System Engineering: Getting from Requirements to a Baseline

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Terminology

- EV – Earned Value
- SE – Systems Engineering
- CM – Configuration Management
- PMB – Performance Measurement
- TPM – Technical Performance Measurement
- Baseline
How do SE and EV Fit?

- Observation - EV is a natural extension of the SE process.
  - EV baseline comes from and depends on SE baseline.
  - EV baseline tied to CM process
  - EV status based on technical progress

- Recognition and application improves engineering team acceptance and use
What is System Engineering

- An interdisciplinary approach to successful systems
- Developing products using a total system perspective
- Focuses on:
  - Defining and documenting customer needs
  - An orderly process through concept decomposition, design synthesis, system development, and integration
- A bridge between user needs and a solution
System Engineering

The disciplined, technical management process by which needs/opportunities are transformed into useful products/services/operations
Performance Analysis Process

- Review customer/user needs
- Review, analyze, and validate studies
- Determine performance values for all expected mission scenarios:
  - System states (e.g., idle, ready, deployed):
  - How often must it do it and for how long?
  - Mandatory (minimum or maximum) levels
  - Goals
Performance Attributes – Definition

- Descriptors that, when quantified, convey requirements in quantitative values.

- Typical attributes:
  - Quantity
  - Quality
  - Coverage
  - Timeliness
  - Availability
Define the Problem and Context

- **User Level (concept independent)**
  - Defined by the User Requirements Statement
  - Defined by the User Operations Concept
- **System Level (concept dependent, design independent)**
  - Defined by System Specification
  - Defined by the System Operations Concept
- **Lower Level (design dependent)**
  - Defined by the specification for the item
  - Describes how the elements at the next lower level interact to implement the design
Requirements Process

- Document requirements in a User Requirements Statement
- During Requirements Definition Phase
  - Then develop Initial System Concept
  - User Operations Concept and System Requirements Document expand on requirements understanding
Operations Concept Documents

- Provide the context of implementation
  - Developed before the corresponding specification
  - Sets the context for the requirements

- User Operations Concept
  - Describes users’ planned operations of the system in the operational environment
  - Content is solution independent

- System Operations Concept
  - Describes how the system will operate
  - Content is solution dependent
System Specification

- Based on stakeholder Requirements Statement and Operations Concept
- Captures Stakeholder Requirements
  - System level interface control documents also set system requirements
  - Operations Concept document establishes the context for the system
- Concept-specific, but not design/implementation-specific
What is System Architecture Development?

- Converting functional and performance requirements into tangible elements that can be implemented in hardware, software or operator actions, or combinations
- Performed at the system level to identify the solution at the next hierarchy level
  - Apply requirements from system level
  - Do successively for lower levels of the system hierarchy
Architectural Selection Process

- Allocate requirements to each component
- Identify candidate solutions
- Use system models to evaluate performance, functionality, and cost
- Compare concepts – tradeoff analysis
- Select final architecture and document selection
Defining the Components

At each level in the system architecture all the components must be defined so that all requirements can be allocated

– The project WBS and implementation will be based upon this definition of components
– Components can consist of hardware, software, personnel, facilities, data, and procedures
Tradeoff Analysis – Definition

Quantitative and/or qualitative comparison of candidate concepts against predetermined, weighted evaluation criteria to surface the best alternatives

– Results in:
  - Yes/No
  - Narrowing of choices
  - Support of selection
Trade Study Process

1. Select Trade Study Team
2. Define and Challenge Decision Statement
3. Establish Decision Criteria
4. Limits or “Musts”
5. Wants
6. Identify and Evaluate Alternative Solutions
7. Weight “Wants”
8. Weighted Scoring of Alternatives
9. Pre-Select Highest Scoring Solutions
10. Perform Risk Analysis
11. Select Best Alternative and Prepare Trade Study Report
Lower Level Specifications

- Process repeated as we go from segments to elements to subsystems to assemblies to subassemblies to parts
- Specification written for each item at each level
- Process stops when we reach the configuration items (CIs) – the end items at which implementation is performed
Baseline Management

- Tie the PMB management process to the configuration management process
  - As configuration evolves the PMB evolves
  - When have a configuration change the baseline should change – change process requires evaluating impact
  - Keep the focus on future
Configuration Management

- Discipline of identifying and formalizing the functional and physical characteristics of a configuration item at discrete points in the product evolution for the purpose of maintaining the integrity of the product system and controlling changes to that item.
Configuration Management

