitable integrated design solutions



# Systems Engineering— Requirements Management

Requirements feedback loop to ensure that:

- All requirements are covered by at least one function
- All functions are justified by a valid requirement (no unnecessary duplication)



**Requirements Management** is key to the control and traceability of requirements throughout the design, development and fielding of a system.

Design feedback loop to ensure that:

- All functions are covered by at least one hardware or software element
- All elements of the physical architecture are justified by a valid functional requirement (no unnecessary duplication)



# Overview

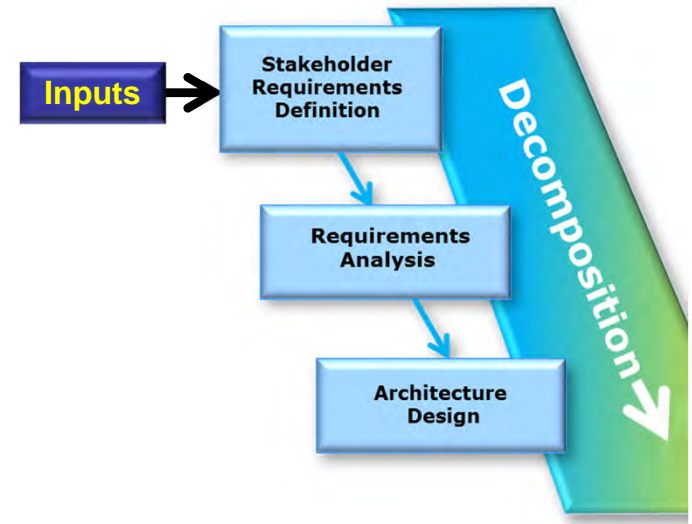
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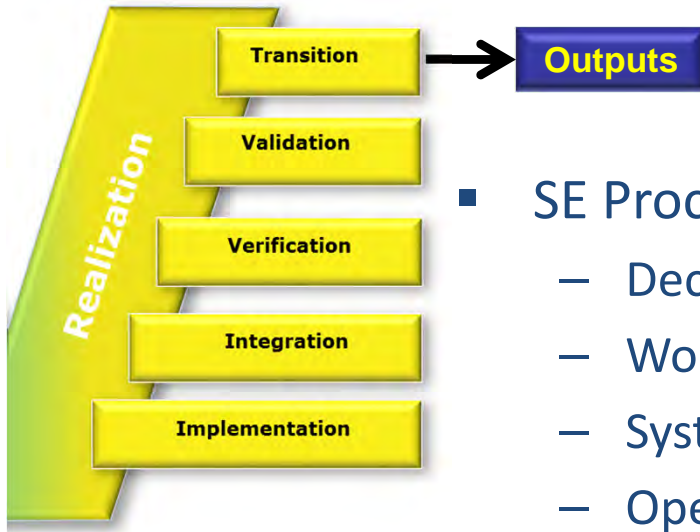
# SE Process Inputs

- SE Process Inputs include:
  - Customer needs/Objectives/Requirements
    - Missions
    - Key Performance Parameters
    - Measures of Effectiveness
    - Environments
    - Constraints
  - Technology base
  - Output requirements from prior application of SE process
  - Program decision requirements
  - Commercial standards and performance specs





# SE Process Outputs



- SE Process Outputs include:
  - Decision data base
  - Work Breakdown Structure (WBS)
  - System/configuration item architectures
  - Operational/technical architectures
  - Program-unique specifications and configuration baselines



