Chapter Presentation
INCOSE Systems Engineering Handbook Fifth Edition
Updating the Reference for Practitioners

Revision Date 5 Oct 2023

Dave WALDEN, ESEP – INCOSE SE Handbook Editor-in-Chief (EIC) (Americas Sector)

Tom SHORTELL, CSEP – INCOSE SE Handbook Deputy EIC (Americas Sector)

Garry ROEDLER, ESEP – INCOSE SE Handbook Editor (Americas Sector)

Bernardo DELICADO, ESEP – INCOSE SE Handbook Editor (EMEA Sector)

Odile MORNAS, ESEP – INCOSE SE Handbook Editor (EMEA Sector)

YIP Yew-Seng, CSEP – INCOSE SE Handbook Editor (Asia Oceania Sector)

David ENDLER, ESEP – INCOSE SE Handbook Editor (EMEA Sector)

Topics

- What is the INCOSE SE Handbook?
- Overall impetus for change
- Handbook development process
- Top-level schedule
- Summary of the Fifth Edition requirements
- Summary of new content added for this version
- Formats & translations
- Impact to INCOSE Certification
- Questions & discussions

Presenter Introduction
Dave Walden, INCOSE ESEP & Founder

- Over 40 Years of Industry Experience
  - Principal Consultant & Instructor at Sysnovation since 2006. Teaching and consulting in various industries, including agriculture, automotive, biomedical & healthcare, consumer goods, defense & aerospace, government departments/agencies, power & energy, and professional services
    - Sysnovation core courses include:
      - SE Principles, Leading SE Exec Overview, Enabling SE Overview for Non-SEs, Requirements Formulation, SE Tool Belt, COTS-Based SE (CBSE), Brownfield SE, System of Systems Engineering (SoSE), Beyond Greenfield Systems Engineering, Leading Effective Technical Reviews, Soft Skills for SEs, INCOSE SEP Prep
      - Also taught for ATI, CESAMES, CSM, Iowa State University, K2B, University of Minnesota, Purdue University, Strategy Bridge, and Vitech
    - Sysnovation core consulting areas include:
      - Coaching/mentoring, non-advocacy reviews, major review preparation, and process improvement
    - **Lead Editor/Editor-in-Chief of the INCOSE SE Handbook Fourth & Fifth Editions, Co-Editor Since v3.2**
    - INCOSE representative in ISO/IEC JTC 1 / SC 07 / WG 10, and WG 22 (Software and systems engineering – process assessments and terminology, respectively)
    - INCOSE Certification Program Manager 2007-2013
  - 13 years at General Dynamics Advanced Information Systems
    - Director/SE IPT Lead for the FCS ICS SoS Program
    - Director of Integrated Process and Quality
    - Systems Engineering lead on numerous programs
  - 10 years at McDonnell Douglas (now Boeing)
    - Avionics analyst on the F-15, YF-23, and IRAD/CRAD
- Education:
  - MS MOT (Mgmt of Technology) – University of Minnesota
  - MS EE & MS CS – Washington University in St. Louis
  - BS EE – Valparaiso University

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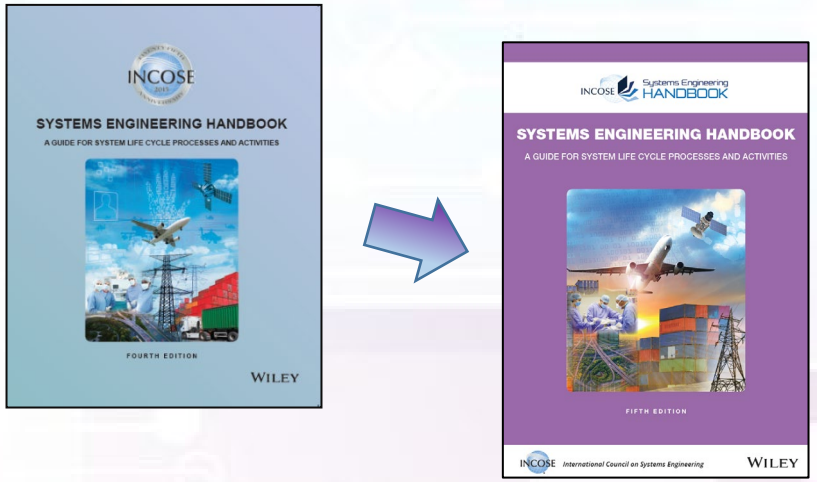
The SE Handbook - Our Flagship Product

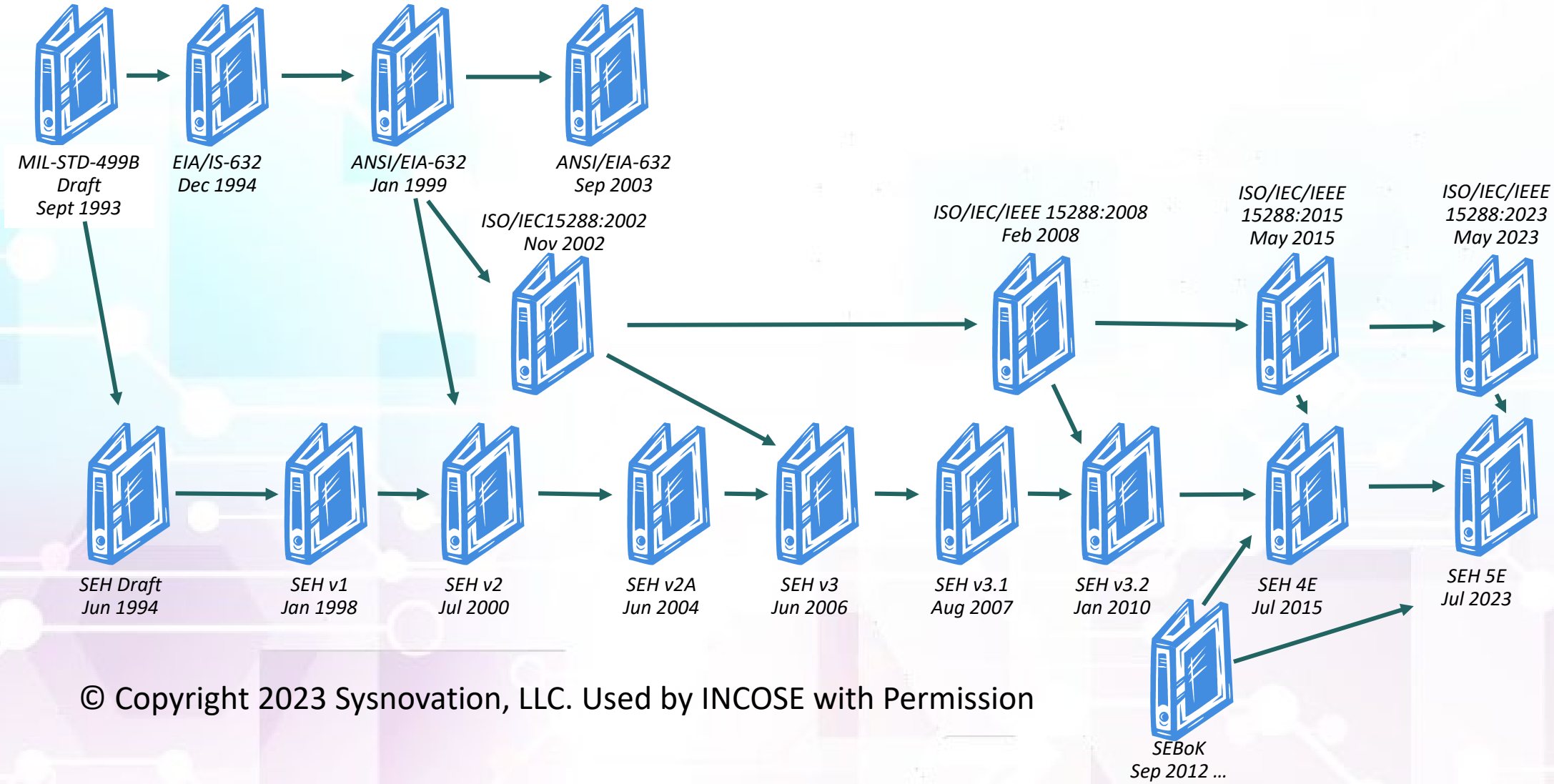
- The INCOSE SE Handbook (SEH)
  - Reflects the state-of-the-good-practice of Systems Engineering
  - Based on ISO/IEC/IEEE 15288
    - Further elaborates the processes and activities to execute the processes
  - Inputs from the entire INCOSE Technical Community
  - Serves as a reference of practices and methods that have proven beneficial to the SE community at large

- Fourth Edition published in July 2015
- Fifth Edition to be published in July 2023



The SEH serves as the basis for the INCOSE CSEP & ASEP exams.

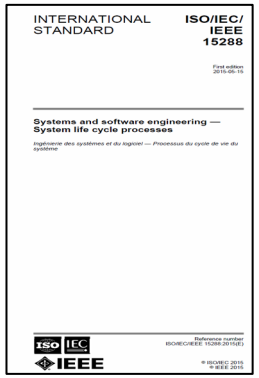
INCOSE Systems Engineering Handbook (SEH) History



Three Main SEH Inputs

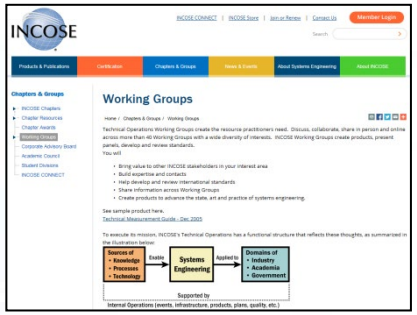
ISO/IEC/IEEE 15288 standard

- Developed by the consensus of SE experts from government, industry, and academia
- Defines a set of processes and associated terminology



INCOSE Working Groups

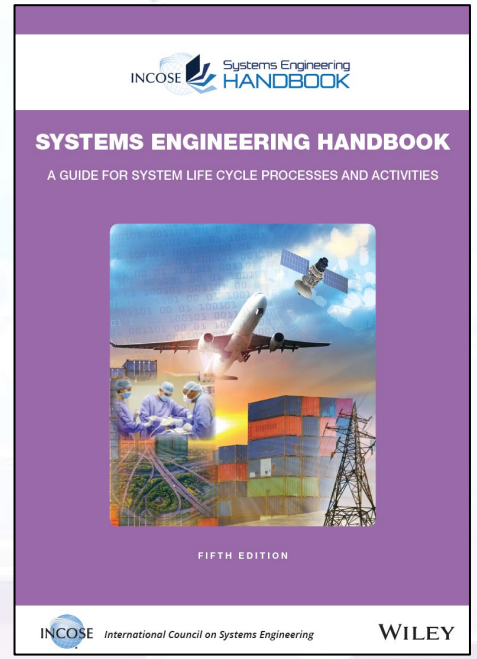
- Subject Matter Experts from the INCOSE technical community serve as section authors
- Handbook includes summaries and pointers to INCOSE Working Group products



SE Body of Knowledge (SEBoK)

- Reflects the state-of-the-knowledge of Systems Engineering
- Provides a widely accepted, community-based, and regularly updated wiki-based baseline of SE knowledge

SEBoK
GUIDE TO THE SYSTEMS ENGINEERING BODY OF KNOWLEDGE



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Motivations for Handbook Update

Since the INCOSE Systems Engineering Handbook reflects the state-of-the-good-practice of Systems Engineering, it generally is updated every 5-8 years to capture/incorporate:

- Changes in Systems Engineering due to improved principles, processes, methods, and tools
  - Add topics
  - Remove topics
  - Refresh other topics
- Updated versions of systems engineering standards (e.g., ISO/IEC/IEEE 15288)
- Reflect the updated vision and new challenges in Systems Engineering

