INCOSE Systems Engineering Handbook v3.2: Improving the Process for SE Practitioners

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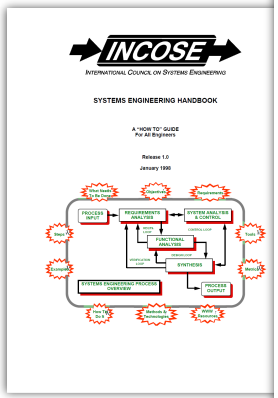
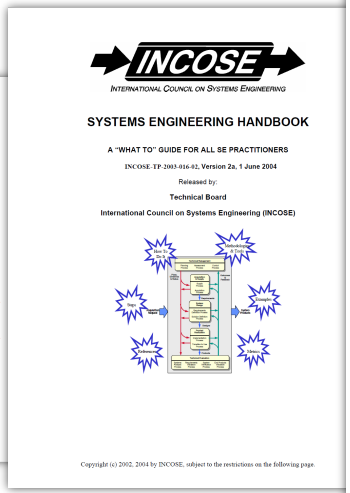
INCOSE Systems Engineering Handbook

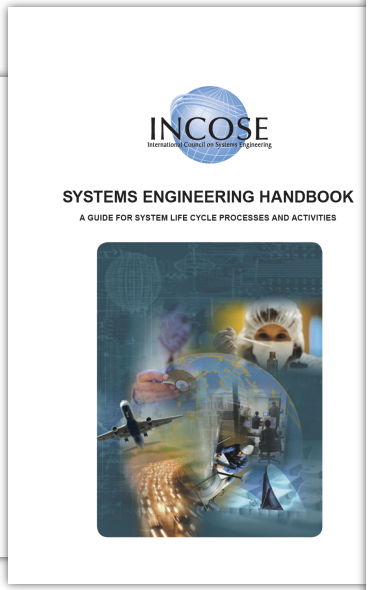
- Official INCOSE reference document and basis for the INCOSE certification examination
- Evolved to accommodate advances in SE discipline
  - Significant advancements in capturing SE knowledge
  - Multiple authors resulted in disjointed, fragmented presentation
  - Not aligned with ISO/IEC 15288:2008



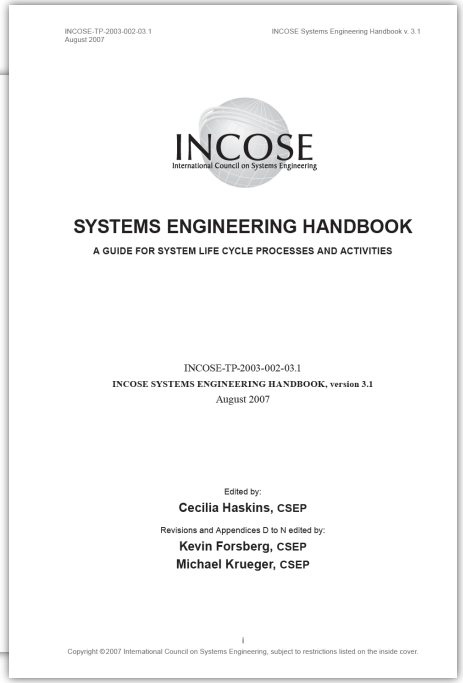
v1, 1998



v2a, 2004



v3, 2006



v3.1, 2007

A Real-Life Story … INL Systems Engineers Struggle to Prepare for CSEP Examination

- September 2008 – 25 SEs take *Preparing Professionals for the INCOSE Systems Engineering "CSEP" Certification* (by CSM)
  - based on *INCOSE Systems Engineering Handbook*, v3.1
- Frustrated by **difficulty accessing information** from v3.1
- Series of "topical" Brown Bag sessions to share insights and study for CSEP exam
- Identified **several inconsistencies** in v3.1