# Standards

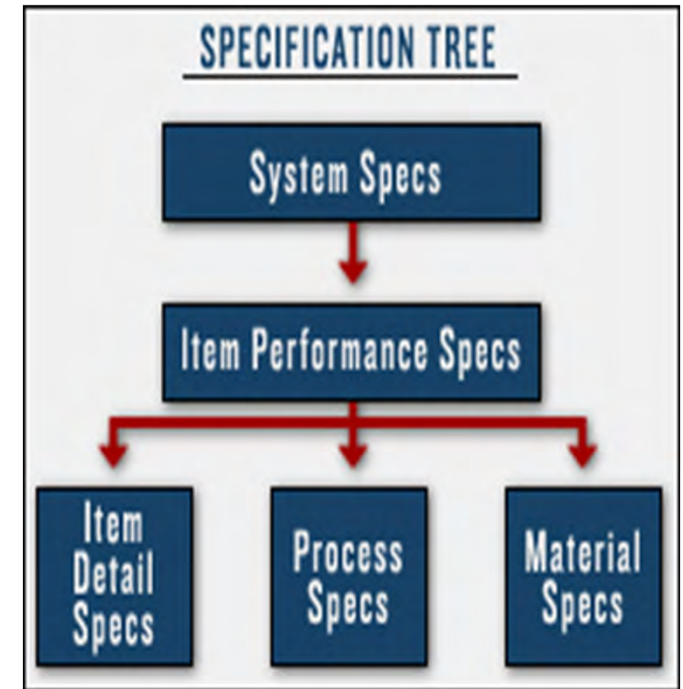
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- Standards and specifications are important in managing the technical aspects of acquisition programs
- What is a standard?
  - A **standard is a description of a process** that describes the practices that are recommended for accomplishing the objectives of that process
  - Both military and industrial standards are used in acquisition
  - Standards are generally used to ensure that a given process is sufficiently well-defined and mature enough to produce the needed output at sufficiently high levels of quality to meet the needs of the eventual users
- What is a specification?
  - A **specification is a technical description of a product or service**
  - Once a product has been designed, developed, and produced, it can be and often is documented with a group of specifications that describe the details of the product



# Program Unique Specifications

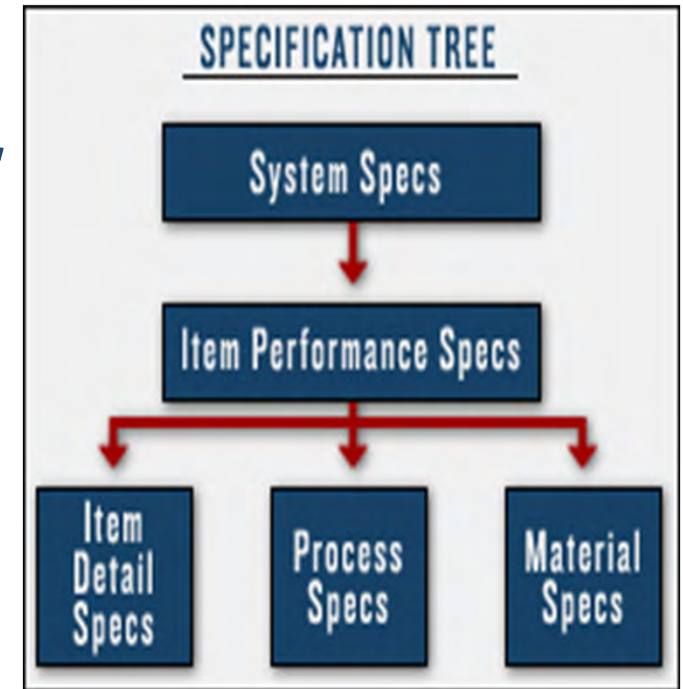
- System Specification
  - Describes what the entire system will do
  - Derived from the Capability Development Document (CDD) KPP's
  - Contains system requirements and how they will be tested or verified
- Item Performance Specification
  - Describes the performance required of the major subsystems below the system level ("design to" requirements)