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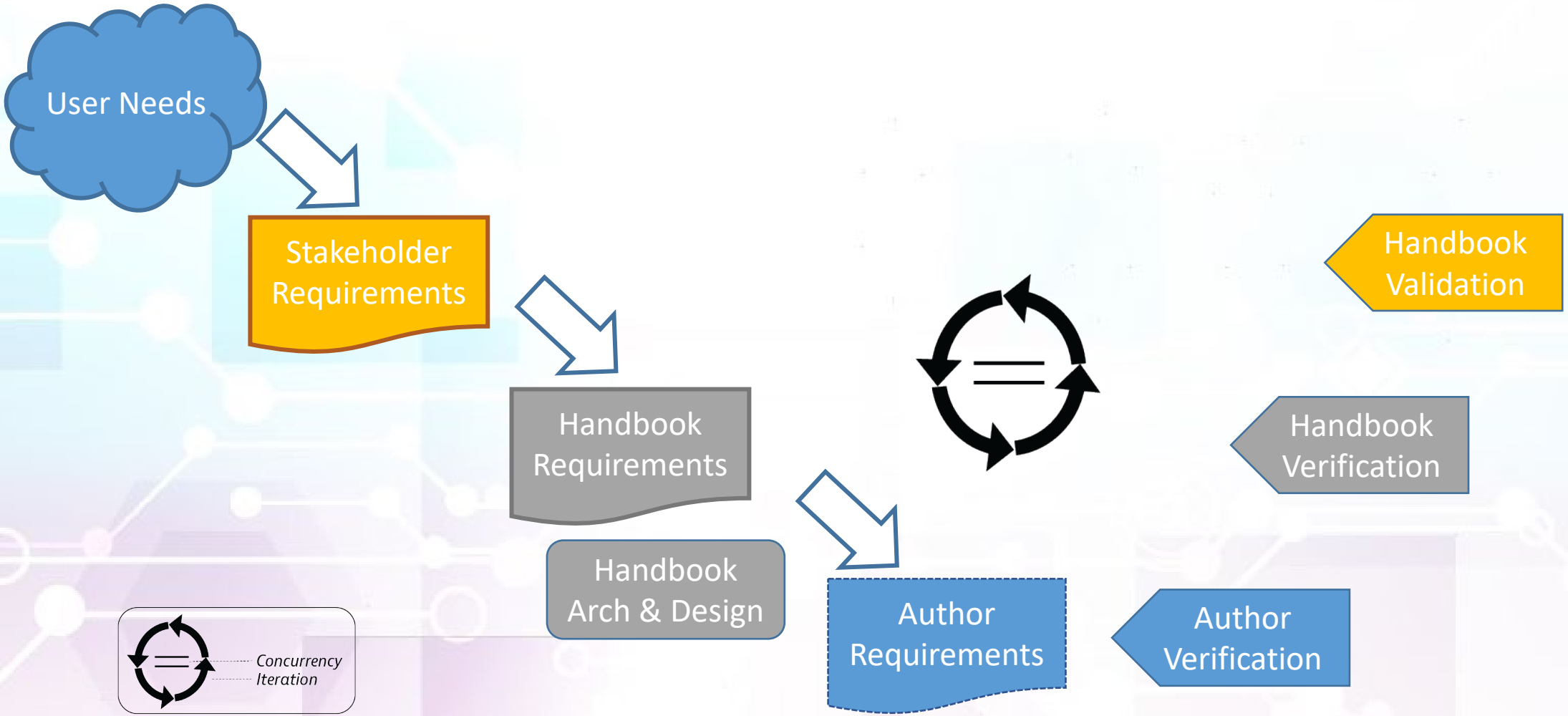
Background

- We followed a tailored version of our SE process to create our SE Handbook
- Our system of interest (SoI) is the INCOSE SE Handbook 5E (in all of its instantiations – hardcopy, electronic, etc.)

SEH5E Development Process Overview



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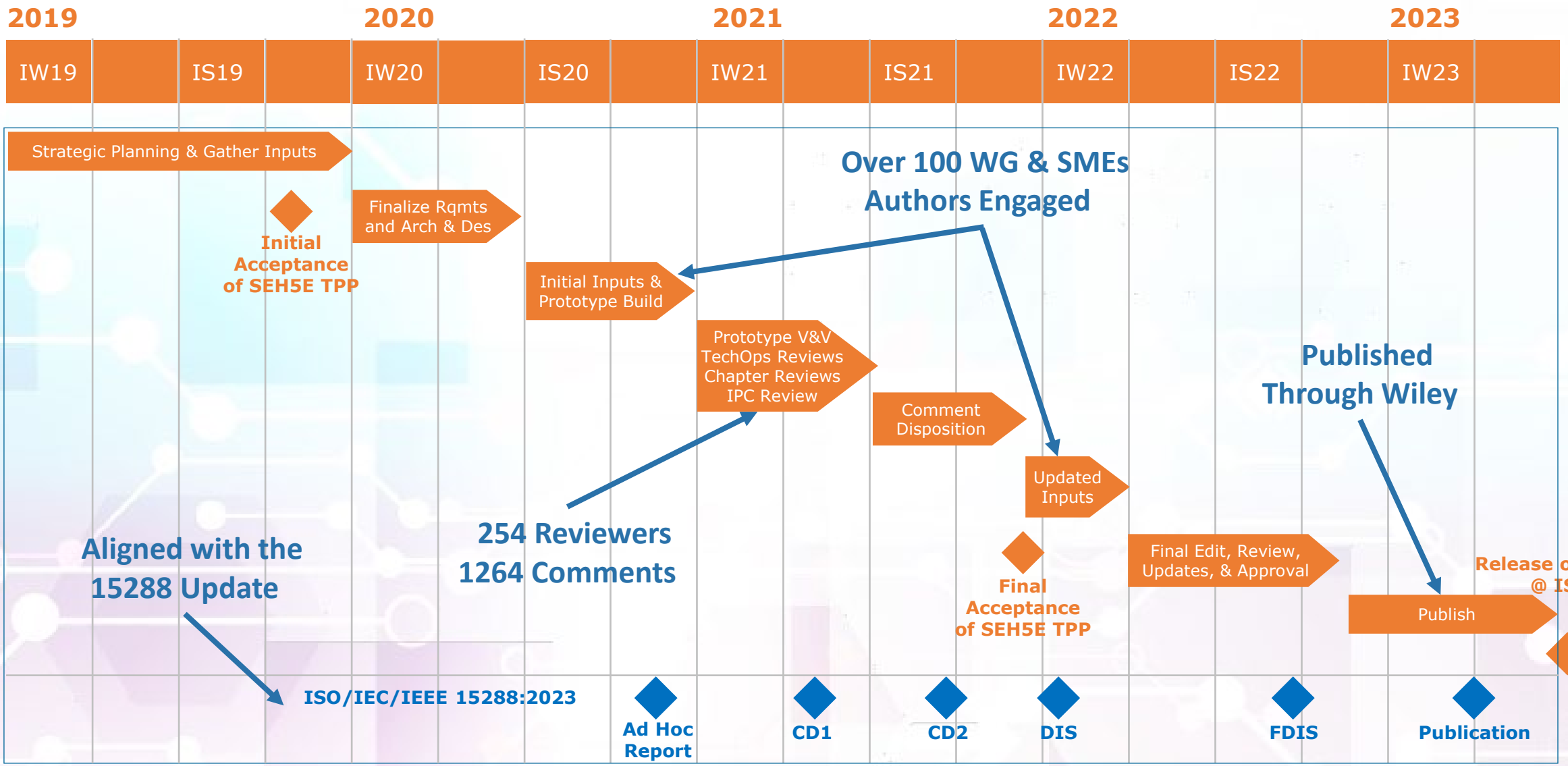
INCOSE SE Handbook 5E Schedule



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Key Inputs for the SE Handbook 5E

INCOSE Systems Engineering HANDBOOK

SEH4E Comments

IW/IS Input Sessions

Survey
- Keep
- Remove
- Modify
- New
- Other

INCOSE CAB
23 Responses

INCOSE WGs
27 Responses

INCOSE CAG
16 Inputs

INCOSE Fellows
13 Responses

Certification Training Providers
3 Responses

Stakeholder Requirements

jama

Vitech

Handbook Requirements

Handbook Arch & Design

Author Requirements

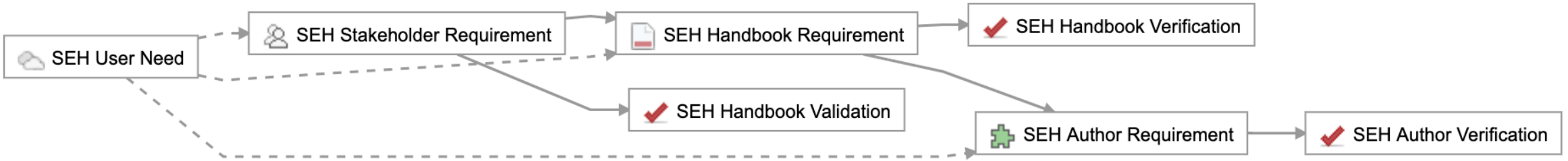
Summary of Handbook Inputs

- Topics
  - New Fellows Definitions of System and SE.
  - Model-Based SE (including beyond SysML)
  - Digital Engineering & Digital Twins
  - Agile SE & DEVSECOPS & Continuous Integration
  - Product Line SE & Reuse
  - Patterns-Based SE
  - Lean SE
  - Cyber Security & Cyber-Physical Systems
  - Connected Services
  - SE Value Proposition
  - Human-Centered Design
  - Model-Based Conceptual Design
  - SE Principles
  - 4th Industrial Revolution & Fast Innovations Cycles
  - Big Data & IoT
  - Machine Learning & AI
  - Natural Systems
  - Cognitive Skills & Soft Skills
  - Best Practices & Pragmatic Application Guidance
  - Deployment Guidance

- Topics (cont.)
  - Benchmarking Information
  - Updated Case Studies
  - Incorporate Latest SE Standards
  - Incorporate INCOSE Products (including partners)

- Architecture & Design
  - Throw Away and Start Over
  - Shorter
  - Longer
  - More Compelling/Appealing
  - Multi-Part
    - Part 1: Domain-Neutral
    - Parts 2-n: Domain-Specific
  - Reorganize (multiple suggestions)
  - Align with INCOSE SE Competency Framework
- Formats
  - e-Documents
  - Web-Enabled
  - Parameterized & “Customizable”
  - (Executable) Model of the Process(es)