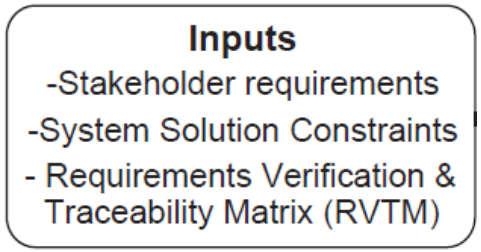
Topic	Handbook v3.1 Reference	Brownbag Dates
Stakeholder Requirements	4.2, 7.2, App I & J	9-Oct-08
Requirements Analysis	4.3, 7.2, App I & J	
Architecture	4.4, 4.7, 8.2, 9.6, App E, K, L	23-Oct-08
Implementation	4.5	
Integration	4.6, App N	
Verification	4.7, 8.10	6-Nov-08
Transition	4.8	
Validation	4.9, 8.9	
Operations	4.10	20-Nov-08
Maintenance	4.11	
Disposal	4.12	
Project Processes & Planning	5.1 - 5.8, 8.6	
Enterprise and Agreement	6.1 - 6.8	4-Dec-08
Decision Mgmt	7.1, 5.5	
Risk and Opportunity	5.6, 7.3	
Acquisition and Supply	8.1, 9.1, App F	
Systems Engineering Planning	App G.1-G.3	8-Jan-09
Tailoring	10.1 - 10.3	
Integrated Product and Process	App H	
SE Analysis "ilities" Part 9.1	9.2 - 9.5, 9.7 - 9.9 178-187	22-Jan-09
Human Systems	App M	
Architecture	App E, K, L	5-Feb-09
Integration	App N	
Configuration Mgmt	5.7, 8.3, App G.4	19-Feb-09
Information & Investment Mgmt	8.4 & 8.5	
Quality & Resource Mgmt	8.7, 8.8	

Inconsistencies in INCOSE Handbook v3.1

- Very few “topics” addressed in a single handbook location
  - Chapters 4 – 6, Overview of processes in plus Context Diagram
  - Chapters 7 – 9, Same processes in greater detail using a **different organizational structure**
  - Appendices D – N, Same processes a **third (or more) time** to capture techniques or practices not previously addressed
- Much of the **text repeated verbatim** in the appendices
- Other portions of **text inconsistent** with similar text presented in the appendices
- **Context diagrams different or inconsistent** with additional details

One Inconsistency Example

Context Diagram for Requirements Analysis v3.1, Figure 4-3



p. 4.5 of 24

"Inputs" for Requirements Analysis v3.1, Section 4.3.3

The primary input … is the **baseline** documented during the Stakeholder Requirements Definition Process. Additional inputs … include applicable **statutes, regulations, and policies**; the intended **operational use and utilization environment** for the system; any design or enterprise **constraints**; **manufacturing**; life cycle **support considerations**; **design considerations** …; and any **decisions or data** resulting from previous phases of development.

p. 4.5 of 24

"Typical Inputs" for Capturing Requirements v3.1, Appendix I.1

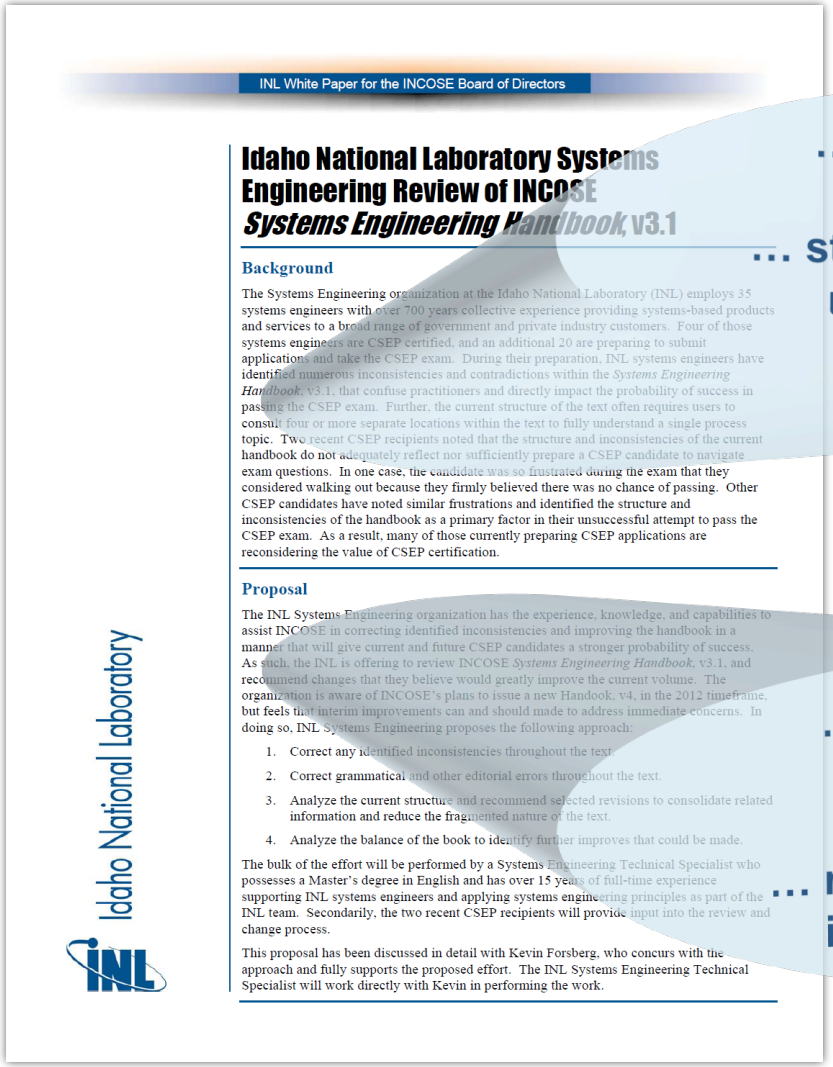
Examples of typical inputs … :
a. New or updated customer needs, requirements, and objectives in terms of missions, measures of effectiveness, technical performance, utilization environments, and constraints
b. Technology base data including identification of key technologies, performance, maturity, cost, and risks
c. The **outputs from the preceding acquisition phase** …
d. Requirements from **contractually cited documents** for the system and its configuration items
e. Technical objectives
f. Records of **meetings and conversations** with the customer

