Human Systems Engineering (Part 2)

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August 21, 2019

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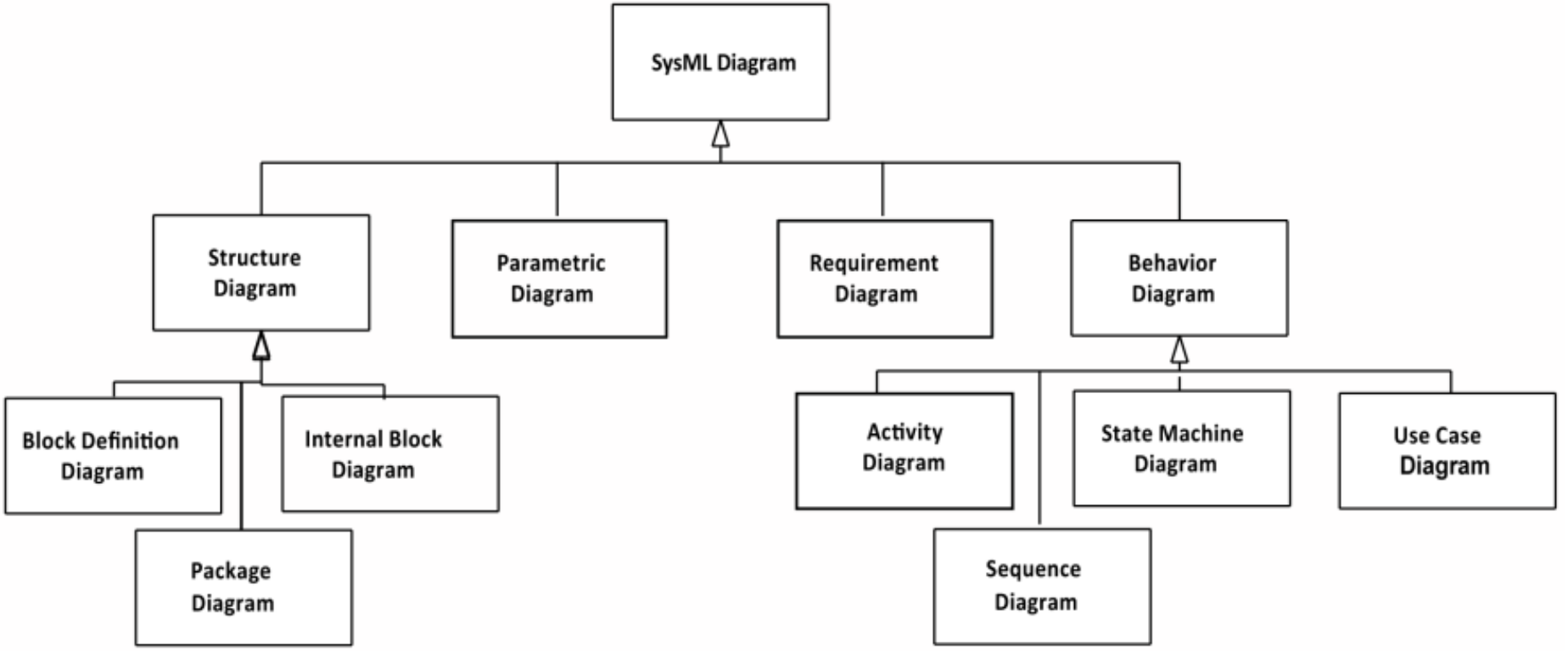
Abstract

- How do we systems engineer humans?
- How do we engineer systems that include humans?
- Do all systems include humans?
  - If so, which humans, how are they included in a system, and how do we perform systems engineering on them?
  - Are they elements of the system like hardware and software are?
  - Do we have hardware, software, and humanware? (Yes, you heard it here first folks, humanware!).
  - How do we model the behavior of humans?
- Are there any systems that do not include humans in any way whatsoever?
- This presentation discusses these questions from the SE Standards and INCOSE SE Handbook perspectives, going back to their earlier versions and coming up to date, including the two most recent approaches.
- At the end of this presentation we ask you to answer the question: Which of the two most recent approaches do you consider to be the optimum and for what reasons?

Abstract (cont)

How Do We Model the Behavior of Humans?