Jama Relationship Diagram for SEH5E

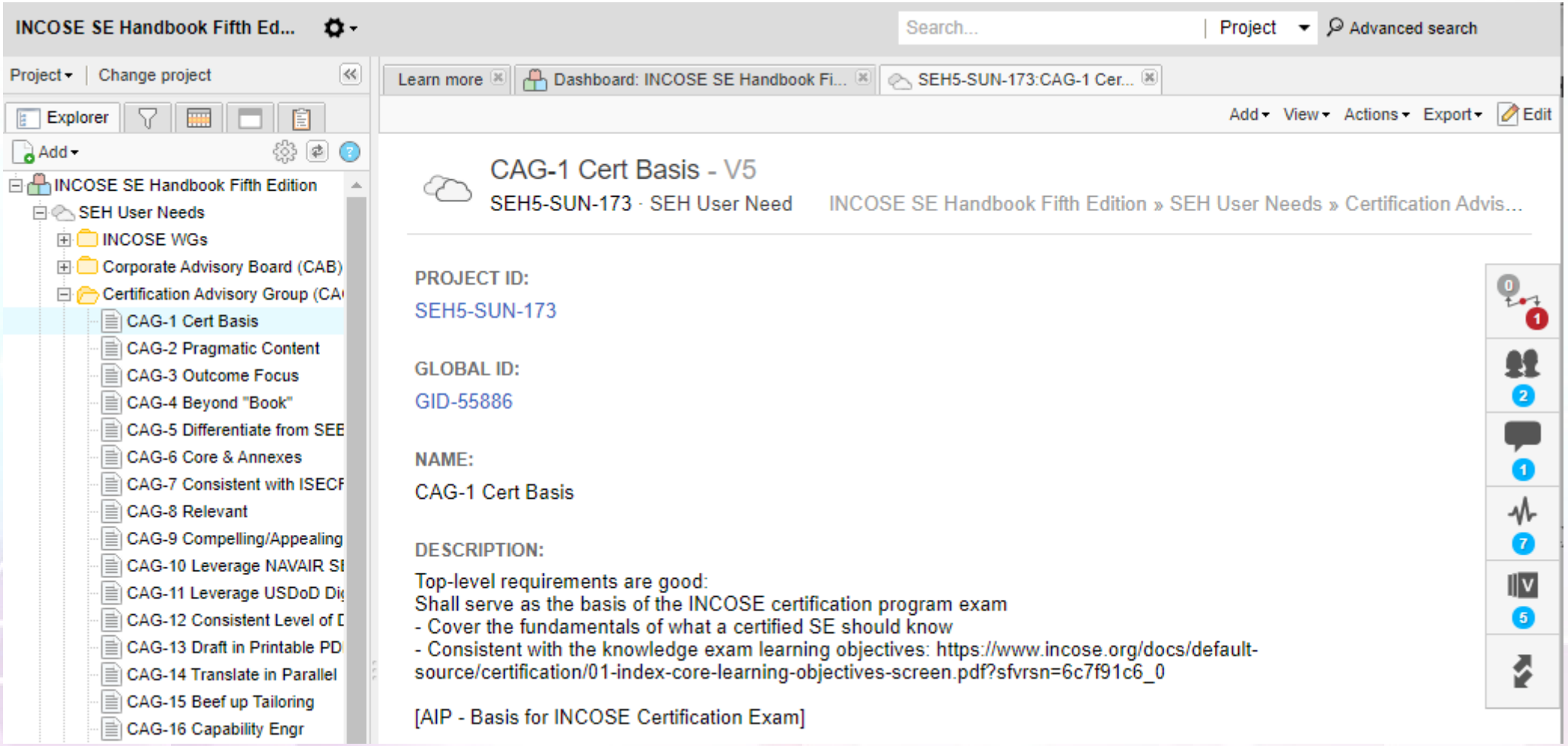


- Tailored to match our handbook process terminology
- Solid lines represent required relationships
- Dashed lines represent optional relationships

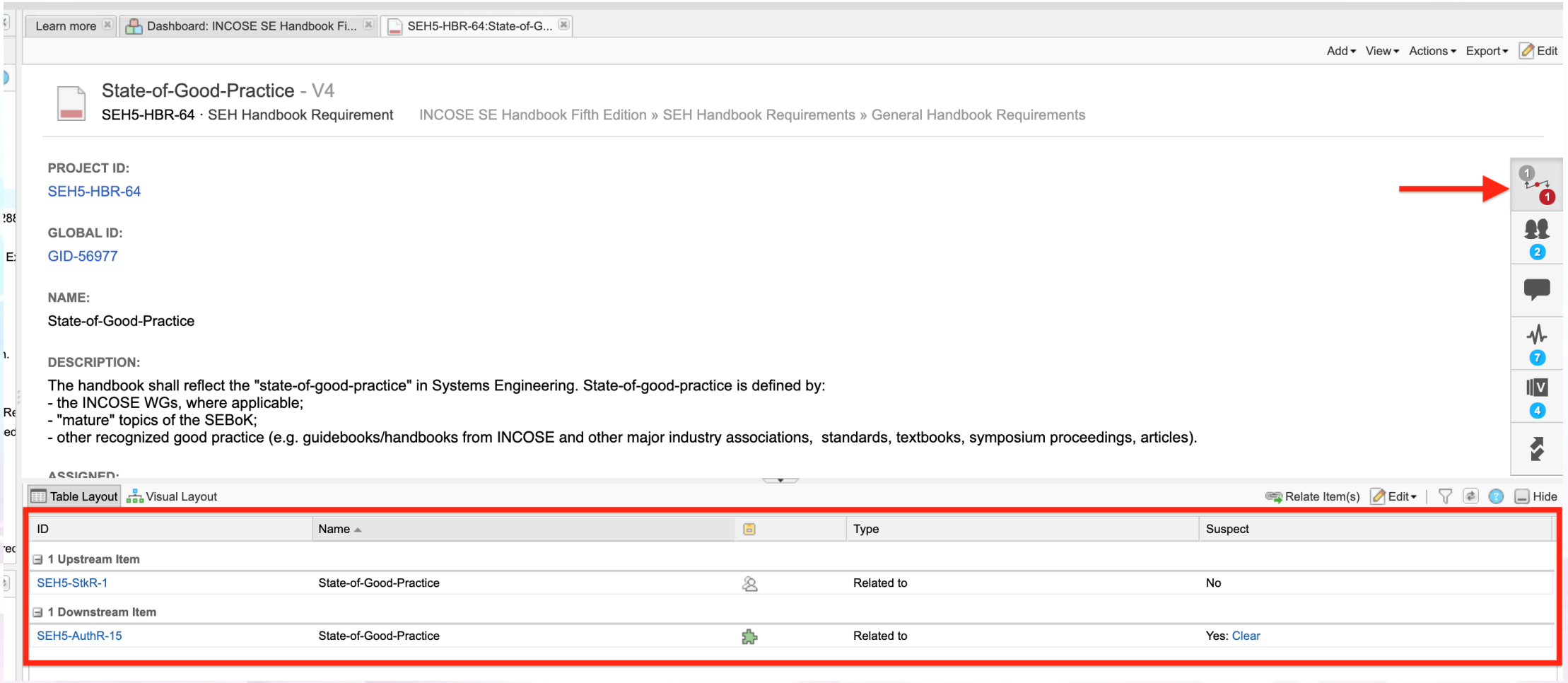
Key Requirement Modeling Concepts

- Purpose of the requirements model
  - Manage the large volume of handbook inputs and requirements
  - Enable editorial team communication
  - Enable the disposition of the inputs
- Guiding modeling concepts
  - Minimize tool customizations (use “out of the box” to the extent practicable)
  - Map the tool schema to the handbook process and terminology
  - Leverage traceability to establish relationships between the various sets of requirements

