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Cost Engineering

Systems Engineering Cost Estimation Aligned with MIL-STD-881F

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Agenda

- Introduction to MIL-STD-881F and Common Elements
- Objectives
- Systems Engineering Processes
- Systems Engineering Activities (per MIL-STD-881F) and Labor Resources
  - Effort Distributions
  - Validation Efforts
- Demonstration

WBS Example - MIL-STD-881

C.3 WORK BREAKDOWN STRUCTURE LEVELS

WBS #	Level 1	Level 2	Level 3	Level 4
1.0	Missile/Ordnance System			
1.1		Missile/Ordnance System Integration, Assembly, Test and Checkout		
1.2		Air Vehicle/Munition		
1.2.1			Air Vehicle/Munition Integration, Assembly, Test and Checkout	
1.2.2			Airframe	
1.2.2.1				Airframe Integration, Assembly, Test and Checkout
1.2.2.2				Primary Structure
1.6		Systems Engineering		
1.6.1			Software Systems Engineering	
1.6.2			Integrated Logistics Support (ILS) Systems Engineering	
1.6.3			Cybersecurity Systems Engineering	
1.6.4			Core Systems Engineering	
1.6.5			Other Systems Engineering 1…n (Specify)	
1.7		Program Management		
1.7.1			Software Program Management	
1.7.2			Integrated Logistics Support (ILS) Program Management	
1.7.3			Cybersecurity Management	
1.7.4			Core Program Management	
1.7.5			Other Program Management 1…n (Specify)	
1.8		System Test and Evaluation		
1.8.1			Developmental Test and Evaluation	
1.8.2			Operational Test and Evaluation	
1.8.3			Cybersecurity Test and Evaluation	
1.8.4			Mock-ups / System Integration Labs (SILs)	
1.8.5			Test and Evaluation Support	
1.13		Operational/Site Activation		
1.13.1			System Assembly, Installation and Checkout on Site 1…n (Specify)	
1.13.2			Contractor Technical Support	
1.13.3			Site Construction	
1.13.4			Site/Ship/Vehicle Conversion	
1.13.5			Sustainment/Interim Contractor Support (ICS)	
1.13.6			Contractor Logistics Support (CLS)	

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PMP

Common Elements

Objectives

- Improve alignment of System Engineering model's activities with MIL-STD-881F
  - Prior version aligned with EIA-632, but cost estimates often must align with MIL-STD-881F
- Improve detail of model's labor resource categories
  - Prior version had only "Systems Engineer" resource, but SE activities are performed by many labor roles.
  - More detailed labor category accounting, such as logistics engineer, RAMS engineer, human factors engineer, etc. provides useful insights.
    - Easier to understand scope of the estimate with more detailed breakdown
    - Improved flexibility. For example, can remove HFE altogether if those studies are unnecessary, or can replace HFE model estimate with bottoms-up estimate when scope is well defined.