SysML Diagram Types



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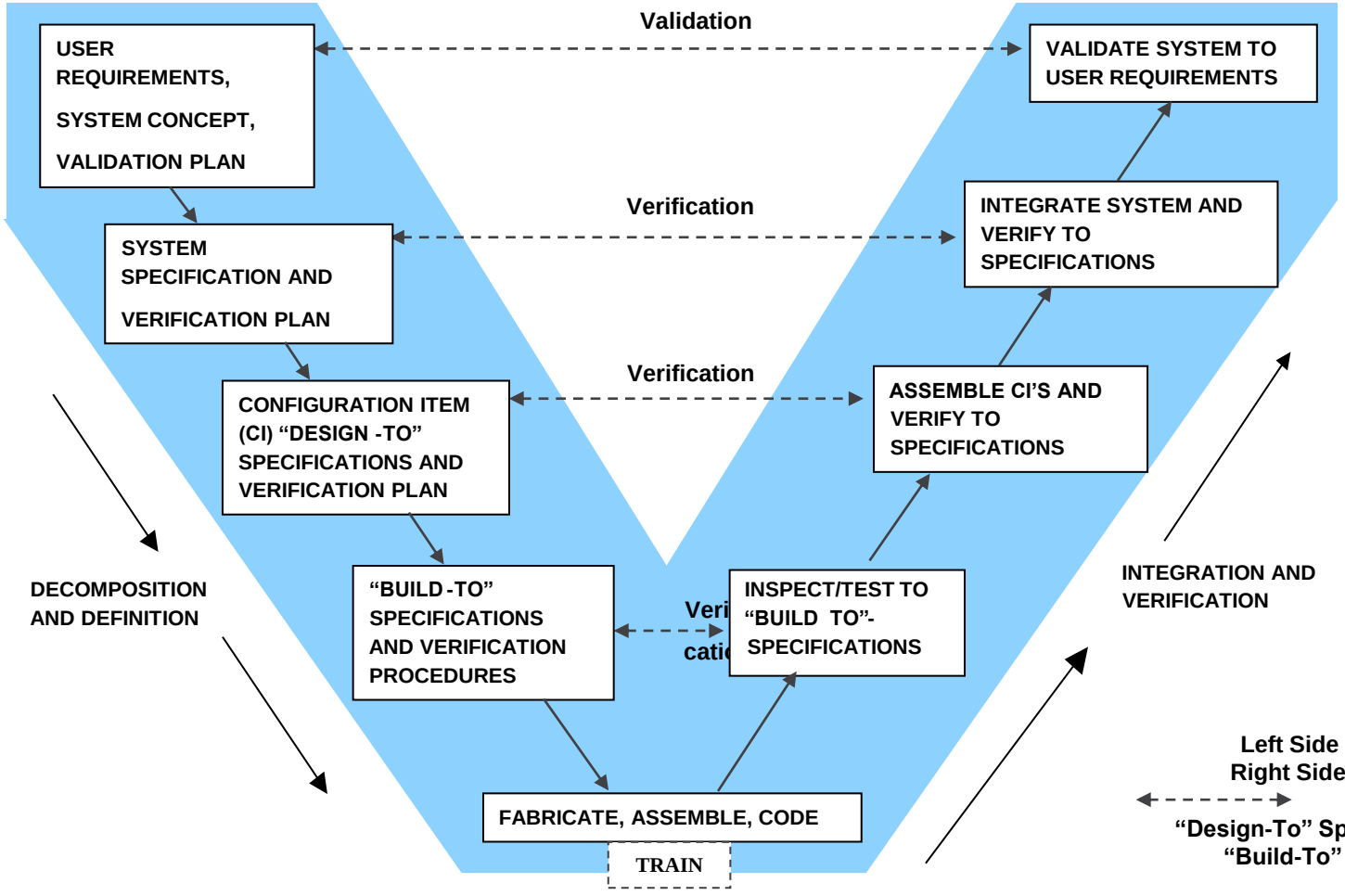
        - SE Handbook V4.0 Tutorial
          - Tutorial ID : 01_October 2015
            - Tutorial Session: 00_Shared Documents
              - Human Systems Engineering
              - Overview of the Systems Engineering Handbook V4.0, IS2019
            - Tutorial Sessions: 01-34
              - 34 Webinar Recordings and Slides
        - Leadership Skills Tutorial
        - SE Technical Processes Tutorial

Contents

What is the V-Model?