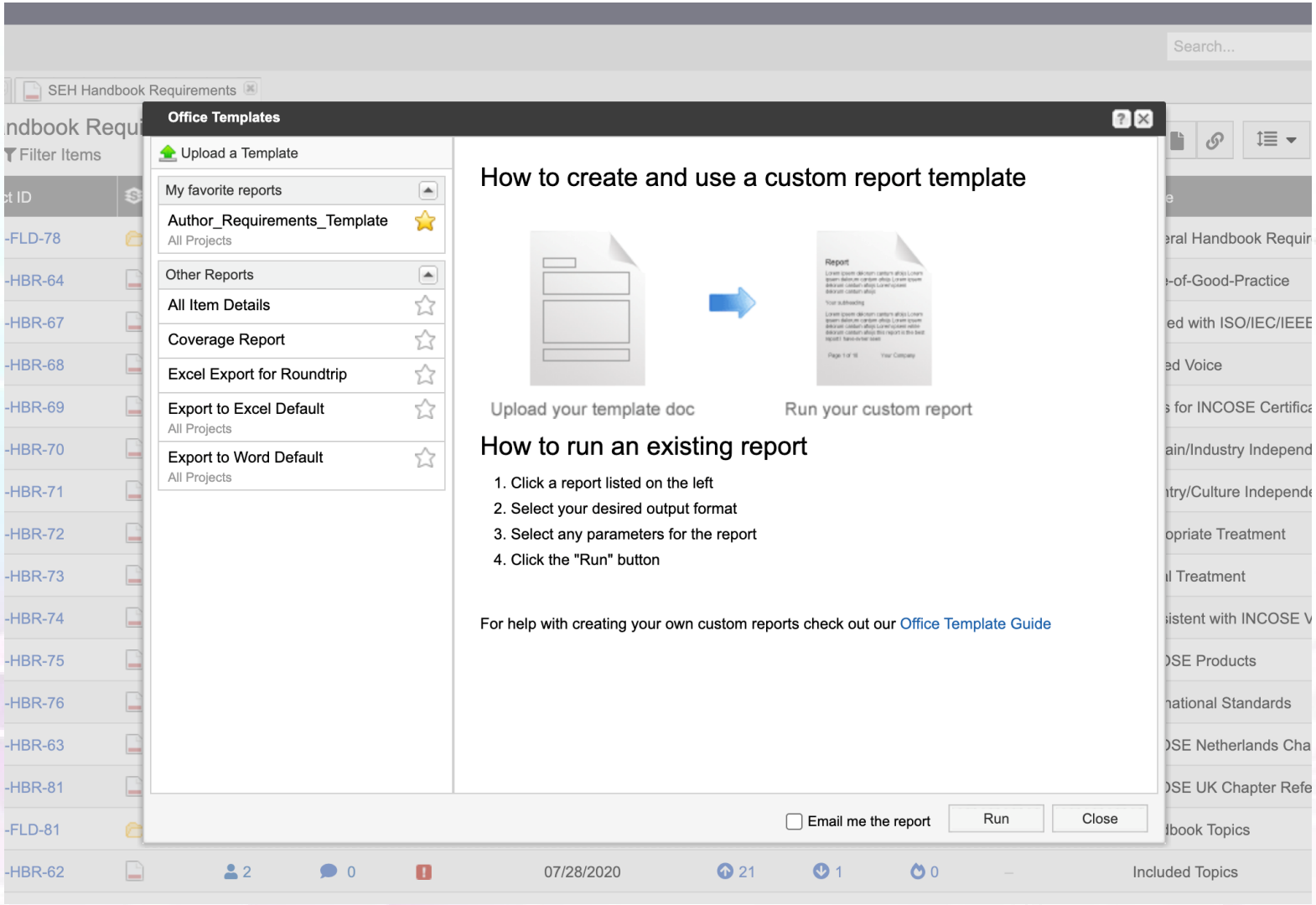
Single Item View – User Need Example



Jama Connect Relationships – System Requirement Traceability Example

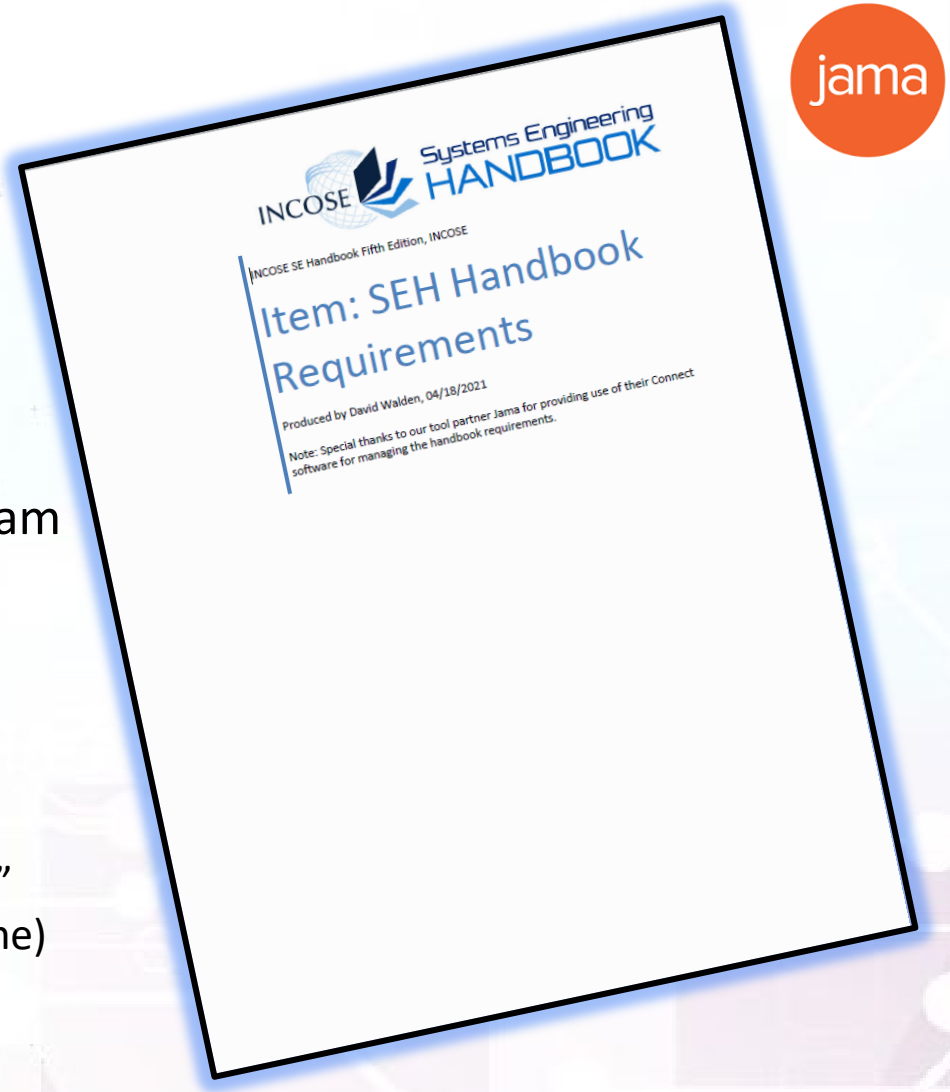


Jama Connect Documentation Creation



INCOSE SEH5E Driving Stakeholder Requirements

- Shall reflect the “state-of-the-good-practice” in Systems Engineering
  - Defined by the INCOSE WGs, where applicable
  - Consistent with international standards
  - Include the “mature” topics of the SEBoK
  - Include other relevant good practice (e.g., textbooks, articles)
- Shall be aligned with ISO/IEC/IEEE 15288
  - Should be aligned with the SEBoK
  - Should be aligned with INCOSE products
- Shall serve as the basis of the INCOSE certification program exam
- Shall be domain/industry independent
  - But should show guidance for different domains
- Shall be country/culture independent
- Should be a “reasonable” size (however, no explicit page limitation)
  - “Appropriate treatment” of SE topics based on “relative importance”
  - “Equal” treatment of “similar” topics (e.g., each ility approx. the same)
  - Cover the fundamentals of what a certified SE should know
  - Reference more detailed INCOSE products



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Structure of 4th Edition

Front Matter

Chapter 1 - Systems Engineering Handbook Scope

Chapter 2 - Systems Engineering Overview

Chapter 3 – Generic Lifecycle Stages

Chapter 4 – Technical Processes

Chapter 5 – Technical Management processes

Chapter 6 – Agreement Processes

Chapter 7 – Organization Project-Enabling Processes

Chapter 8 – Tailoring process and Application of Systems Engineering

Chapter 9 – Cross-cutting Systems Engineering Processes

Chapter 10 – Specialty Engineering Activities

Appendices

Major Changes for SEH 4E to 5E

- Significantly restructured the handbook due to the changes and new topics
- Moved to single-column format for improved readability/accessibility
- Provided more focus on foundational concepts, to provide reader with overview perspectives
- Kept alignment with the 15288 processes, reordered them to be consistent with the 15288 order
- Updated the IPO diagrams to be more “model and information centric”
- Added new topics like Brownfield, COTS, IoT/Big Data, Cyber-Physical Systems (CPS), Natural Systems, Digital Engineering, etc. based on stakeholder inputs
- Elaborated more on the practices of SE in terms of competencies/soft skills and relationship to other domains
- Engaged a graphic designer for key “impactful” figures
- Added additional domain-specific applications and support for domain annexes

Structure of 5th Edition

Front Matter

Part I - Systems Engineering introduction

Part II - System Life Cycle Concepts, Models and Processes

Part III - Life Cycle Analyses and Methods

Part IV - Tailoring and Application Considerations

Part V - Systems Engineering in Practice

Part VI - Case Studies

Appendices

Front Matter

Part I - Systems Engineering introduction

1.1 What is Systems Engineering?
1.2 Why is Systems Engineering Important?
1.3 Systems Concepts
1.3.1 System Boundary and the System of Interest (SoI)
1.3.2 Emergence
1.3.3 Interfacing Systems, Interoperating Systems, and Enabling Systems
1.3.4 System Innovation Ecosystem
1.3.5 The Hierarchy within a System
1.3.6 Systems States and Modes
1.3.7 Complexity
1.4 Systems Engineering Foundations
1.4.1 Uncertainty
1.4.2 Cognitive Bias
1.4.3 Systems Engineering Principles
1.4.4 Systems Engineering Heuristics
1.5 System Science and Systems Thinking

Part II - System Life Cycle Concepts, Models and Processes

2.1 Life Cycle Terms and Concepts
2.1.1 Life Cycle Characteristics
2.1.2 Typical Life Cycle Stages
2.1.3 Decision Gates
2.1.4 Technical Reviews and Audits

2.2 Life Cycle Model Approaches
2.2.1 Sequential Methods
2.2.2 Incremental Methods
2.2.3 Evolutionary Methods

2.3 System Life Cycle Processes
2.3.1 Introduction to the System Life Cycle Processes
2.3.1.1 Format and Conventions
2.3.1.2 Concurrency, Iteration, and Recursion
2.3.2 Agreement Processes
2.3.3 Organizational Project Enabling Processes
2.3.4 Technical Management Processes
2.3.5 Technical Processes

Part III - Life Cycle Analyses and Methods

3.1 Quality Characteristics and Approaches
3.1.1 Introduction to Quality Characteristics
3.1.2 Affordability Analysis
3.1.3 Agility Engineering
3.1.4 Human Systems Integration
3.1.5 Interoperability Analysis
3.1.6 Logistics Engineering
3.1.7 Manufacturability/Producibility Analysis
3.1.8 Reliability, Availability, Maintainability Engineering
3.1.9 Resilience Engineering
3.1.10 Sustainability Engineering
3.1.11 System Safety Engineering
3.1.12 System Security Engineering
3.1.13 Loss-Driven Systems Engineering

3.2 Systems Engineering Analysis and Methods
3.2.1 Modeling, Analysis, and Simulation
3.2.2 Prototyping
3.2.3 Traceability
3.2.4 Interface Management
3.2.5 Architecture Frameworks
3.2.6 Patterns
3.2.7 Design Thinking
3.2.8 Biomimicry

Part IV - Tailoring and Application Considerations

4.1 Tailoring Considerations

4.2 SE Methodology / Approach Considerations
4.2.1 Model-Based SE
4.2.2 Agile Systems Engineering
4.2.3 Lean Systems Engineering
4.2.4 Product Line Engineering (PLE)

4.3 System Types Considerations
4.3.1 Greenfield/Clean Sheet Systems
4.3.2 Brownfield/Legacy Systems
4.3.3 Commercial-off-the-Shelf (COTS)-Based Systems
4.3.4 Software-Intensive Systems
4.3.5 Cyber-Physical Systems (CPS)
4.3.6 System of Systems (SoS)
4.3.7 Internet of Things (IoT)/Big Data-Driven Systems
4.3.8 Service Systems
4.3.9 Enterprise Systems

4.4 Application of Systems Engineering for Specific Product Sector or Domain Application
4.4.1 Automotive Systems
4.4.2 Biomedical and Healthcare Systems
4.4.3 Commercial Aerospace Systems
4.4.4 Defense Systems
4.4.5 Infrastructure Systems
4.4.6 Oil & Gas Systems
4.4.7 Power & Energy Systems
4.4.8 Space Systems
4.4.9 Telecommunication Systems
4.4.10 Transportation Systems

Part V - Systems Engineering in Practice

5.1 Systems Engineering Competencies
5.1.1 Difference between Hard and Soft Skills
5.1.2 Systems Engineering Professional Competencies
5.1.3 Technical Leadership
5.1.4 Ethics
5.2 Diversity, Equity, and Inclusion
5.3 Systems Engineering Relationships to other Disciplines
5.3.1 SE and Software Engineering (SWE)
5.3.2 SE and Hardware Engineering (HWE)
5.3.3 SE and Project Management (PM)
5.3.4 SE and Industrial Engineering (IE)
5.3.5 SE and Operations Research (OR)
5.4 Digital Engineering
5.5 Systems Engineering Transformation
5.6 Future of SE

Part VI - Case Studies

6.1 Case 1: Radiation Therapy—The Therac-25
6.2 Case 2: Joining Two Countries—The Øresund Bridge
6.3 Case 3: Cybersecurity Considerations in Systems Engineering—The Stuxnet Attack on a Cyber-Physical System
6.4 Case 4: Design for Maintainability—Incubators
6.5 Case 5: Artificial Intelligence in Systems Engineering - Autonomous Vehicles
6.6 Other case studies

The highlighted topics are additions to the 5th Edition (i.e., not present In the 4th Edition)
Note: Additional topics were removed from the 4th Edition (not shown)