p. I-3 of 26

… The Rest of the Story

- Three SEs submit applications and take exam
  - **1 passed** CSEP and CSEP-Acq
  - **1 struggled** with exam, but passed
  - **1 did NOT pass** exam (has since passed)
- All 3 indicate disjointed, fragmented nature of v3.1 as **primary reason for frustration and struggle**
- Rest of INL SEs **questioned value of CSEP certification** based on v3.1
- In the past 12 months:
  - Nine INL SEs now CSEP certified
  - One received ESEP Recognition
  - 15 preparing to submit applications and take CSEP exam

Idaho National Laboratory Offers to Assist INCOSE in Revising Handbook



INL White Paper for the INCOSE Board of Directors

Idaho National Laboratory Systems Engineering Review of INCOSE *Systems Engineering Handbook*, v3.1

Background

The Systems Engineering organization at the Idaho National Laboratory (INL) employs 35 systems engineers with over 700 years collective experience providing systems-based products and services to a broad range of government and private industry customers. Four of those systems engineers are CSEP certified, and an additional 20 are preparing to submit applications and take the CSEP exam. During their preparation, INL systems engineers have identified numerous inconsistencies and contradictions within the *Systems Engineering Handbook*, v3.1, that confuse practitioners and directly impact the probability of success in passing the CSEP exam. Further, the current structure of the text often requires users to consult four or more separate locations within the text to fully understand a single process topic. Two recent CSEP recipients noted that the structure and inconsistencies of the current handbook do not adequately reflect nor sufficiently prepare a CSEP candidate to navigate exam questions. In one case, the candidate was so frustrated during the exam that they considered walking out because they firmly believed there was no chance of passing. Other CSEP candidates have noted similar frustrations and identified the structure and inconsistencies of the handbook as a primary factor in their unsuccessful attempt to pass the CSEP exam. As a result, many of those currently preparing CSEP applications are reconsidering the value of CSEP certification.

Proposal

The INL Systems Engineering organization has the experience, knowledge, and capabilities to assist INCOSE in correcting identified inconsistencies and improving the handbook in a manner that will give current and future CSEP candidates a stronger probability of success. As such, the INL is offering to review INCOSE *Systems Engineering Handbook*, v3.1, and recommend changes that they believe would greatly improve the current volume. The organization is aware of INCOSE's plans to issue a new Handook, v4, in the 2012 timeframe, but feels that interim improvements can and should made to address immediate concerns. In doing so, INL Systems Engineering proposes the following approach:

1. Correct any identified inconsistencies throughout the text.
2. Correct grammatical and other editorial errors throughout the text.
3. Analyze the current structure and recommend selected revisions to consolidate related information and reduce the fragmented nature of the text.
4. Analyze the balance of the book to identify further improves that could be made.