Forsberg

Original V-Model (Entity V-Model)



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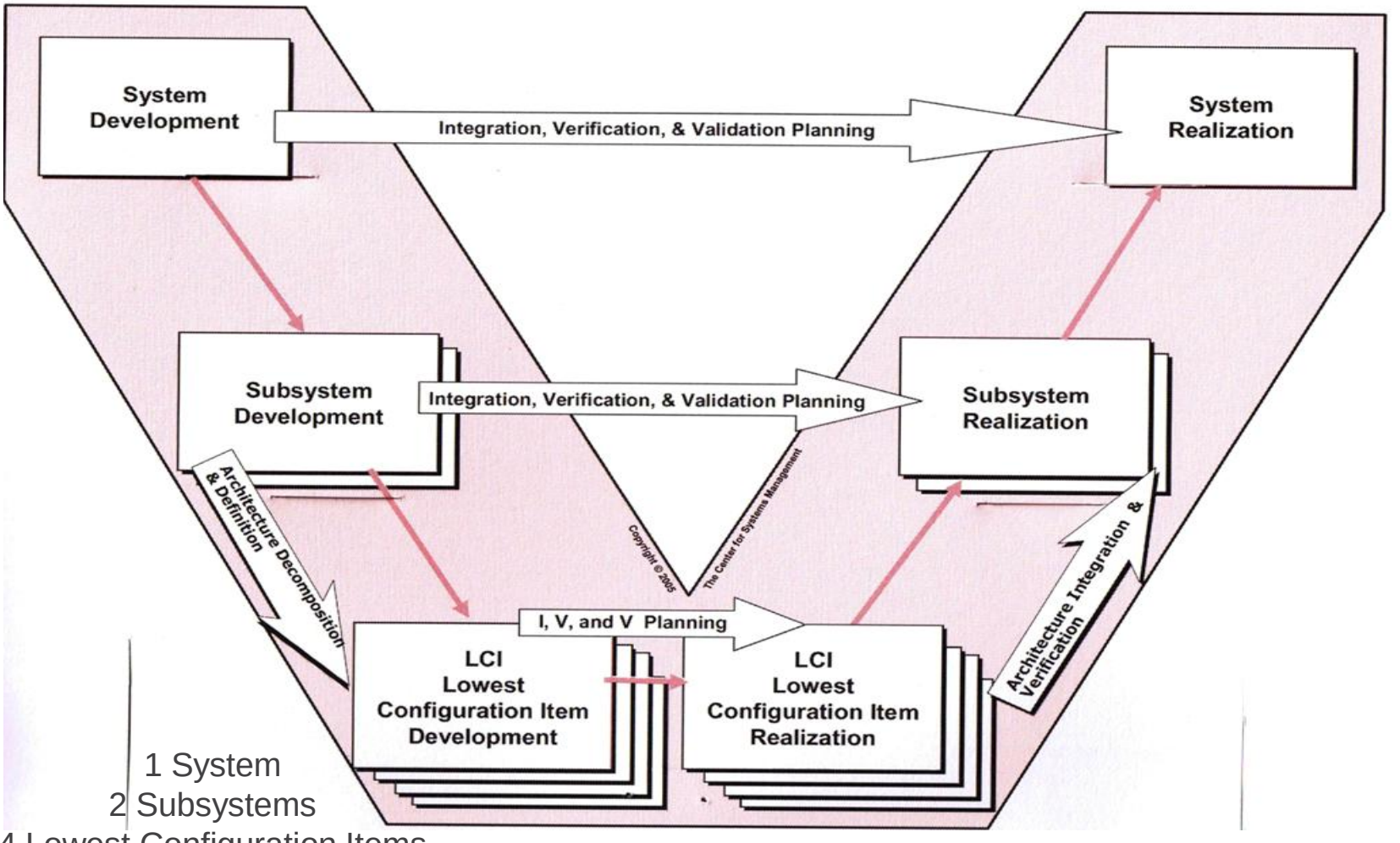
What is the V-Model? (cont)