Appendices

Removed Sections from the 4E to 5E

2.11.2 Professional Certification

3.5 What is Best for Your Organization, Project, or Team?

3.6.3 Case 3: Prototype System—The Superhigh-Speed Train in China

8.6 Application of SE for Very Small & Micro Enterprises

9.3 Functions-Based Systems Engineering Method

9.7 Integrated Product and Process Development

10.2 Electromagnetic Compatibility

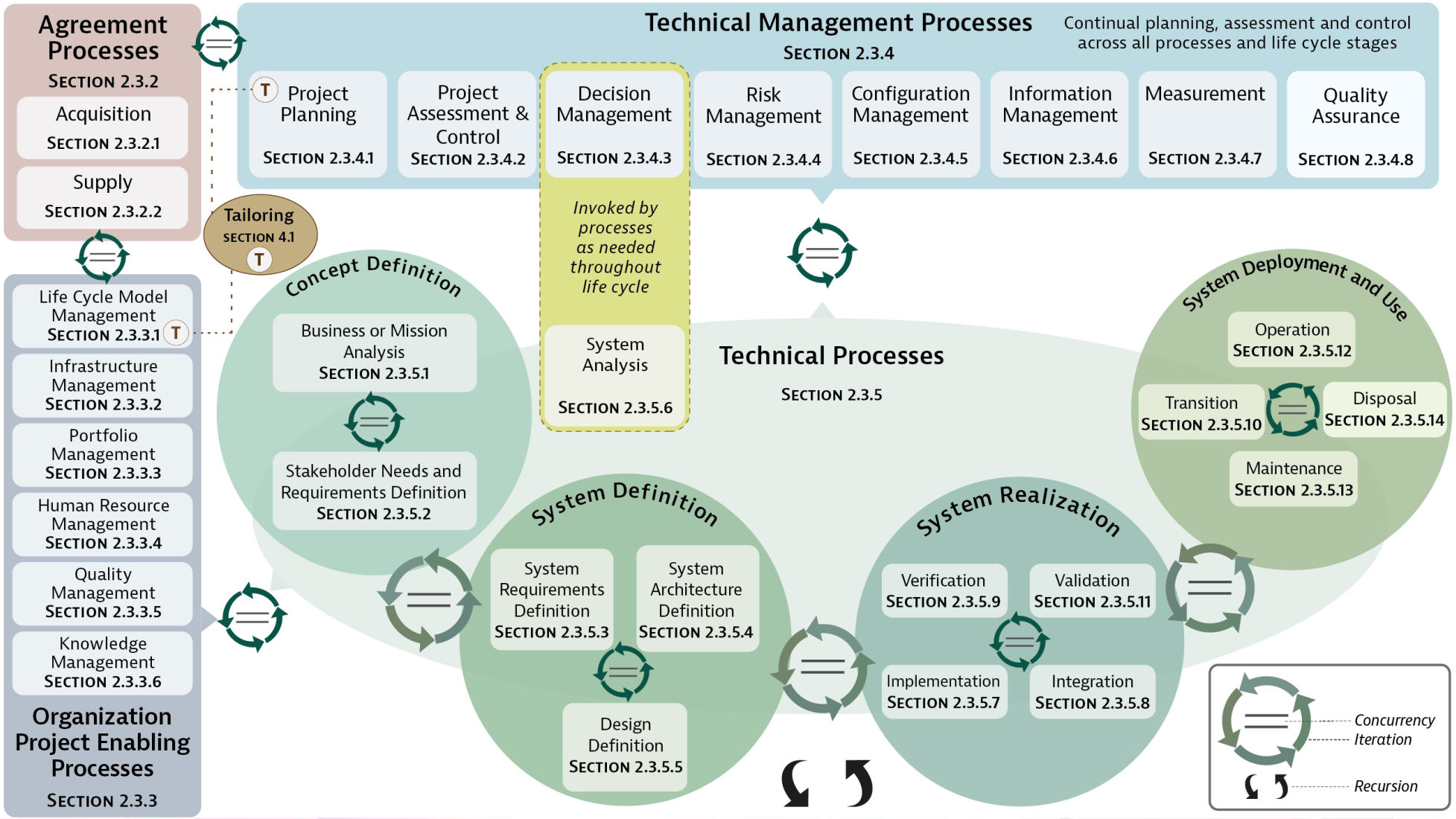
10.7 Mass Properties Engineering

10.12 Training Needs Analysis

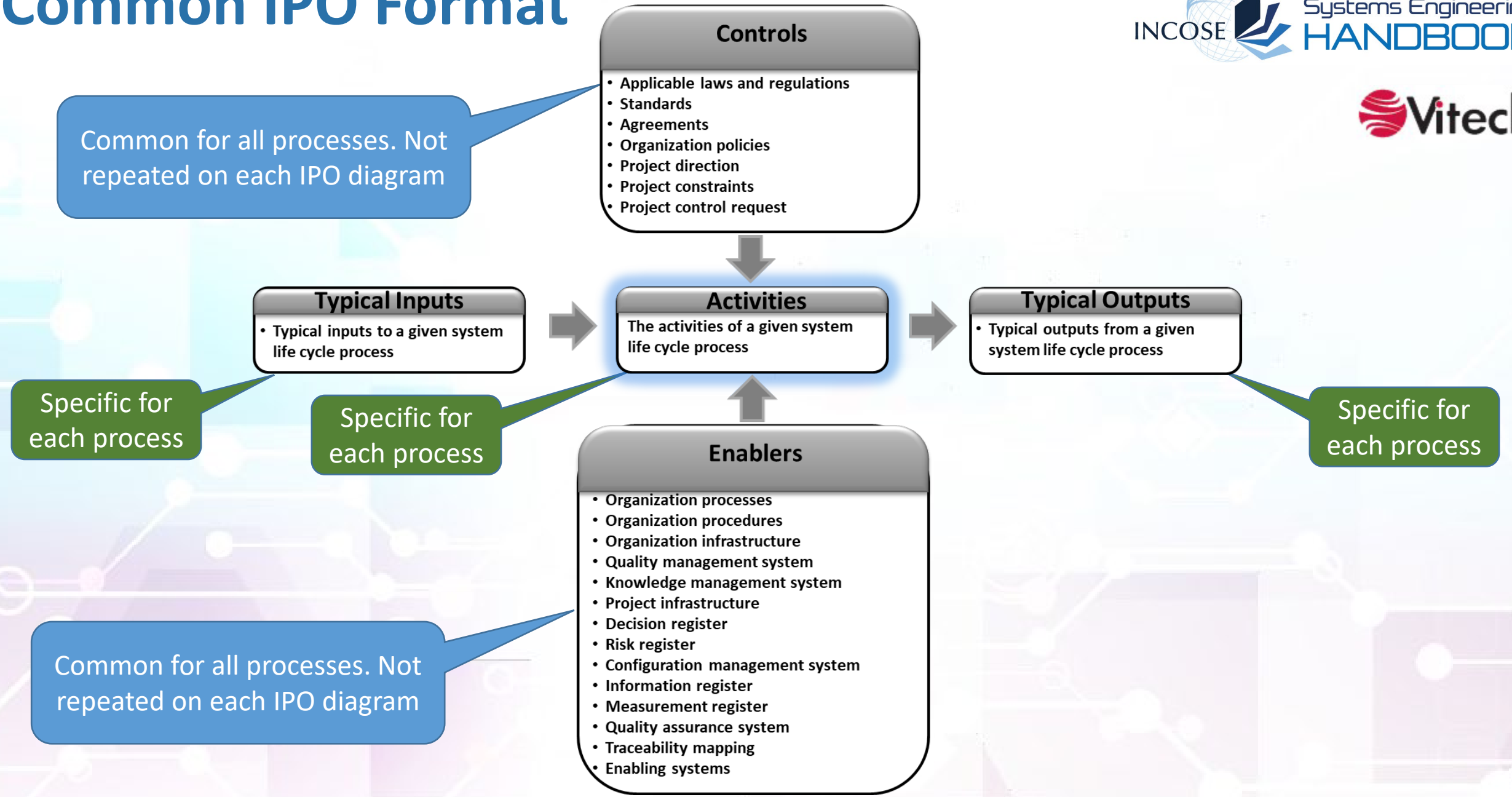
10.14 Value Engineering

Note 1: Does not include sections that were renamed between the 4E and 5E.
Note 2: Some of these 4E sections have been absorbed into other 5E topics.

Figure 2.10 System life cycle processes per ISO/IEC/IEEE 15288



Common IPO Format

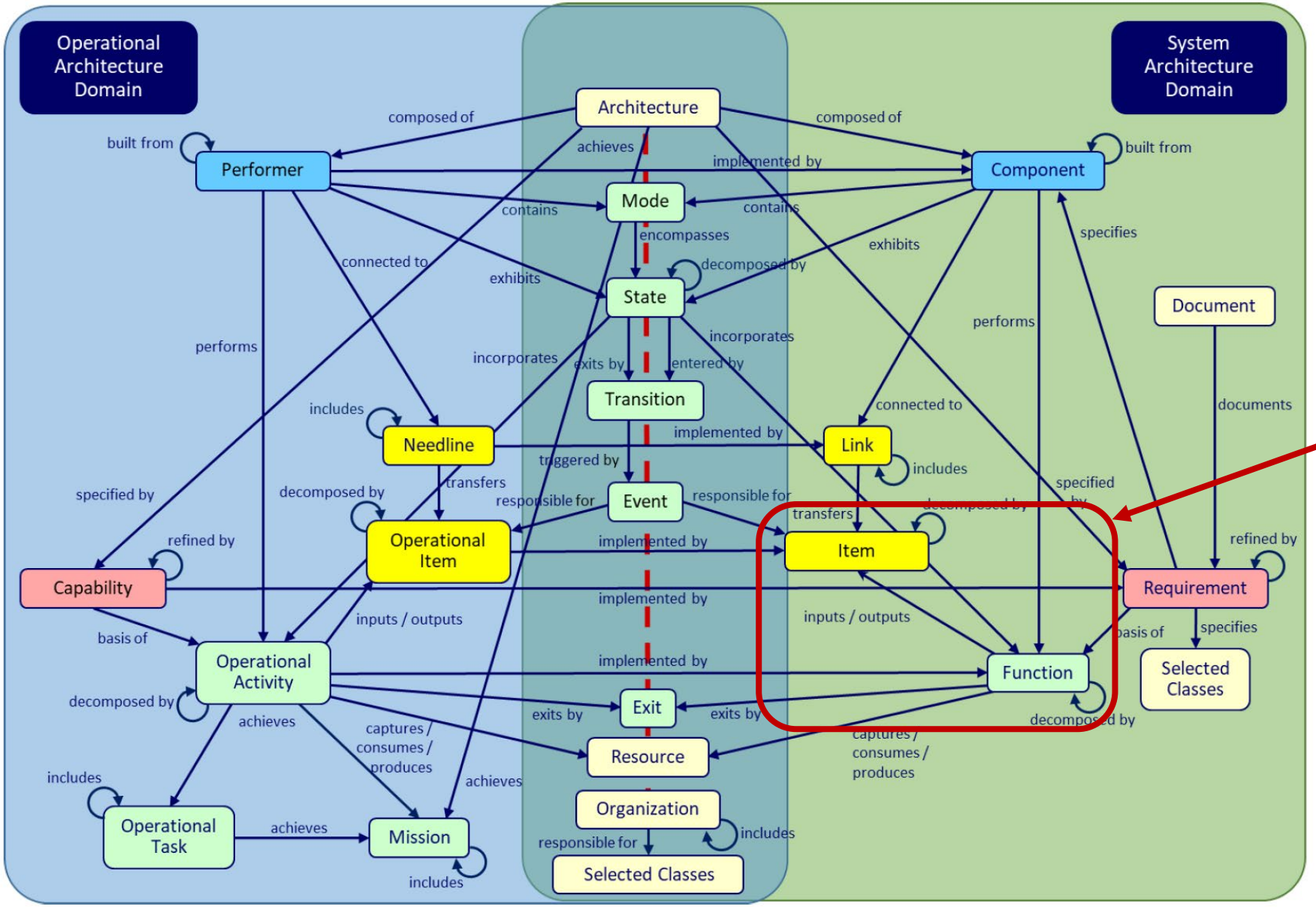


Key Process Modeling Concepts

- Purpose of the process model
  - Ensure a consistent set of IPO diagrams
  - Help create a process N^2 diagram
  - Not required to be "executable" – depends on project/system & methodology
- Goals
  - Continuity with 3rd & 4th Editions
  - Consistent with:
    - ISO/IEC/IEEE 15288
    - ISO/IEC/IEEE 15289
    - ISO/IEC/IEEE 24765 & SEVOCAB
    - ISO/IEC 33060

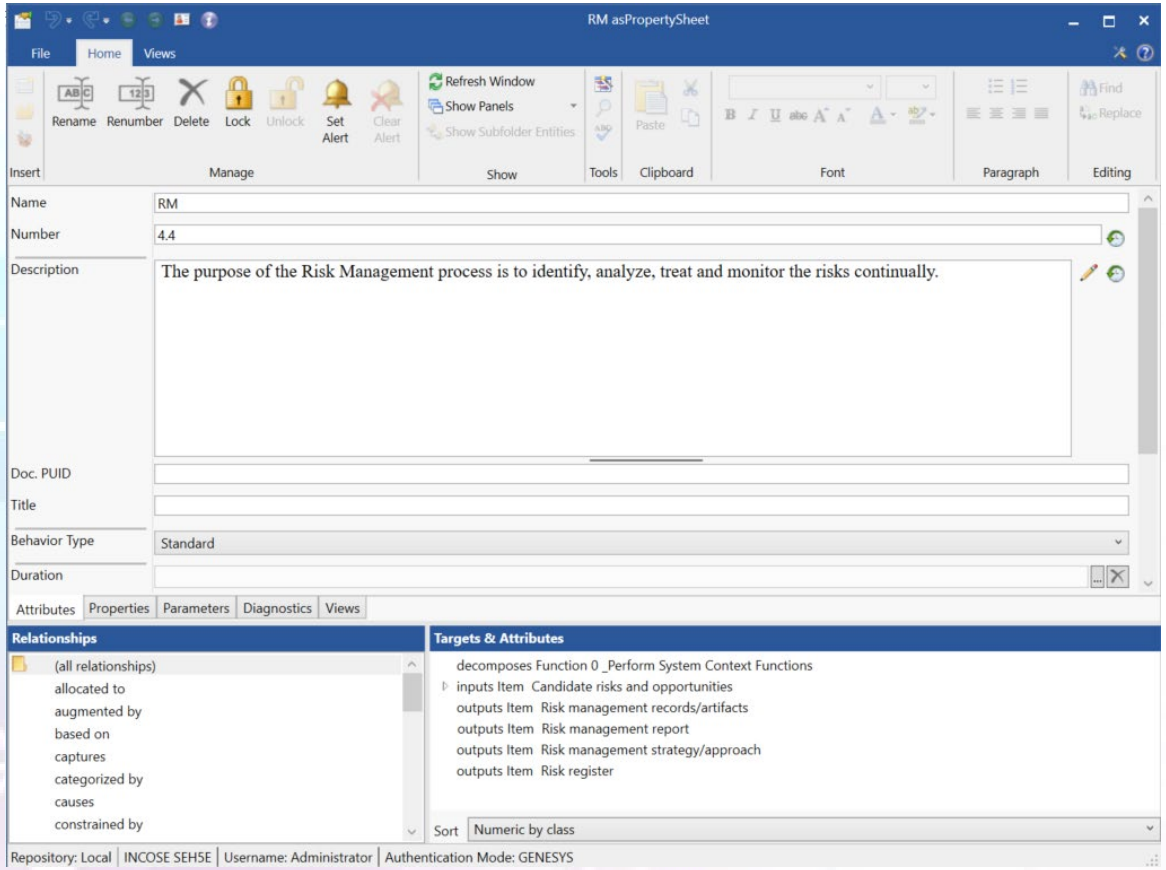
- Guiding modeling concepts
  - Minimize tool customizations (use "out of the box" to the extent practicable)
  - The SoI is the set of 15288/ Handbook system life cycle processes
  - Represents "a" way, not "the" way the processes can be connected
    - Emphasize "typical" inputs & outputs
    - When needed, assumes a traditional contracted greenfield system development
    - Assumes tailoring as required
  - Transition from "documentation-centric" to "model- and information-centric"
    - Eliminates the "Initial-Draft-Updated-Final-etc." items in the 4E
  - Support both "sequential" and "situational" processes
  - Support the concurrent, iterative, and recursive nature of the processes
  - Express consistent patterns