The bulk of the effort will be performed by a Systems Engineering Technical Specialist who possesses a Master's degree in English and has over 15 years of full-time experience supporting INL systems engineers and applying systems engineering principles as part of the INL team. Secondarily, the two recent CSEP recipients will provide input into the review and change process.

This proposal has been discussed in detail with Kevin Forsberg, who concurs with the approach and fully supports the proposed effort. The INL Systems Engineering Technical Specialist will work directly with Kevin in performing the work.

Idaho National Laboratory

INL

…numerous inconsistencies …

… structure of the text often requires users to consult four or more separate locations …

…assist INCOSE in correcting identified inconsistencies …

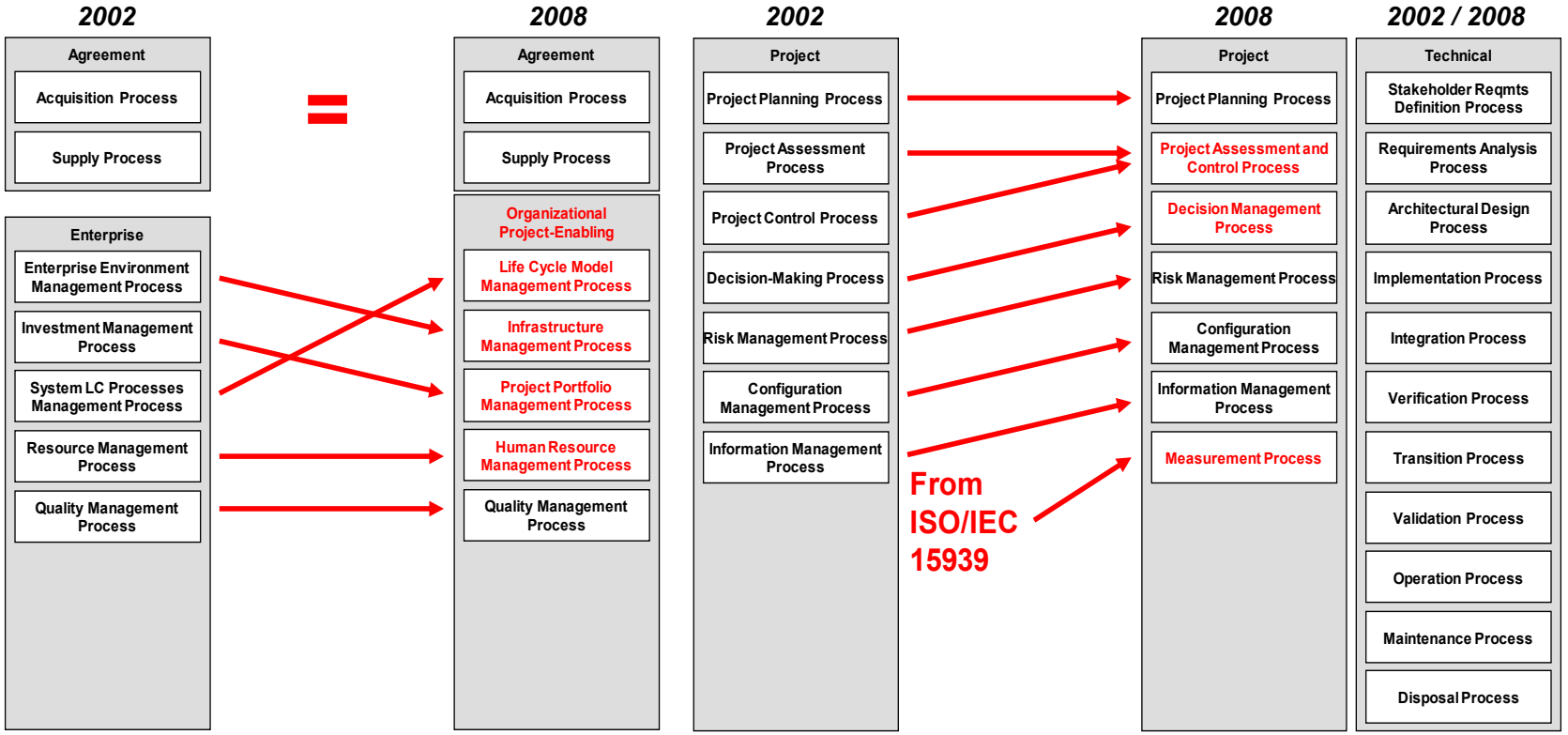
… recommend changes [to] greatly improve the current volume …

Revision Objectives

1. **Align the text with ISO/IEC 15288:2008**, *System and software engineering – System life-cycle processes*
2. **Resolve technical inconsistencies** in v3.1
3. **Consolidate related process information** to remove the multiple and disjointed treatment of topics
4. **Minimize the impact** to the INCOSE certification exam.