Systems Engineering Process

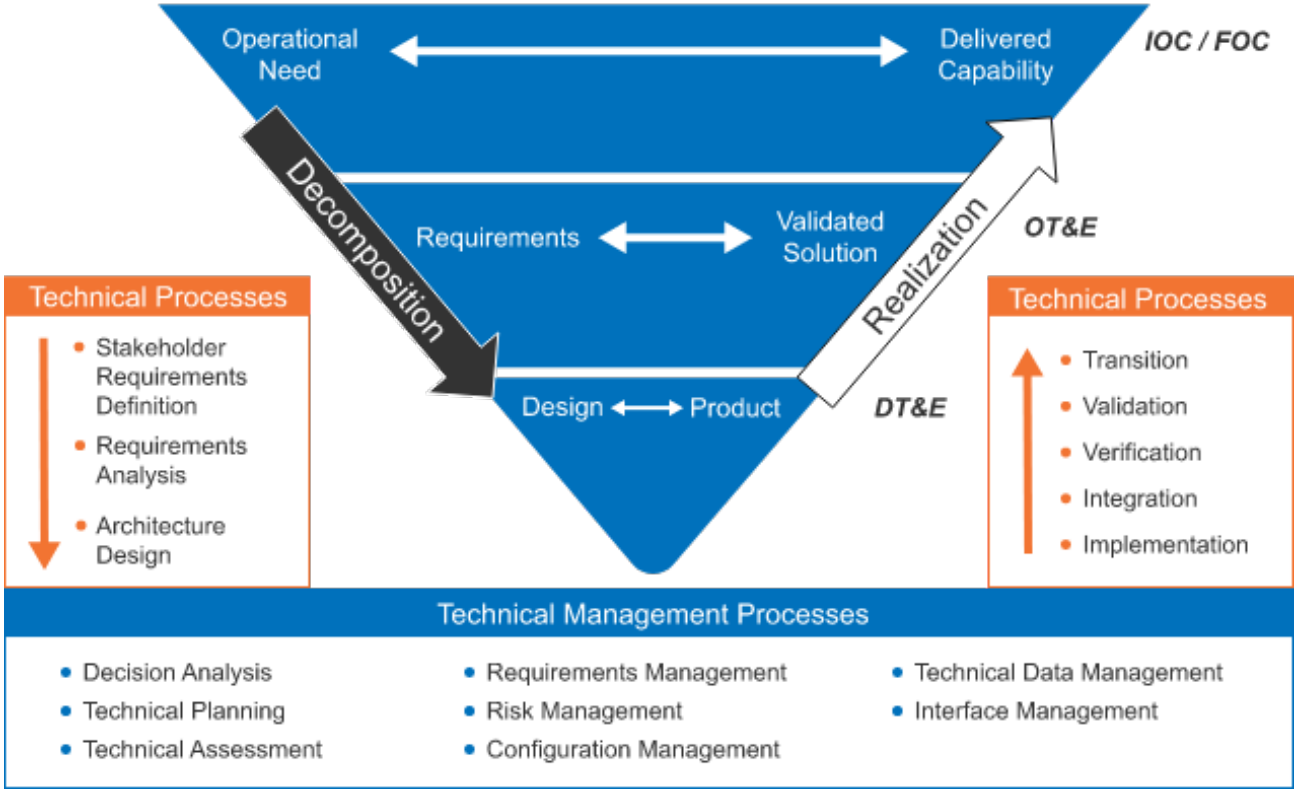

Figure 30 is a representation of how much effort is typically focused on each of the ISE processes throughout the acquisition life cycle. The PM and Systems Engineer should apply appropriate resources with the requisite skill sets to ensure successful execution of each process.

Figure 30: Notional Emphasis of Systems Engineering Processes throughout the Defense Weapon System Acquisition Life Cycle

		EMD	P&D	O&S
	Legend: ● = Major Use; ◉ = Moderate Use; ○ = Minor Use			
TECH MGMT PROCESSES	Decision Analysis	●	●	●
	Technical Planning	●	●	●
	Technical Assessment	●	●	●
	Requirements Management	●	●	●
	Risk & Opportunity Management	●	●	●
	Configuration Management	●	●	●
	Technical Data Management	●	●	●
	Interface Management	●	●	●
TECHNICAL PROCESSES	Stakeholder Requirements Definition	◉	○	○
	Requirements Analysis	●	○	○
	Architecture Design	●	○	○
	Implementation	●	◉	○
	Integration	●	●	○
	Verification	●	●	◉
	Validation	●	●	●
	Transition	●	●	●

Source: DAU Systems Engineering Guidebook

MIL-STD-881F Systems Engineering (SE) Categories

- **Software SE**
  - All Systems Engineering efforts driven by software development
- **Cybersecurity SE**
  - All SE efforts to identify and minimize risks associated with security vulnerabilities
- **Integrated Logistics Support (ILS) SE**
  - Includes SE efforts to ensure that the system is designed, built, and maintained to meet its availability and supportability requirements
- **Core SE**
  - Includes all 16 Technical Processes and Technical Management processes
  - Includes system-level Specialty Engineering activities
    - Examples: Producibility, Safety, Human Factors, Environmental, Radiation, Thermal, Acoustics, etc.
    - Does not include specialties already included in ILS, such as Logistics Engineering, and most RAMS engineering efforts)

Labor Resources

- ILS SE
  - Systems Engineer
  - RAMS Engineer
  - Logistics Engineer
  - Test Engineer
  - Training Engineer
- Core SE – Technical Management Processes
  - Systems Engineer
  - Quality Assurance Analyst
  - Configuration Manager
  - Design Engineer
  - Test Engineer
  - 5 Specialty Engineers (RAMS, Industrial, Safety, Human Factors, Other Specialty)
- Core SE – Requirements Definition & Analysis
  - Systems Engineer
  - Project Stakeholder
  - Business Analyst
  - 5 Specialty Engineers
- Core SE – System Design
  - Systems Engineer
  - Design Engineer
  - 5 Specialty Engineers
- Core SE - IIVVT
  - Systems Engineer
  - Design Engineer
  - Test Engineer
  - 5 Specialty Engineers

Effort Distribution Among Activities

- Software based on existing CERs
- Cybersecurity based on Cybersecurity Cost Factors Study (2023 update in the works)
- The effort distribution between ILS and Core activities can vary. Key drivers include:
  - System Readiness Level (SRL) at program start
    - Lower SRL programs have larger scope of engineering activities to mature the technology and component/subsystem interfaces and more risks to manage (higher Core SE)
  - Logistics Support Requirements
    - High part counts, high complexity, global operations, all contribute to complex logistics and supply chain requirements, and increased ILS scope.
    - No/Low Maintenance Equipment (e.g. space systems, “discard at failure” equipment) has reduced ILS scope.
    - Fixed location equipment, infrequently used equipment (e.g. missiles) has reduced ILS scope.
    - Equipment subjected to high wear-and-tear/damage (e.g. harsh operating environments, constant usage, combat equipment) have increased ILS scope.