GENESYS Schema Utilization



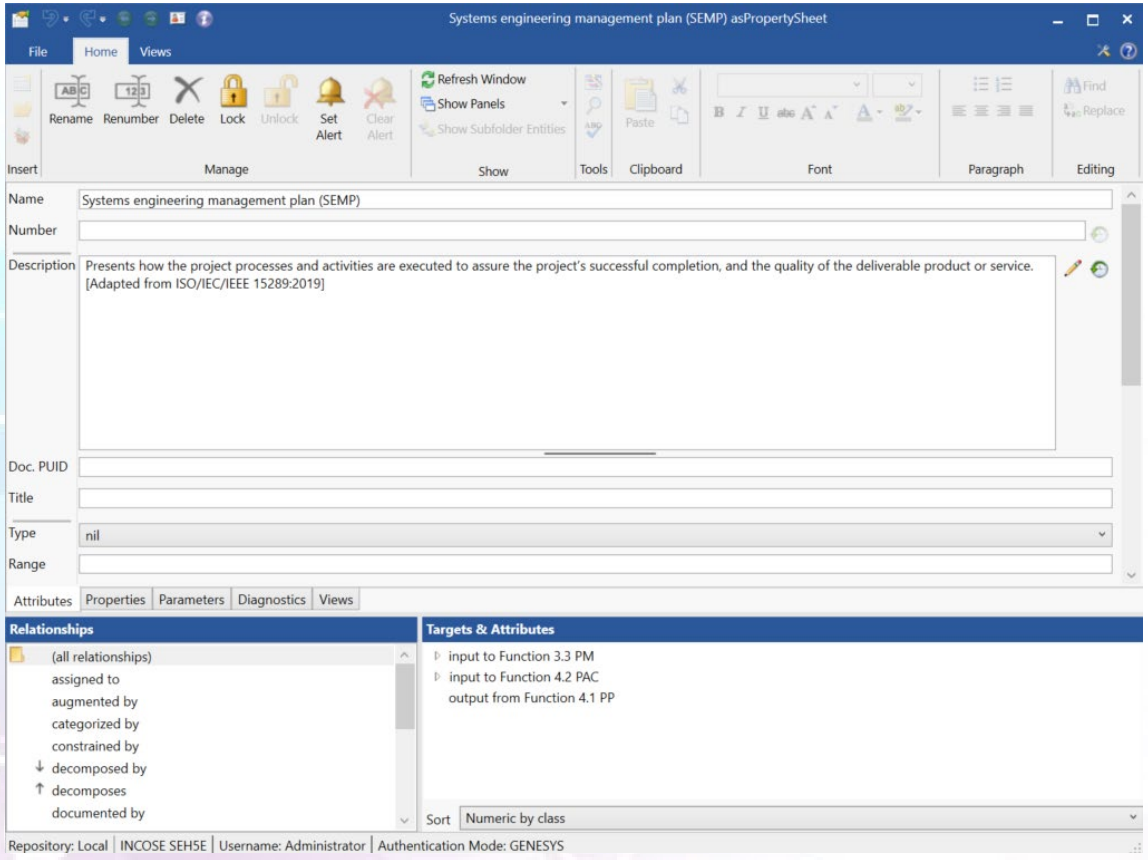
Parts of Schema Used

GENESYS Function Example



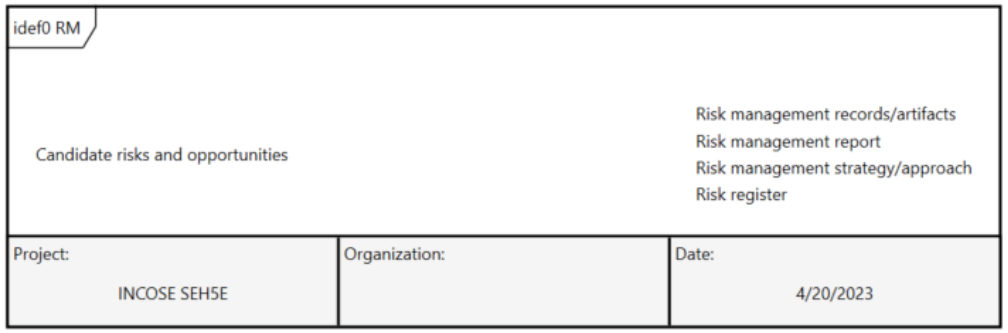
- Each of the handbook/15288 life cycle processes is a separate GENESYS **function**
  - Names are the process acronyms
  - Numbered to ensure they are listed in the correct order
  - Descriptions come from 15288
- They all decompose the functional **context** (to allow for an overall N^2 diagram)
- We created some additional "functions" for our purposes:
  - EXT – External (to our SoI)
  - CTL – Controls (go to all processes)
  - ENAB – Enablers (go to all processes)
  - SIT – Situational (can come from any process)
- Our SEH5E model has **36 functions**

GENESYS Item Example

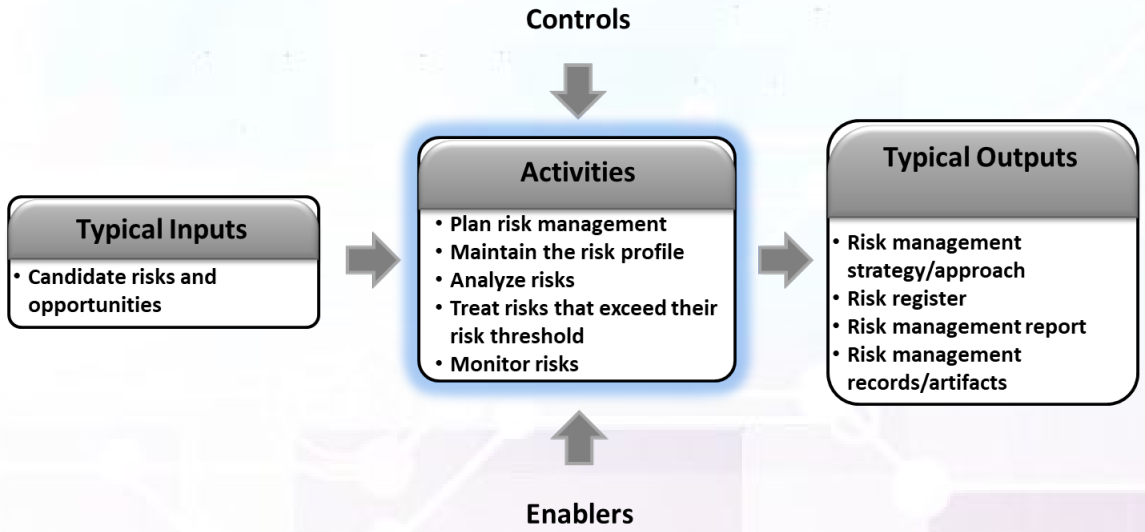


- Each "Typical Input" and "Typical Output" is a separate GENESYS **item**
  - Names reflect the handbook IPO diagrams and Appendix E
  - Numbering not needed (since the IPO diagrams require reformatting)
  - Descriptions match handbook Appendix E
- Primary **item relationships** used:
  - input to
  - output from
- Our SEH5E model has **217 items**

Transitioning to Handbook IPO Diagrams

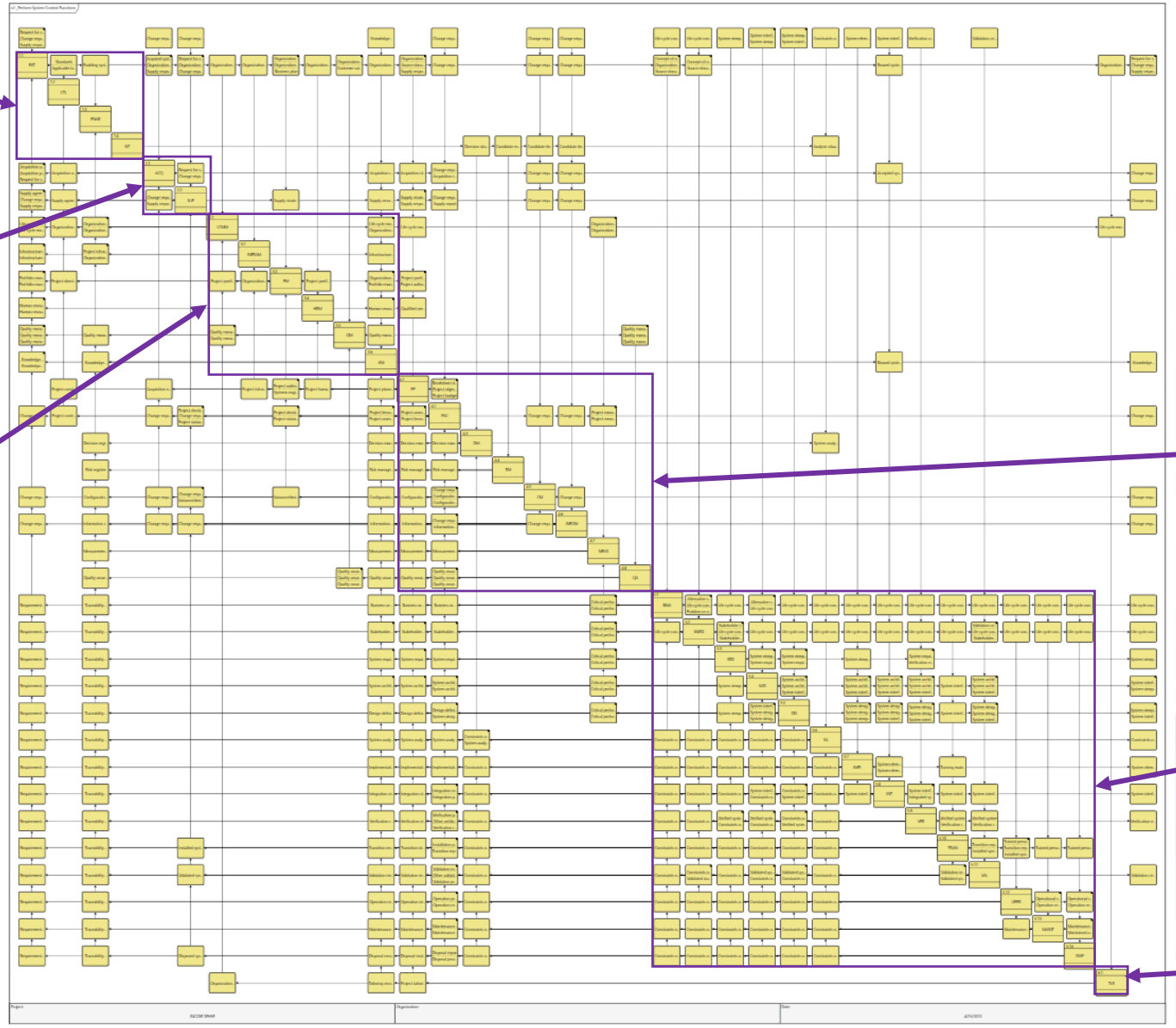


Representative GENESYS Diagram



Handbook IPO Diagram

GENESYS N² Diagram



Modeling Aids
(EXT, CTL, ENAB, SIT)