New ISO/IEC 15288:2008

- ISO/IEC 15288:2002 (Systems Engineering) and ISO/IEC 12207:1995 (Software Engineering) updated and integrated
  - **Single standard** with common vocabulary
  - **Generic, integrated process** with jointly planned levels of prescription



Source: Moore and Roedler, 2008

Plan for Consolidation of Process Information

- INL proposed a new outline to reorganize the Handbook by topic and consolidate related chapters and appendices into subsections

4. Technical Processes
4.1 Introduction
4.2 Stakeholder Requirements Definition Process
- 7.2 Requirements Management
- I.1 Capturing Source Requirements
- I.2 Concept of Operations
- I.3 Define/Derive/Refine Functional/Performance Requirements

4.3 Requirements Analysis Process
- I.4 Requirements Allocation and Traceability
- I.5 Development of Specification Tree and Specifications
- I.6 Requirements and Design Loops

NEW 4.4 - Appendix J: Functional Analysis and Allocation
- J.1 Purpose of Functional Analysis/Allocation Task
- J.2 Major Steps in the Functional Analysis/Allocation Process
- J.3 Tools Used to Support Functional Analysis/Allocation
- J.4 Metrics Used in Functional Analysis/Allocation

4.4 Architectural Design Process
- 8.2 Architectural Design
- L.3 Trade Studies
- Appendix K: Systems Architecture Synthesis
- K.1 Define/Refine System Element Alternatives
- K.2 Synthesize Multiple System Architectures
- K.3 Select Preferred System Architecture/Element Solution
- K.4 Define/Refine/Integrate Systems Physical Configuration

4.5 Implementation Process
4.6 Integration Process
- N.1 System Build
- N.2 System Integration with External Systems

4.7 Verification Process
- 8.10 Verification

4.8 Transition Process
4.9 Validation Process
- 8.9 Validation

4.10 Operation Process
4.11 Maintenance Process
4.12 Disposal Process

5. Project Processes
5.1 Introduction
5.2 Project Planning Process
- 8.6 Project Planning
- G.1 System Engineering Plan (SEP)

5.3 Project Assessment Process
5.4 Project Control Process
5.5 Decision-Making Process
- 7.1 Decision Management

5.6 Risk and Opportunity Management Process
- 7.3 Risk and Opportunity Management

5.7 Configuration Management Process
- 8.3 Configuration Management
- G.4 Configuration Management

5.8 Information Management Process
- 8.4 Information Management

6. Enterprise and Agreement Processes
6.1 Introduction
6.2 Enterprise Environment Management Process
6.3 Investment Management Process
- 8.5 Investment Management
- L.1 Life Cycle Cost Analysis

6.4 System Life Cycle Process Management Process
6.5 Resource Management Process
- 8.8 Resource Management

6.6 Quality Management Process
- 8.7 Quality Management

6.7 Acquisition Process
- 8.1 Acquisition and Supply

6.8 Supply Process
- 8.1 Acquisition and Supply

Alignment of INCOSE SE Handbook with ISO/IEC 15288:2008

- **Chapters 4 – 5 remain in same order** as v3.1, with two new subsections
  - *4.12 Cross-cutting Technical Methods*
  - *5.7 Measurement Process* (from ISO/IEC 15939)
- **Chapter 6 reduced** to address only *Agreement Processes*
- *Enterprise* processes moved from Chapter 6 to **new Chapter 7**, *Organizational Project-Enabling Processes*
- Use of "organizational" instead of "enterprise"
- Updated "Purpose" of each process to match ISO/IEC 15288:2008

Consolidation of Process Information

- Each process Chapter in v3.2 divided into two subsections
  - *Overview*
    - Retains the **original chapter structure**
    - Presents **updated context diagrams and summary** Purpose, Description, Inputs, Outputs, and Process Activities consistent with ISO/IEC 15288:2008.
  - *Elaboration*
    - Combines the text from v3.1 Chapters 7 – 9 and appendices into **new, consolidated descriptions** of the principles introduced in the *Overview*.
- Chapters 7 – 9 replaced in v3.2
  - Chapter 7, *Organizational Project-Enabling Processes*
  - Chapter 8, *Tailoring Processes* (formerly Chapter 10)
  - Chapter 9, *Specialty Engineering Activities* (formerly Chapter 8, Systems Engineering Support Activities).

