Project Management Through the Eye of the Systems Engineer

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Topics

- What Is Systems Engineering?
- Project Examples (Case Studies)
- Summary
What Is Systems Engineering (SE)?

From the INCOSE Web Site (www.incose.org):

“Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: Operations, Cost & Schedule, Performance Training & Support, Test, Manufacturing, and Disposal.”
What Is Systems Engineering (SE)? (cont’d)

From the INCOSE Web Site (www.incose.org):

“Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.”
Basic Components of Applied Systems Engineering

Systems Engineering is Comprised of Three Major Components:

- Requirements and Functions Analysis and Management
- Design and Engineering Analysis and Modeling
- Integration and Interface Management

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Integrated Systems Engineering

- Requirements Analysis
- Functional Design Criteria
- Performance Requirements
- Conceptual Design
- Systems Design Description
- Requirements Verification

- Trade/Alternatives Studies
- Failure/Reliability Analysis
- Make/Buy Options
- Project Risk Analysis
- Process Hazards Analysis
- Throughput Analysis

- Interface Definition
- Hardware/Software Compatibility
- Vendor Specifications
- Process Transfer Functions
- Utilities Input/Output
- Process Flow Verification
Classic SE “V” Chart
Use of Systems Engineering in the Project Management Process

- Identifies the issues most likely to be of concern for project management early in project evolution
- For design and engineering projects, allows the preliminary identification of systems, structures and components that have the highest potential to impact cost, schedule and technical project baselines
Use of Systems Engineering in the Project Management Process

• Provides a systematic process for evaluating and reducing the number of engineering features that must be considered for more rigorous subsequent evaluation

• Develops the process sequentially, with increasingly more accurate information to be utilized in subsequent engineering analyses
“Typical” Project Organization

- Project Manager
  - Quality Assurance
  - Safety
  - Environmental

- Project Controls
  * Cost
  * Scheduling
  * Contracting
  * Other

- Discipline Engineering
  * Mechanical
  * Electrical
  * Aerospace
  * Process
  * Others (Except Systems Eng)

- Operations
  * Startup
  * Testing
  * Procedures
  * Other

- Systems Engineering
  * Requirements
  * Not Much Else
Fully Integrated Project Organization

Project Manager

Project Controls
- Cost
- Scheduling
- Contracting
- Other

- Cost Baseline
- Schedule Baseline

Discipline Engineering
- Mechanical
- Electrical
- Aerospace
- Process
- Others

- Design Criteria
- Design Analysis
- Eng. Studies

Operations
- Startup
- Testing
- Procedures
- Other

- Test Planning
- Validation
- Optimization

Systems Engineering
- Analysis
- Integration
- Design

Cross-Cut SE Functions
Project Examples
(Case Studies)
Project Example #1 Overview:

- One-of-a-kind facility for supporting the national nuclear power program
- Utilized advanced technology developed over a 20-year period at a national laboratory
- Involved technology transfer from government research to private (commercial) applications
- Required scale-up of developmental concepts for reliable, duty-cycle processes into a production plant format
Project Example #1
Management/SE Issues:

- Project had advanced to the advanced conceptual design phase
- Research-based development, so no consistent project management program had been implemented
- Project organized by Work Breakdown Structure, but not defined in terms of systems
- Critical systems (in terms of safety, engineering effort, long-lead procurement, etc.) difficult to define and evaluate
Project Example #1
Management/SE Approach:

• Evaluated SE techniques that would allow a screening of systems based on importance (primary process, support, auxiliary, etc.) and ranking based on function (safety, process integrity, etc.)
• Divided the entire plant into 24 primary systems (and associated subsystems)
• Reorganized project into a Systems Breakdown Structure to complement Work Breakdown Structure
• Selected a modified (systems-level) Failure Modes and Effects Analysis (FMEA) technique for prioritization
# Project Example #1
Implementation of a Systems Breakdown Structure

## Work Breakdown Structure

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Program Level</td>
</tr>
<tr>
<td>1.1</td>
<td>Project Level Element 1</td>
</tr>
<tr>
<td>1.2</td>
<td>Project Level Element 2</td>
</tr>
<tr>
<td>1.2.1</td>
<td>Task Element 1</td>
</tr>
<tr>
<td>1.2.2</td>
<td>Task Element 2</td>
</tr>
<tr>
<td>1.2.3</td>
<td>Task Element 3</td>
</tr>
</tbody>
</table>