Agreement Processes

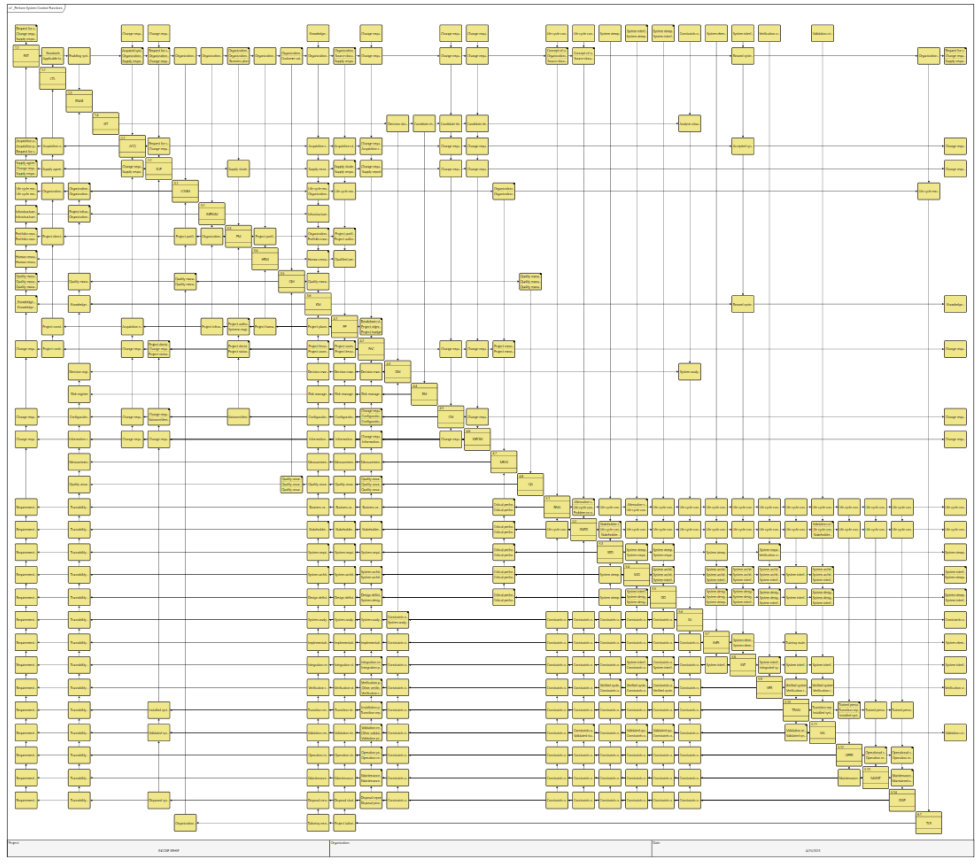
Organizational Project Enabling Processes

Technical Management Processes

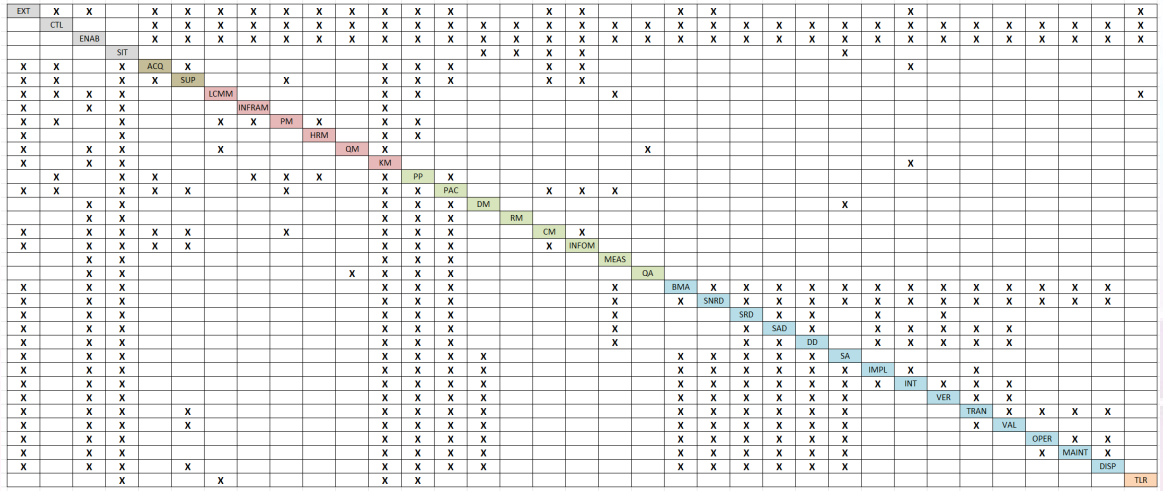
Technical Processes

Tailoring Process

Transitioning to Handbook IPO Diagrams



GENESYS N^2 Diagram



Handbook N^2 Diagram

Summary of Tool Usage for the SEH5E

- Overall, the team had success using Jama Connect to capture and manage the numerous requirements for the handbook Fifth Edition
  - The tool created an organized structure, collaboration center, and easy to use coverage views to spot gaps in content, beyond what is possible in other documentation tools.
  - Requirements documents were easily generated from the tool.
- The team also had success using Vitech/Zuken GENESYS to model the system life cycle processes within the handbook, particularly in the area of typical process inputs and outputs.
  - The use of the model enforced necessary discipline in the identification and naming of the information items and defining the transfer of these information items between processes.
  - Still a need to “reformat” the IPO and N^2 diagrams for publication purposes.