Sample of Consolidated Structure

v3.1 Structure

4 TECHNICAL PROCESSES
4.1 Introduction
4.2 Stakeholder Requirements Definition Process
4.3 Requirements Analysis Process
…

7 ENABLING SYSTEMS ENGINEERING PROCESS ACTIVITIES 7.1
7.1. Decision Management
7.2 Requirements Management
7.3 Risk And Opportunity Management
…

APPENDIX I: REQUIREMENTS DEFINITION PROCESS
I.1 Capturing Source Requirements
I.2 Concept Of Operations
I.3 Define/Derive/Refine Functional/Performance Requirements
I.4 Requirements Allocation And Traceability
I.5 Development Of Specification Tree And Specifications
I.6 Requirements And Design Loops
…

v3.2 Structure

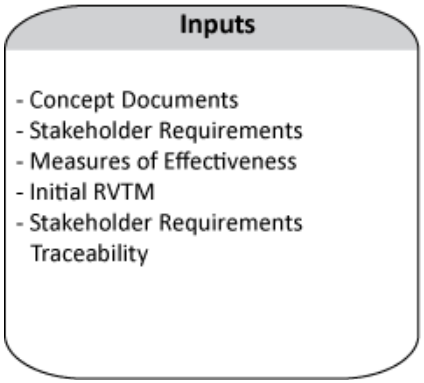
4 TECHNICAL PROCESSES
4.1 Stakeholder Requirements Definition (SRD) Process
4.2 Requirements Analysis (RA) Process
4.2.1 Overview
4.2.2 Elaboration

4.3 Architectural Design (AD) Process
4.4 Implementation (IMPL) Process
4.5 Integration (INT) Process
4.6 Verification (VER) Process
4.7 Transition (TRAN) Process
4.8 Validation (VAL) Process
4.9 Operation (OPER) Process
4.10 Maintenance (MAINT) Process
4.11 Disposal (DISP) Process
4.12 Cross-Cutting Technical Methods
4.13 References

Resolution of Inconsistencies (1 of 2)

- Combined different process versions into **a single, comprehensive set of details** in the *Overview* section of each chapter
  - Used CORE (Vitech Corporation) to model Handbook and ensure consistency
  - Erred on the side of inclusion rather than exclusion
  - Updated context diagrams to reflect the larger set of process principles

Context Diagram for Requirements Analysis v3.2, Figure 4-4



p. 71

"Inputs" for Requirements Analysis v3.2, Section 4.2.1.3

The primary input … is the project baseline documented during the Stakeholder Requirements Definition Process:

- *Concept Documents*
- *Stakeholder Requirements*
- *Initial RVTM*
- *Stakeholder Requirements Traceability.*

p. 71

Resolution of Inconsistencies (2 of 2)

- Consolidated text from Chapters 7 – 9 and the appendices to create **new, comprehensive elaborations**
  - Redundant text removed
  - Paragraphs reordered to improve flow and readability
  - Inconsistent descriptions compared, combined, and revised to be consistent with ISO/IEC 15288:2008
  - Numerous illustrations added or revised to reflect evolutions in SE methodology and clarify otherwise vague or incomplete concepts.