CSM



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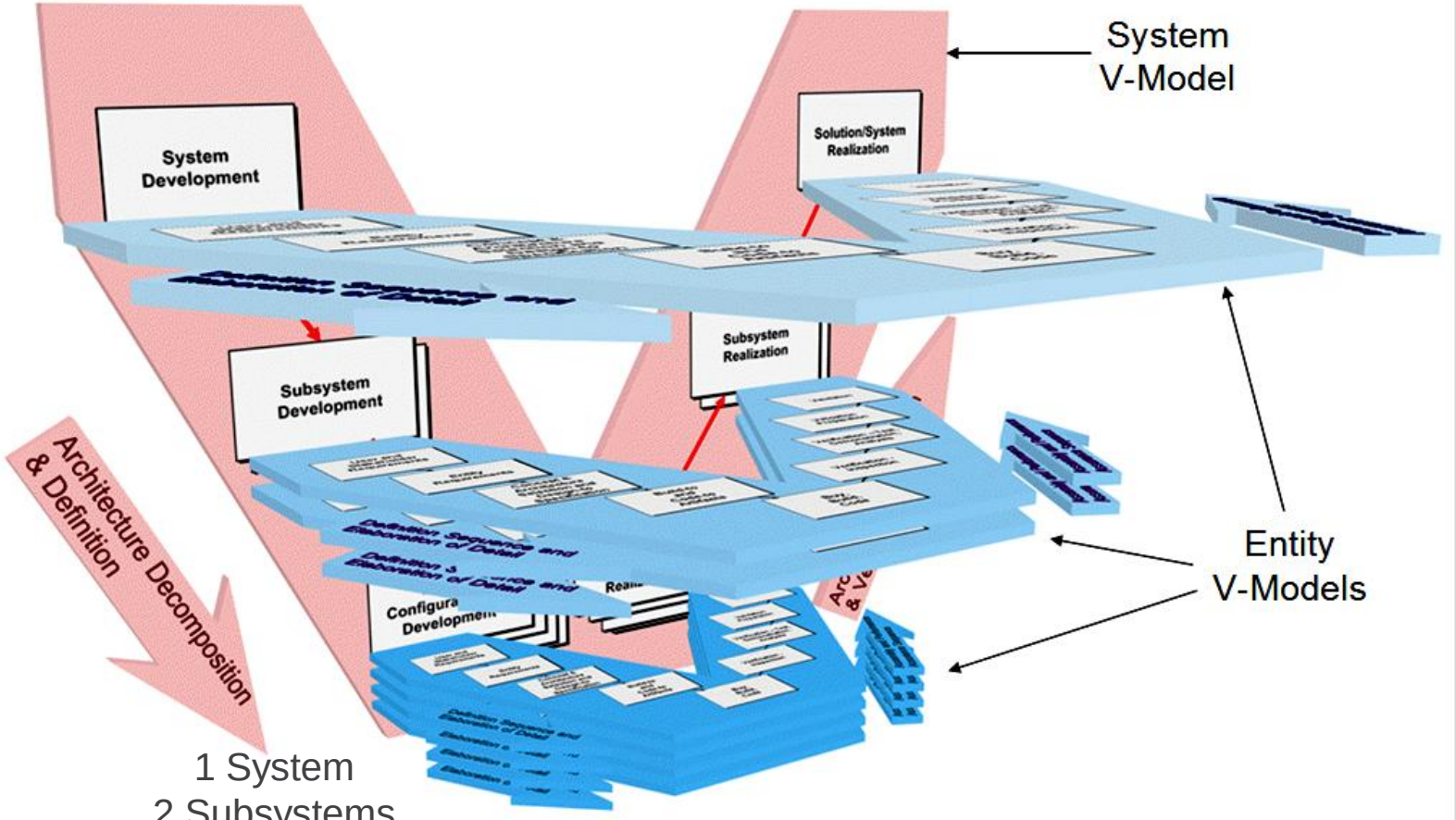
What is the V-Model? (cont)