Figure 2.12 Concurrency, iteration, and recursion

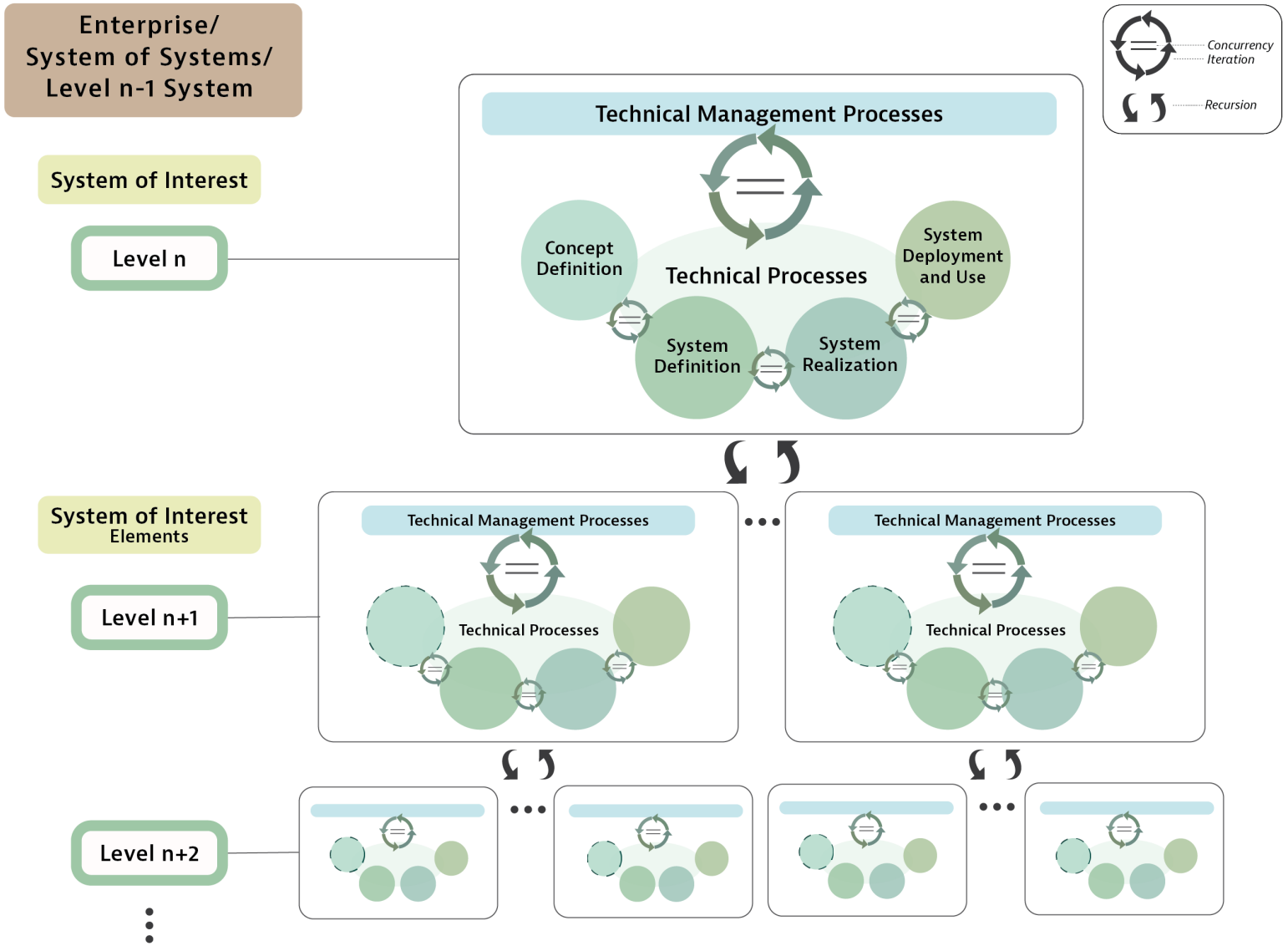


Figure 2.38 Technical processes in context

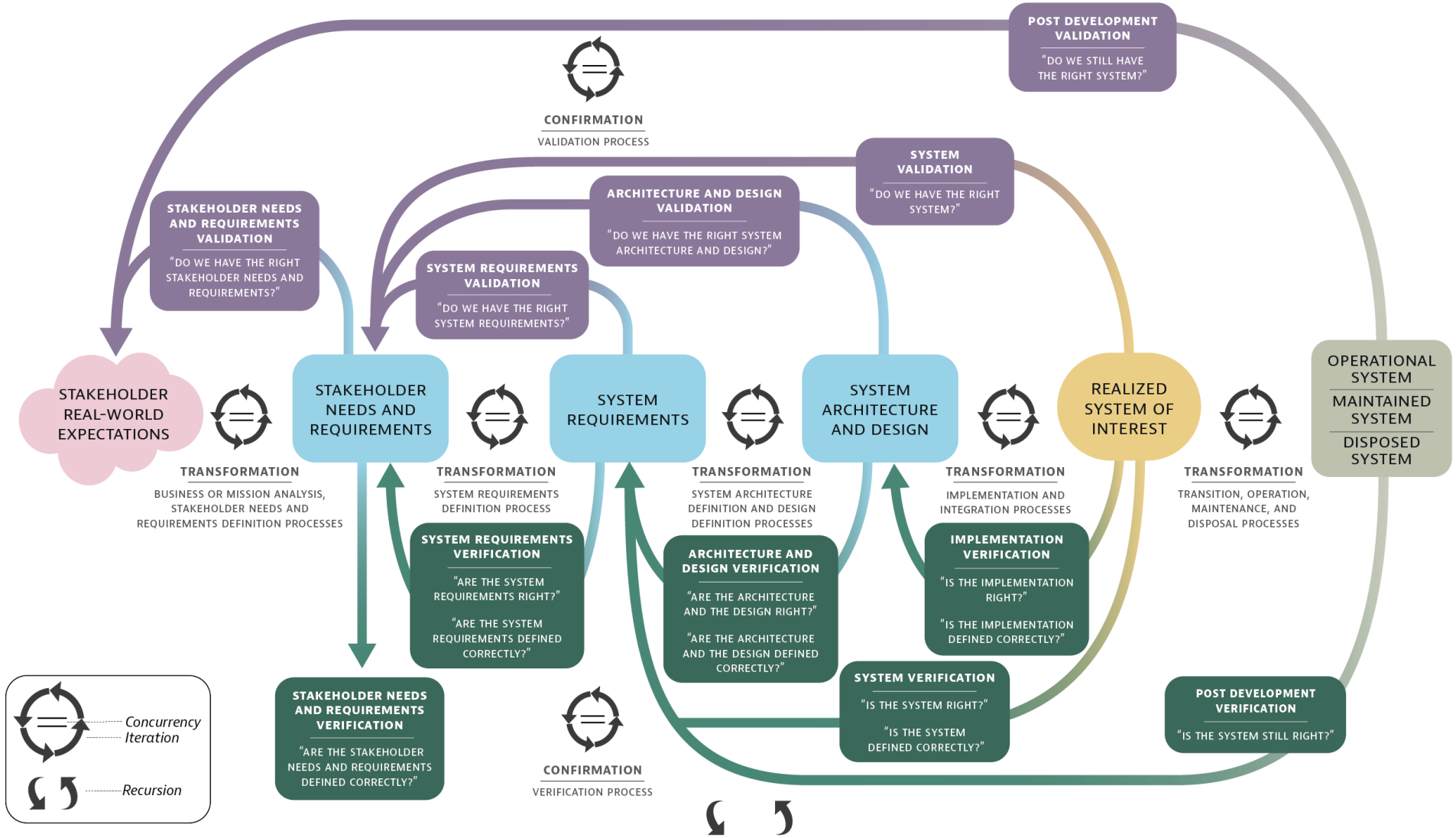


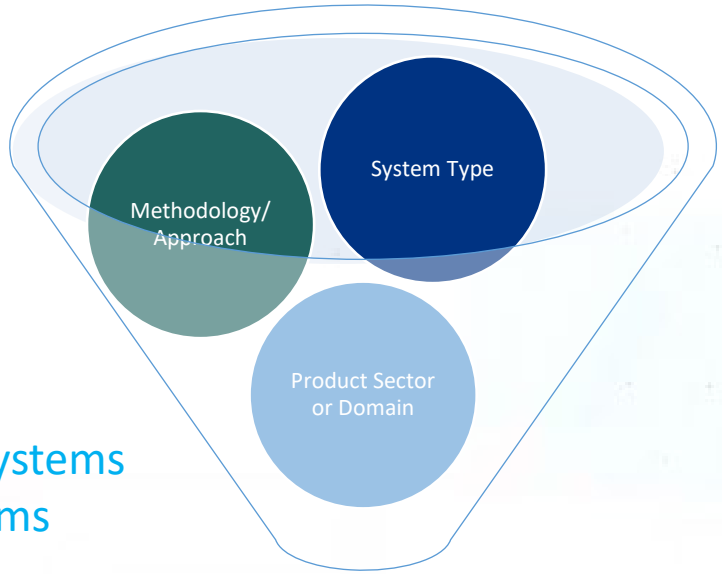
Table 3.1 Quality Characteristic approaches

QC Approach	An approach that …	Representative QCs
Affordability Analysis	maximizes value, providing cost effective capability over the entire life cycle	Affordability, Cost-Effectiveness, Life Cycle Cost (LCC), Value Robustness
Agility Engineering	enables change in a timely and cost-effective manner	Adaptability, Agility, Changeability, Evolvability, Extensibility, Flexibility, Modularity, Reconfigurability, Scalability
Human Systems Integration	integrates technology, organizations, and people effectively	Desirability, Ergonomics, Habitability, Human Factors, Human-Computer Interaction (HCI), Human-Machine Interface (HMI), Usability, User Interface (UI). User eXperience (UX)
Interoperability Analysis	ensures the system interacts effectively with other systems	Compatibility, Connectivity, Interoperability
Logistics Engineering	enables support for the entire life cycle	Supportability
Manufacturability/Producibility Analysis	enables production in a responsible and cost effective manner	Manufacturability, Producibility
Reliability, Availability, Maintainability Engineering	enables the system to perform without failure, to be operational when needed, and to be retained in or restored to a required functional state	Accessibility, Availability, Interchangeability, Maintainability, Reliability, Repairability, Testability
Resilience Engineering	provides required capability when facing adversity	Resilience, Robustness, Survivability
Sustainability Engineering	supports the circular economy over its life	Disposability, Environmental Impact, Sustainability
System Safety Engineering	reduces the likelihood of harm to people, assets, and the wider environment	Safety
System Security Engineering	identifies, protects from, detects, responds to, and recovers from anomalous and disruptive events, including those in a cyber contested environment	Cybersecurity, Information Assurance (IA), Physical Security, Trustworthiness

Considerations for Tailoring

INCOSE Systems Engineering HANDBOOK

4.2.1 Model-Based SE
4.2.2 Agile Systems Engineering
4.2.3 Lean Systems Engineering
4.2.4 Product Line Engineering (PLE)



Project Tailoring

4.3.1 Greenfield/Clean Sheet Systems
4.3.2 Brownfield/Legacy Systems
4.3.3 Commercial-off-the-Shelf (COTS)-Based Systems
4.3.4 Software-Intensive Systems
4.3.5 Cyber-Physical Systems (CPS)
4.3.6 Systems of Systems (SoS)
4.3.7 Internet of Things (IoT)/Big Data-Driven Systems
4.3.8 Service Systems
4.3.9 Enterprise Systems

4.4.1 Automotive Systems
4.4.2 Biomedical and Healthcare Systems
4.4.3 Commercial Aerospace Systems
4.4.4 Defense Systems
4.4.5 Infrastructure Systems
4.4.6 Oil & Gas Systems
4.4.7 Power & Energy Systems
4.4.8 Space Systems
4.4.9 Telecommunication Systems
4.4.10 Transportation Systems

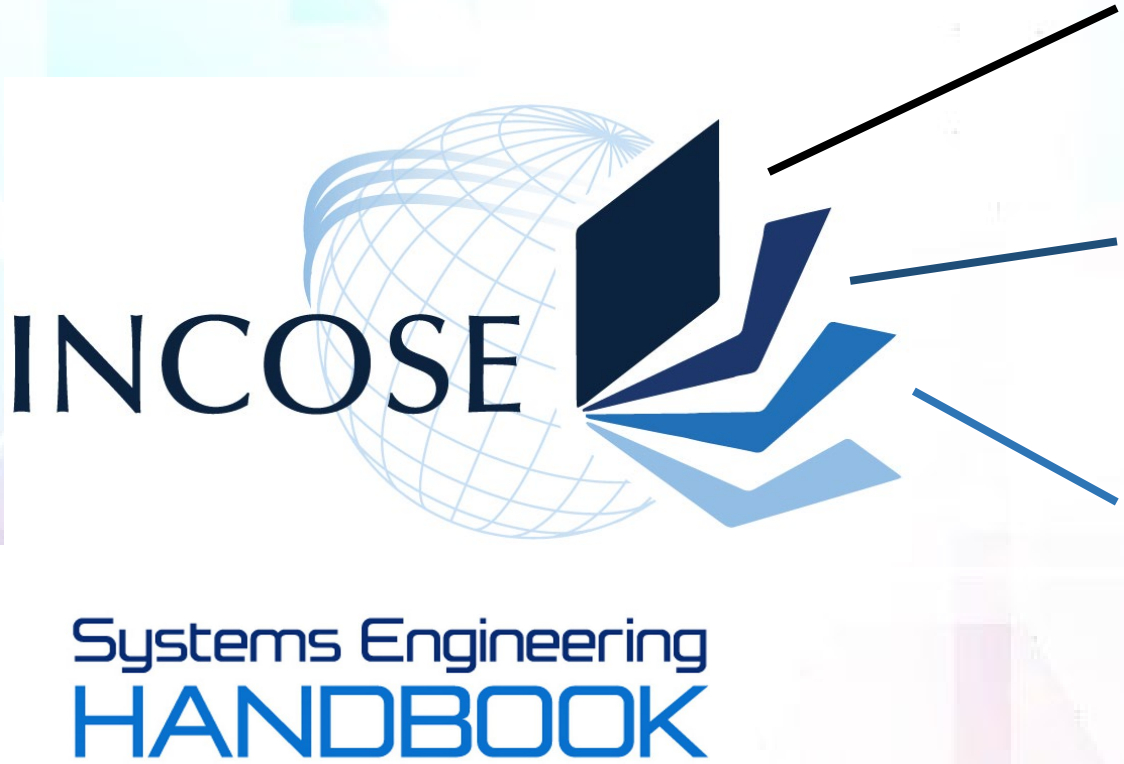
Note: These considerations are not exhaustive nor mutually exclusive.

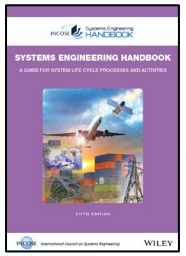
Adapted from: (INCOSE SEH, 2023)

Topics

- What is the INCOSE SE Handbook?
- Overall impetus for change
- Handbook development process
- Top-level schedule
- Summary of the Fifth Edition requirements
- Summary of new content added for this version
- **Formats & translations**
- Impact to INCOSE Certification
- Questions & discussions

Anticipated Formats





Hardcopy

PDF

eBook

Anticipated Fifth Edition Translations

As of this time, we are aware of the following potential translations of the Fifth Edition. Either Wiley or the Chapters will lead the translations.

EMEA (and SA)

- **French**
  - AFIS (French Chapter)
  - Tunisian Chapter
- **German**
  - GfSE (German Chapter)
  - Swiss Chapter
- **Italian**
  - Italian Chapter
- **Spanish**
  - AEIS (Spain Chapter)
  - Colombia & Mexico (potential Chapters, localized versions of Spanish language may be needed)
- **Turkish**
  - Turkish Chapter

Asia-Oceania

- **Chinese**
  - Chinese Chapter (simplified characters)
  - Taiwan Chapter (traditional characters)
- **Japanese**
  - JCOSE (Japan Chapter)
- **Korean**
  - KCOSE (Korean Chapter)

Handbook translation focal points are Bernardo Delicado and Yip Yew Seng.

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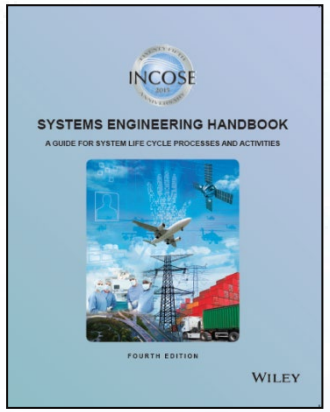
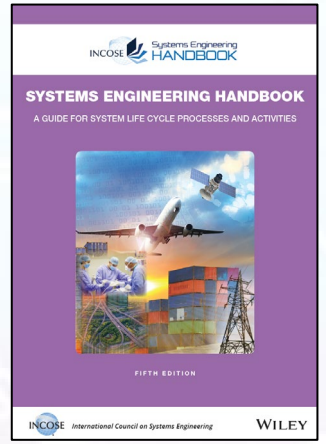
INCOSE Certification

Expert Systems Engineering Professional ***ESEP***	**Knowledge** Experience (25+ years) Leadership
Certified Systems Engineering Professional ***CSEP***	**Knowledge** Experience (5+ years)
Associate Systems Engineering Professional ***ASEP***	**Knowledge**

Exam Knowledge Basis





SEH5E Impact to Certification Exam

- Starting on 1 August 2023, all exams are based on the overlapping content found in both the INCOSE System Engineering Handbook Fourth Edition and Fifth Editions.
- Content found in only one version of the other is not on the exam as of 1 August 2023.
- New content in the Fifth Edition may be added as soon as 1 August 2024 but no earlier.

Source: https://www.incose.org/systems-engineering-certification/taking-the-exam, as of 5 Oct 2023
The INCOSE Certification website is always the authority on the current transition status!

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Questions & Discussions