## System Breakdown Structure

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Structure Level</td>
</tr>
<tr>
<td>1.1</td>
<td>System 1</td>
</tr>
<tr>
<td>1.2</td>
<td>System 2</td>
</tr>
<tr>
<td>1.2.1</td>
<td>Subsystem/Component 1</td>
</tr>
<tr>
<td>1.2.2</td>
<td>Subsystem/Component 2</td>
</tr>
<tr>
<td>1.2.3</td>
<td>Subsystem/Component 3</td>
</tr>
</tbody>
</table>

Conversion of Project Elements into Systems
Project Example #1
Utilization of the Failure Modes & Effects Analysis (FMEA) Technique

<table>
<thead>
<tr>
<th>Record No.</th>
<th>Subsystem or Item</th>
<th>Function</th>
<th>Failure Mode</th>
<th>Causes</th>
<th>Local Effect</th>
<th>Next Higher Effect</th>
<th>End Effect</th>
<th>Severity Class*</th>
<th>Operations and Protective Features</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

* Range from Minor Impact (1) to Extremely Severe (5 or 6)
Project Example #2
Successes/Results:

• Systems were prioritized based on function and importance
• Limited engineering resources were applied to most critical design applications
• Decisions were made on safety system up front, limiting the systems that required detailed analysis later in the project
• Project savings (earned value) were realized as directly related to SE efforts
Project Example #2
Overview:

• National facility for testing and evaluating state-of-the-art and cutting-edge propulsion technologies
• Most of the processes to be tested are developmental, and required involvement in research and testing to determine viability
• Design must accommodate laboratory- and bench-scale analysis of materials, energies and technologies that require special engineering considerations
Project Example #2
Management/SE Issues:

• Many of the technologies to be considered for the design involved exotic and hazardous energies and substances
• Scientific requirements for testing and experiment programs were being developed concurrently with advancing facility design
• Project management was based on traditional approach of project structure and organization – and was at risk of managing with inadequate requirements
Project Example #2
Management/SE Approach:

• Evaluated the 90% and 100% Engineering Studies to determine areas of potential concern
• Conducted initial evaluations and verification of the criteria and parameters presented in existing design documentation
• Interviewed scientists and prospective users to determine scope and magnitude of hazards associated with planned experimentation
• Implemented a Requirements Capture and Validation process
Project Example #2
Requirements Capture and Validation Process

- Review of Engineering Documentation
- Interviews with Scientists and Technologists
- Review of Standards and Regulations
- Requirements Capture
- Calculations and Modeling
- Follow-up Interviews with Scientists
- Working Sessions with Design Engineers
- Requirements Validation
- Design Verification
Project Example #2
Successes/Results:

• Process involved communications with all parties involved in design and facility utilization, which expedited design development

• Capture of requirements identified disconnects between information provided to designers and expectations of researchers

• Costly processes initially under consideration (e.g., tritium fusion) were evaluated, discussed, and submitted to cost/benefit analysis for impacts on design

• Utilizing input from review process, design team was allowed to proceed with design utilizing best compromise of safety, cost, and preferences of users
How Does It All Come Together?

- The elements of project design, operation and closure all progress (more or less) in a predictable, organized manner
- The project management process is most effective when conducted in a structured, planned sequence
- By applying the principles of systems engineering (up-front planning, work element integration, requirements management, etc.), project management elements can be sequenced to occur during the design and operations processes at the points where requirements are most important and the impact is most effective
Why Isn’t SE Always Used for PM Programs?

• May be in conflict with management that prefers large “contingency” funding
• May not be well understood by traditional project management approach
• Requires a high degree of emphasis in “up front” planning and evaluation, which places higher responsibility on the PM to be proactive and interactive
Summary

1. SE is directly related to, and may incorporate, many management functions
2. The SE requires information from the management and organization processes, and therefore must understand and support/participate in these processes
3. Project management is a driver for many SE requirements, analyses, and criteria
4. All cross-cut functions such as project management are best represented by the SE process
5. The tools utilized by the project manager are often the same as those used by the SE