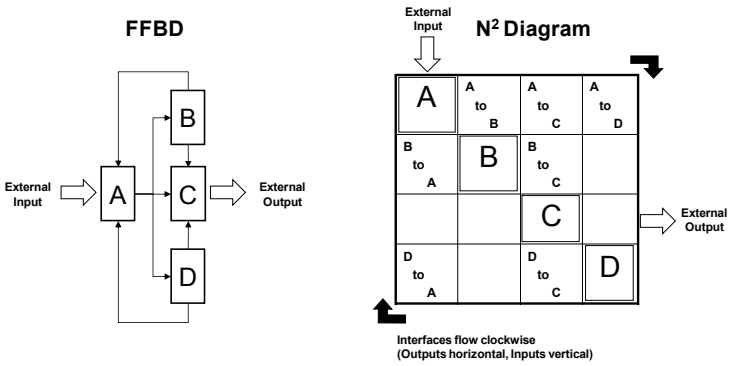


Figure 4-23. Sample FFBD and N^2 Diagram

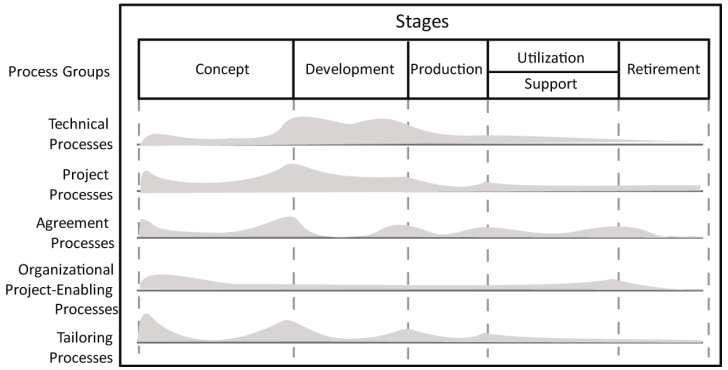


Figure 3-2. SE level of effort across life-cycle stages

Expansion and Addition of New Technical Information (1 of 3)

- **Revisions made by subject matter experts** to bring information up-to-date with current theories and practices
  - *Modeling* (Section 4.12.1)
  - *Systems Modeling Language*, or SysML™ (Section 4.12.3)
  - *Usability Analysis/Human Systems Integration* (Section 9.12).
- **Chapter 9 revised and expanded** to introduce specialty engineering areas
  - *Cost-Effectiveness Analysis*
  - *Interoperability Analysis*
  - *Life-cycle Cost Analysis*
  - *Value Engineering* (New)

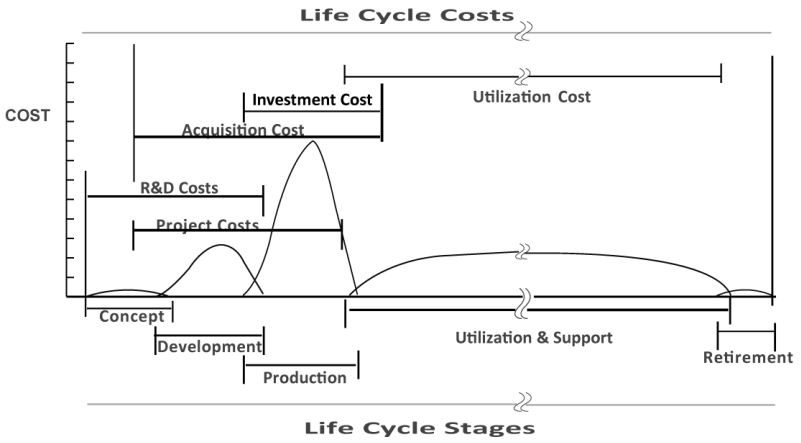


Figure 9-3, Life-Cycle Cost Elements (not to scale)

Expansion and Addition of New Technical Information (2 of 3)

- Addition of evolving SE principles and methodologies
  - *Lean Development* (Section 3.3.3.3)
  - *Agile Development* (Section 3.4.4)
  - *Measurement* (Section 5.7)
  - *Cross-Cutting Technical Methods* (Section 4.12),
    - Modeling, Simulation, and Prototyping
    - Functions-Based Systems Engineering
    - Object-Oriented Systems Engineering