# Program Unique Specifications (cont.)

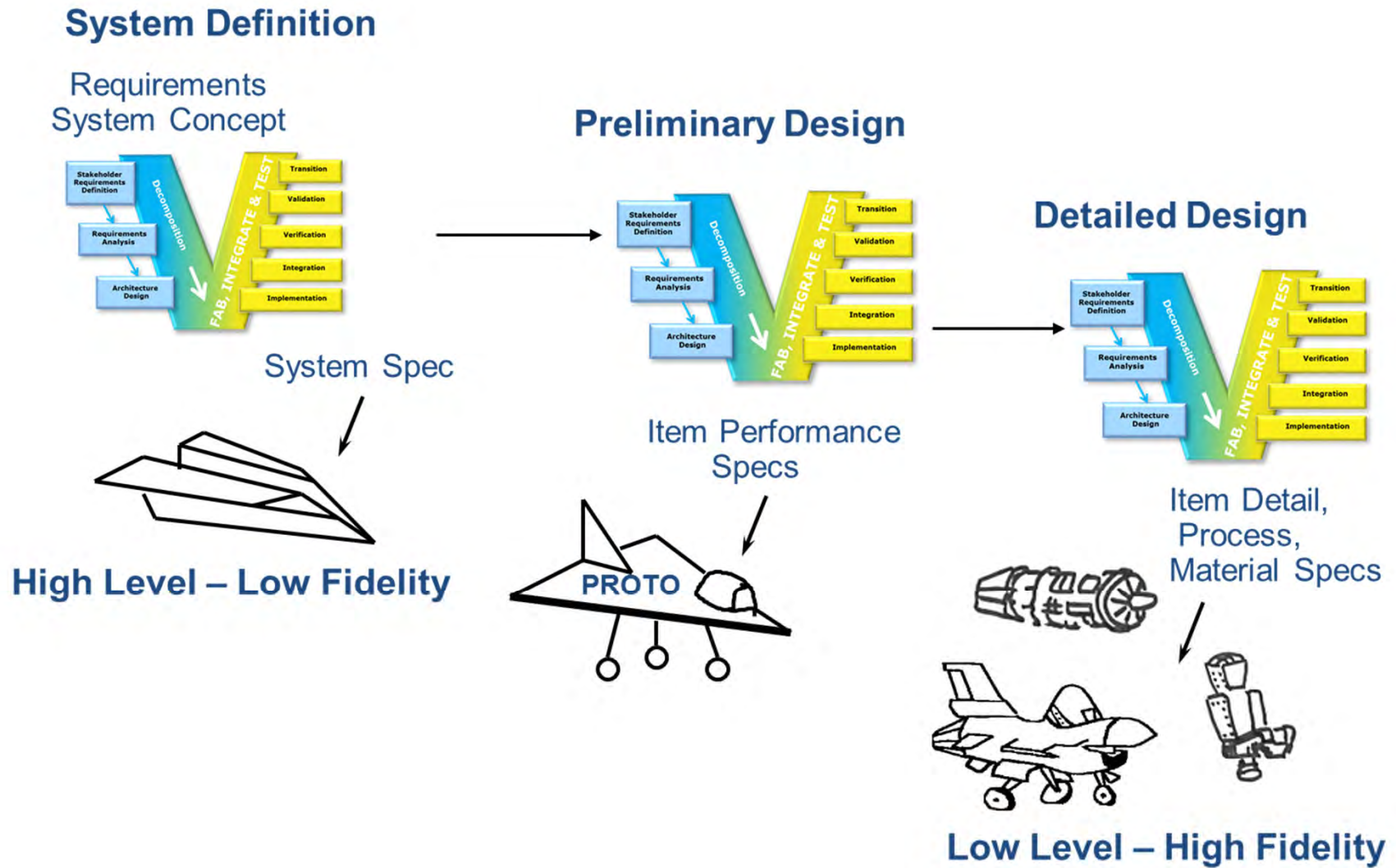
- Item Detail Specification
  - Describes specific design parameters or "*build to*" requirements
- Item Process Specification
  - Define processes to be performed during fabrication, such as:
    - Welding, soldering, bonding
- Item Material Specification
  - Defines raw materials or semi-fabricated material, such as:
    - Copper pipes, aluminum wire



Used during  
production



# Specifications & Levels of Development





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# Government and Industry Roles

- The Government's primary responsibility
  - Manage total program
  - Set the user requirements and ensure they are met
  - Ensure that the Contractor has responsible design, testing, and manufacturing processes
  - Identify and manage technical risks
  - Verify that technical solutions satisfy customer needs
- The Contractor's primary responsibility
  - Use SE Process in planning, designing, and internally testing the system and its required support components
  - Meet the Government's contractual needs
- Together, the Government and the Contractor work to
  - Translate the design
  - Define the design
  - Monitor the design
  - Ensure design quality
  - Test the design