Effort Distribution Among Resources

- Within each activity, the effort distribution across the labor resources can vary due to:
  - Safety Risk Level
  - Criticality Level
    - Highly critical systems have higher RAMS Engineer efforts
  - Human Factors Considerations
    - Systems needing highly skilled operators/maintainers have higher HFE. Simple user interface or autonomous systems require less HFE.
  - Other Specialty Engineering (OSE) Scope
    - Harsh operating environments typically have higher OSE scope
    - Specialty engineering needs can vary greatly from system to system:
      - Radiation, Acoustics, Thermal, Electromagnetic Interference/Compatibility, Aerodynamics, Environmental, Chemical Engineering(e.g., for hazardous material handling and disposal), etc.

Model Validation with Data

- Detailed Datasets, with Systems Engineering cost broken down into specific activities, specialty engineering categories, etc.
  - 2 Satellite Payload Programs
  - Aircraft Command and Control System Program
  - Space Launch Program
- Employment Data
  - Gather employment numbers for various specialty engineering disciplines within aerospace and defense industry.

Demonstration

Wrap-up

- Work in progress
  - Will continue iterating on design
  - Current focus on improving model structure and effort distribution
  - Future iterations will address overlap of cost drivers and effort distribution drivers, and refining estimation of these more detailed categories.
  - Feedback and data welcome
- Questions?
- Contact: gurney.thompson@unisonglobal.com

Backup

Other Systems Engineering Model Updates

- COSYSMO 3.0 Implementation
  - Design For Reuse
  - Design With Reuse
- Number of Requirements/Interfaces/Op Scenarios Adjustment Factors
- Revisit CER mappings from System/Assembly models
  - Contractor Operational Test Support -> System Test and Evaluation
  - System - Quality Assurance/Configuration Manager Resources -> Systems Engineering
    - Option to map QA to Program Management?

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		Pre-MDD	MSA	TMRR	EMD	P&D	O&S
TECH MGMT PROCESSES	Decision Analysis	●	●	●	●	●	●
	Technical Planning	●	●	●	●	●	●
	Technical Assessment	◉	●	●	●	●	●
	Requirements Management	◉	●	●	●	●	●
	Risk & Opportunity Management	◉	●	●	●	●	●
	Configuration Management	○	◉	●	●	●	●
	Technical Data Management	○	●	●	●	●	●
	Interface Management	◉	●	●	●	●	●
TECHNICAL PROCESSES	Stakeholder Requirements Definition	◉	●	●	◉	○	○
	Requirements Analysis	◉	●	●	●	○	○
	Architecture Design	◉	●	●	●	○	○
	Implementation	○	◉	◉	●	◉	○
	Integration	○	◉	◉	●	●	○
	Verification	○	◉	◉	●	●	◉
	Validation	○	◉	◉	●	●	●
	Transition	○	○	◉	●	●	●

Source: DAU Systems Engineering Guidebook

Section Name	Input Field
Type of System	Custom
System Readiness Level (SRL)	6
System Criticality Level	0.0
Safety Risk Level	0.0
Logistics Support Requirements	0.0
Human Factors Considerations	0.0
Other Specialty Engineering Considerations	0.0

Section Name	Input Field	Units
Type of System	Custom	
System Readiness Level (SRL)		
System Criticality Level		
Safety Risk Level		
Logistics Support Requirements		
Human Factors Considerations		
Other Specialty Engineering Considerations		

Fixed Location Military Equipment
Military Ground Vehicle
Maritime System
Subsonic Missile
Supersonic Missile
Intercontinental Ballistic Missile (ICBM)
Unmanned Aerial Vehicle (UAV)
Aircraft (Piloted)
Unmanned Space System
Manned Space System

WBS is the Foundation

Per Cost Estimating Body of Knowledge (CEBoK) Module 1 Cost Est. Basics:

- A Work Breakdown Structure (WBS) establishes a **common frame of reference** for relating job tasks to each other and relating project costs at the summary level of detail
  - It provides a consistent and visible framework for specifying the objectives, labor, materials, and contracts of the system/program.
  - The structure is used to define the total program/system by providing detailed definitions of individual elements required (via a WBS Dictionary)
- A WBS should be tailored for each system or program for the purpose of **capturing all the idiosyncrasies** endemic to each system/program
- Estimate uses a WBS that is at a level of detail appropriate to ensure that **cost elements are neither omitted nor double-counted**
- Estimate is presented in a WBS fully **traceable to the system specification**
- WBS structure is **aligned to organizational structure performing the work**; WBS element tasks are traceable to data, which is traceable back to the respective source documents