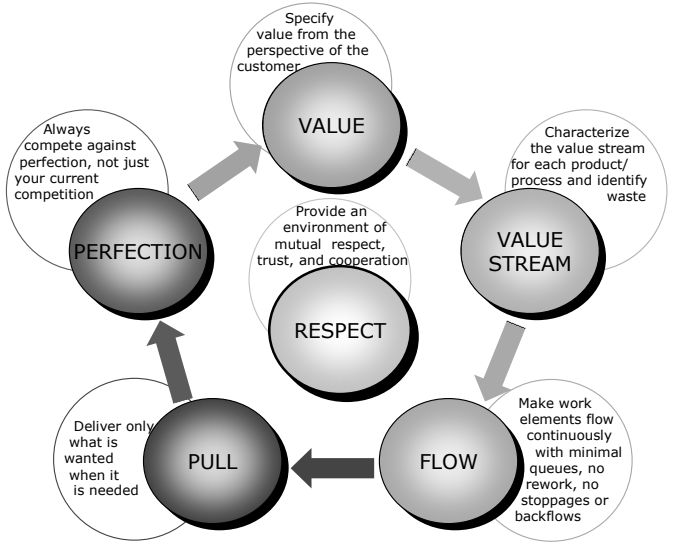


Figure 3-9, Lean Development Principles

Expansion and Addition of New Technical Information (3 of 3)

- Reduced the number and content of the remaining appendices
  - **Appendix A** provides a more complete picture of the interdependencies of SE process steps.
  - New **Appendix B** maps SE life-cycle process steps in v3.2 to five other industry-accepted standards
    - ISO/IEC 15288:2002
    - ISO/IEC 15288:2008
    - ISO/IEC 26702:2007 IEEE 1220™
    - ANSI EIA-632
    - CMMI® for Development v1.2.

ISO/IEC 15288:2002 System Life Cycle Process	INCOSE SE Handbook v3.2 Section	Notes/Comments
6.1 Agreement Processes		
6.1.1 Acquisition Process	6.1 Acquisition Process	
6.1.2 Supply Process	6.2 Supply Process	
6.2 Enterprise Processes		
6.2.1 Enterprise Environment Management Process	7.1 Life Cycle Model Management Process	Policies & procedures
6.2.2 Investment Management Process	7.3 Project Portfolio Management Process	
6.2.3 System Life Cycle Process Mgmt Process	7.1 Life Cycle Model Management Process	Methods & tools Enterprise measures

  - **Appendix C**: Complete list of acronyms
  - **Appendix D**: Glossary of common SE terms
  - **Appendix E**: Acknowledgements for v3, v3.1, and v3.2.
  - **Appendix F**: Instruction for providing comments
  - New **Topical Index**

Handbook v3.2 Review by INCOSE

- An extensive review of the draft handbook v3.2 was accomplished by the **INCOSE technical community**
- The review team was lead by Yoshi Ohkami (ESEP) and Dick Wray and included, in alphabetical order:
  - Stu Allison, Samantha Brown, James Cademartori (CSEP), John Clark (CSEP), Kevin Forsberg (ESEP), Cheryl Jones, Troy Petersen (CSEP), Karen Richter, Garry Roedler (ESEP), Seiko Shirasaka, Pete Suthon (CSEP), L. Mark Walker (CSEP), Hironori Washizaki, and Mike Zabat (CSEP).
- The review team provided **over 300 comments** that significantly improved the quality of the handbook.
- All comments were dispositioned by the editorial team
  - Held an in-person meeting in late 2009
  - Reviewers were consulted for clarification, if needed

Minimized Impact to CSEP Exam

- ASEP/CSEP exam questions reviewed against v3.2 changes
  - The Certification Advisory Group (CAG) conducted a detailed review of the test items to identify all issues with v3.2
  - A few questions identified as needing to be updated/replaced
- New/modified items vetted by the CAG at the International Workshop in February 2010
- Updates exam with new items released in May 2010
- Either handbook v3.1 or v3.2 can now be used to prepare for ASEP/CSEP exam
- Handbook v3.2 will become sole basis for CSEP exam in January 2011 (i.e., v3.1 will be retired)

Conclusion

- Revised *INCOSE Systems Engineering Handbook v3.2* aligns with the structure and principles of ISO/IEC 15288:2008.
- Life-cycle process steps now presented without duplication or redundancy in a single location within the text.
- Revised Handbook serves as a **comprehensive instructional and reference manual** for effectively understanding SE processes and conducting SE work, and **better serves certification candidates** preparing for the CSEP exam.

The *INCOSE Systems Engineering Handbook v3.2* was formally accepted and approved by the INCOSE Technical Committee on **January 25, 2010**.

The Handbook was initially approved by ISO/IEC for publication as an **ISO/IEC Technical Report in June 2010**. Comments have been incorporated, and final approval is pending.