CSM

Dual V-Model Example



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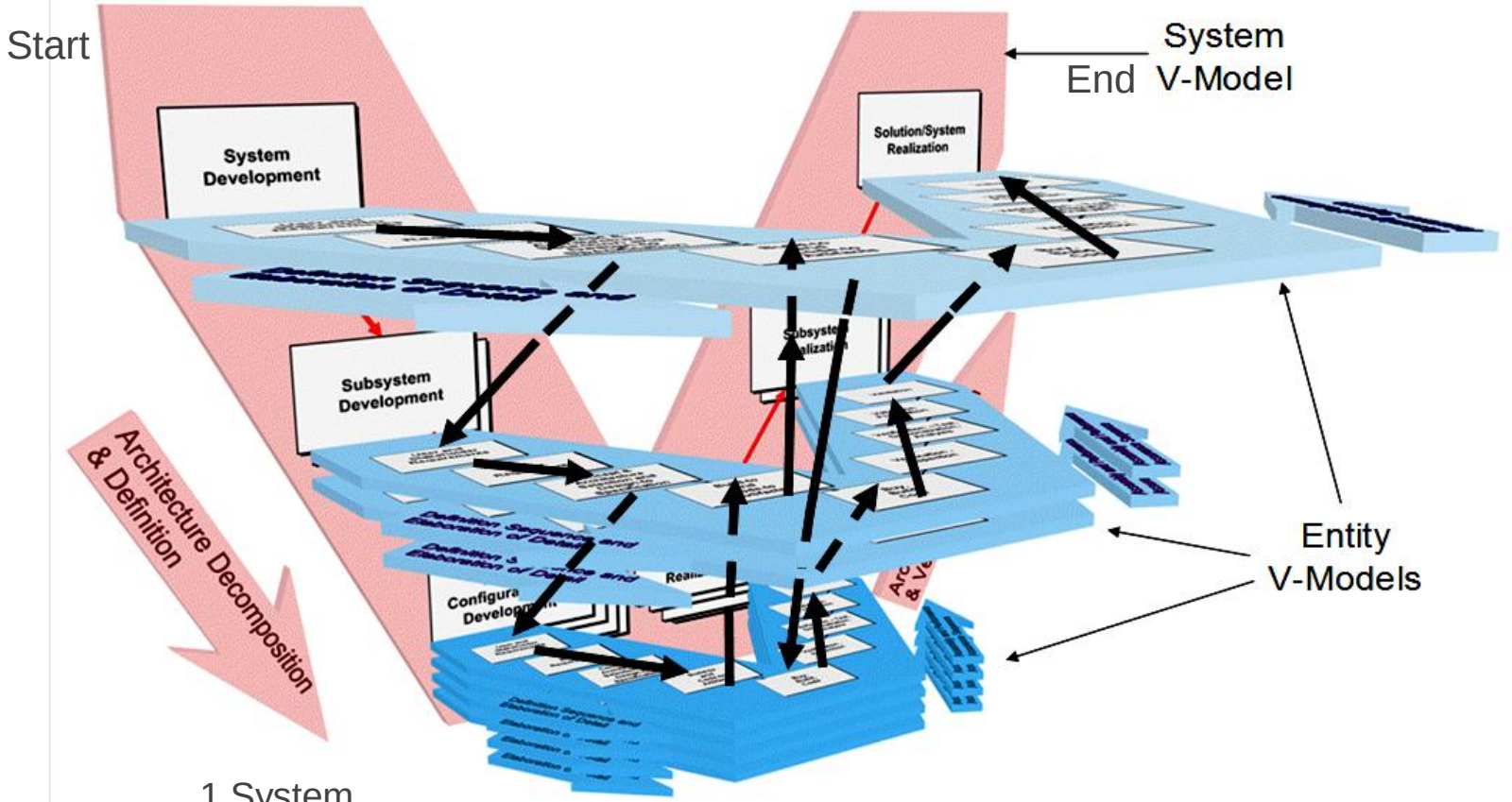
What is the V-Model? (cont)

CSM

Dual V-Model Example Sequence (Recursion)



1 System
2 Subsystems
4 Lowest Configuration Items (LCIs)

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What is Human Systems Engineering?

Human Element

What is Human Systems Engineering? (cont)

(SEH V2a-2004, Appendix B, Human Systems Engineering)

- "Human" Engineering specializes in the interaction of the human with other humans and with the system.
- The "Human" engineer specializes in job and task design between the human, others and the system.
- The primary goal of the "human" engineer is to determine the performance of the human in order to optimize the performance of the overall system.
- The human engineer specializes in job and task design and the interaction of humans with one another and with automation, and his or her responsibility covers the human subsystems within the system to be designed.
- Significant interactions occur between human engineers and systems engineers during system development.
  - These interactions include information that must be shared, decisions that must be made, and actions or decisions that require approval.
- The human engineer specializes in job and task design and the interaction of humans with one another and with automation, and his or her responsibility covers the human subsystems within the system to be designed.