- The configuration management function
  - Applies to hardware and software requirements and configuration throughout the life cycle
  - Should be documented in a CM plan
  - Applied during all phases of the program
  - Procedures are adapted to be consistent with program requirements
- Provides foundation for control of baselines and traceability
4 Elements of CM

- **Identification** – the definition and establishment of the baseline plans, requirements and configuration items
- **Control** – the formal process used to assure discipline in making changes to the baseline
- **Verification** – that the baseline configuration requirements are incorporated into products and tested
- **Accounting** – tracking the baseline, audit trail from the authorization of changes to the documentation, and the source for definition of the configuration baseline
Configuration Item

- Configuration Item -
  - satisfies an end use
  - selected for separate management
- Every component of a system MUST belong to some CI
- Requires Individual Specification

Select the Configuration Items to facilitate management accountability and replacement capability
Configuration Item Example

- Your car’s battery is a CI to you because you can readily buy a replacement to a specification in a supply store.
- Your car’s battery cells are not a CI to you because you cannot buy them in a consumer’s supply store.
- Is your car a CI to you?
- Is the alternator?
- Is the alternator rotor?
Formal Definition of Baselines

- “Design to” Baseline – functional, performance, interoperability and interface requirements and the verifications required.
- “Build to” Baseline – a CI’s functional, performance, interoperability and interface requirements and the verifications required.
- “As Built” Baseline – the approved, combined performance/design documentation utilized for the production/procurement of the CI.
Question:

- When in this process are we **ABLE** to create a PMB?
  - Reflects what intend to do
  - Reflects how intend to do it
  - Basis for resource allocations

- How does “proposal” fit in this process?
Understand Customer Requirements, Develop System Concept and Validation Plan

Develop System Specification and System Verification Plan

Expand Specifications into CI “Design-to” Specifications and CI Verification Plan

Evolve “Design-to” Specs. into “Build-to” Documentation and Verification Procedures

Fab, Assemble, and Code to “Code-to” and “Build-to” Documentation

Integrate CIs and Perform CI Verification to CI “Design-to” Specifications

Integrate Sys. and Perform Sys. Verification to Performance Specifications

Verify to “Build-to” Documentation

Integrate Sys. and Validate System to User Validation Plan

Demonstrate and Validate System to User Validation Plan

Core of the “Vee”
Plans, Specifications, and Requirements are Under Progressive Configuration Management

When is the Project Defined?
Typical Project Cycle?

Begin

Name the Product

Advertise the Product

Buy the Team Tee Shirts

Release Product at V1.0

Fix Bugs

Code a Little; Define Requirements a Little

Define Requirements

Release “Real” Product at V2.0

Buy the Team Tee Shirts
Conclusion

- Initial baseline is an allocation rather than a real plan
- Baseline must evolve
- Acknowledge
  - It will change
  - Variances are normal
  - IT IS HARD TO DO!
True Progress

- Tied to accomplishment of technical objectives
- Not about work, but about results
- EV status reflects technical progress in achieving performance objectives
Technical Performance Measurement

- **Purpose:**
  - Visibility of actual versus planned performance of high risk parameters
  - Early detection and/or prediction of performance problems
  - Assess impact of proposed changes

- **Candidates:**
  - Major effect on system performance
  - High risk, complexity
  - Major impact on schedule or cost
TPM Process

Performance Specifications

Incentive Structure

Risk Analysis

Acceptance Criteria

Allocated Parameters

Select/Quantify Parameters

Technical and Managerial Experience

Collect, analyze, present data from Integration and Verification activities

Screens:
- Must be quantifiable
- Must be capable of test or analysis
- Must have system impact
Typical Parameters

- Weight
- Power
- Computer throughput
- Direction Finding (DF) accuracy
- Reaction time and responsiveness
- Sensitivity
- Reliability/Availability/Maintainability
- Processing time
Performance Measurements

Specified “Not to Exceed” Value

Action Team to Bring Back into Spec

Demonstrated Variance

Predicted Variance

Current Estimate

Achievement to Date

Estimated Value

Allocated Value

Calculated Value

Measured Value

Proposal

PDR

CDR

Test

Delivery

Planned Value Profile

Demonstrated Values

Specified “Not to Exceed” Value

100%

90%

80%

70%

Specified “Not to Exceed” Value

Planned Value Profile

Achievement to Date

Action Team to Bring Back into Spec

Estimated Value

Allocated Value

Calculated Value

Measured Value

Proposal

PDR

CDR

Test

Delivery
EV and SE

- EV should reflect status and performance in the SE process
  - Baselines evolve together
  - Baselines change together
  - Progress occurs together

- SE is a fundamental to successful PM

- Make EV part of SE responsibility!?