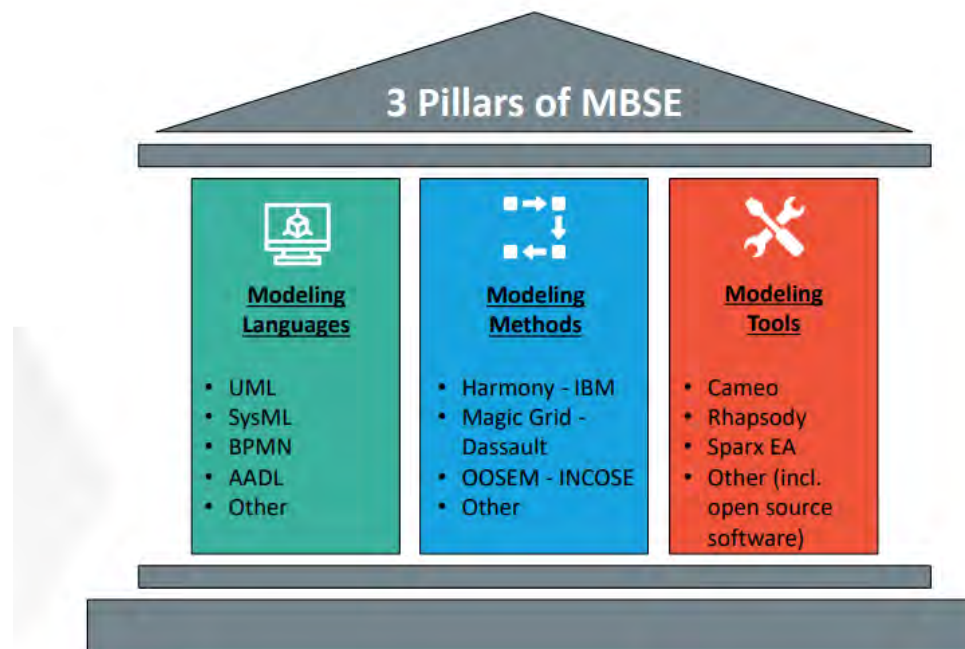
# Government and Industry Roles (cont.)

Task	Government Role	Contractor Role
Translate the need	<ul style="list-style-type: none"> <li>Engages in translating operational needs, cited in the CDD, into a system performance specification</li> <li>Updates system performance specification to reflect changes in the operational need</li> <li>Supports all performance specification development</li> </ul>	<ul style="list-style-type: none"> <li>Normally participates in developing the system performance specifications</li> <li>Translates the system performance specification into technical design specifications</li> </ul>
Define the design	<ul style="list-style-type: none"> <li>Establishes system-level performance thresholds and objectives</li> </ul>	<ul style="list-style-type: none"> <li>Allocates system-level performance thresholds and objectives to subsystems and lower design specifications</li> </ul>
Monitor the design	<ul style="list-style-type: none"> <li>Monitors program technical progress through IPTs, technical reviews, and periodic program reviews</li> </ul>	<ul style="list-style-type: none"> <li>Manages and integrates technical design progress using internal management standards</li> </ul>
Ensure design quality	<ul style="list-style-type: none"> <li>Verifies Contractor performance through review and approval of Contractor technical deliverables</li> </ul>	<ul style="list-style-type: none"> <li>Validates internal and subcontractor technical performance through established quality control standards</li> </ul>
Test the design	<ul style="list-style-type: none"> <li>Verifies system performance through conduct of development and/or operational testing</li> </ul>	<ul style="list-style-type: none"> <li>Verifies components/system performance through internal testing and participation in Government developmental testing</li> </ul>



# (MBSE) Model-Based Systems Engineering

- Model Based Systems Engineering is the practice of developing a set of related system models that help define, design, and document a system under development.
- The formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later system life-cycle phases.





# Summary

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What Department of Defense policy mandates the use of Systems Engineering and a Systems Engineering plan that is approved by the MDA?

A good design is more than good performance; what are characteristics of a good design?

What are the common supporting disciplines in the System Engineering Process?



# Summary

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What are the key tenets of IPPD to planning and executing an acquisition program?

What are the various technical processes that are undertaken while engineering a complex system?

What management processes are used to ensure that the technical activities lead to the desired outcomes?



# Summary

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What are the continuum of systems specifications and how do they relate to the technical maturity of systems?

What is the role of the Systems Engineering Process in the product life-cycle to include balancing cost, schedule and performance?

What are the inputs and outputs of the Systems Engineering Process?

Inputs

Outputs