What is Human Systems Engineering? (cont)

(SEH V2a, Appendix B, Human Systems Engineering)

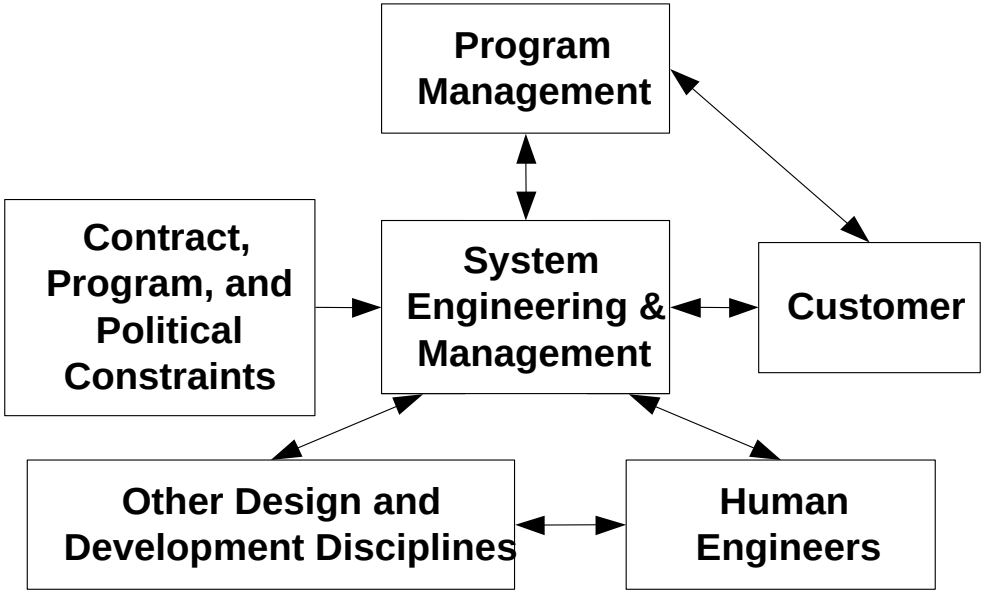


Figure B-1. Context of Interactions between the Systems Engineer and the Human Engineer.

Based on the interactions described in Appendix B, four overarching interactions or themes have been selected as significant.

- Scenario Definition and User Review
- Participation in Function Analysis
- Function Allocation Decisions
- Compatibility of Models

V4.0 10.0 Specialty Engineering

10.13 Usability Analysis/Human Systems Integration

- Human Systems Integration (HSI) is
  - The interdisciplinary technical and management process for integrating human considerations within and across all system elements.
- HSI focuses on the human, an integral element of every system, over the system life cycle.
- It is an essential enabler to SE practice as it promotes a "total system" approach that includes humans, technology (e.g. hardware, software), the operational context, and the necessary interfaces between and among the elements to make them all work in harmony.
- The "human" in HSI includes **all** personnel who interact with the system in any capacity, such as:
  - System owners
  - Operators
  - Maintainers
  - Trainers
  - Users/customers
  - Decision makers
  - Support personnel
  - Peripheral personnel
- Humans are an element of most systems, so many systems benefit from HSI application.
- HSI establishes human-centered disciplines and concerns into the SE pro-cess to improve the overall system design and performance.

V4.0 10.0 Specialty Engineering (cont)

10.13 Usability Analysis/Human Systems Integration

- The primary objective of HSI is to:
  - Ensure that human capabilities and limitations are treated as critical system elements, regardless of whether humans in the system operate as individuals, crews, teams, units, or organiza-tions.
- The technology elements of the system have inherent capabilities; similarly,

  Humans possess particular Knowledge, Skills, and Abilities (KSAs), expertise, and cultural experiences.
- Deliberate design effort is essential to ensure development of quality interfaces between technology elements and the system's intended users, operators, maintainers, and support personnel in operational environments.
- It is also important to acknowledge that humans outside the system may be affected by its operation.
- While many systems and design engineers intuitively understand that the human operator and maintainer are part of the system under development, they often lack the expertise or information needed to fully specify and incorporate human capabilities.
- HSI brings this technical expertise into the SE Process and serves as the focal point for human considerations in the system Concept, Development, Production, Utilization, Support, and Retire-ment Stages.
- The comprehensive application of HSI to system development, design, and acquisition is intended to
  - Optimize total system performance (e.g., humans, hardware, and software) while
  - Accommodating the char-acteristics of the population that will use, operate, main-tain, and support the system and
  - Support efforts to reduce LCC.

V4.0 10.0 Specialty Engineering (cont)

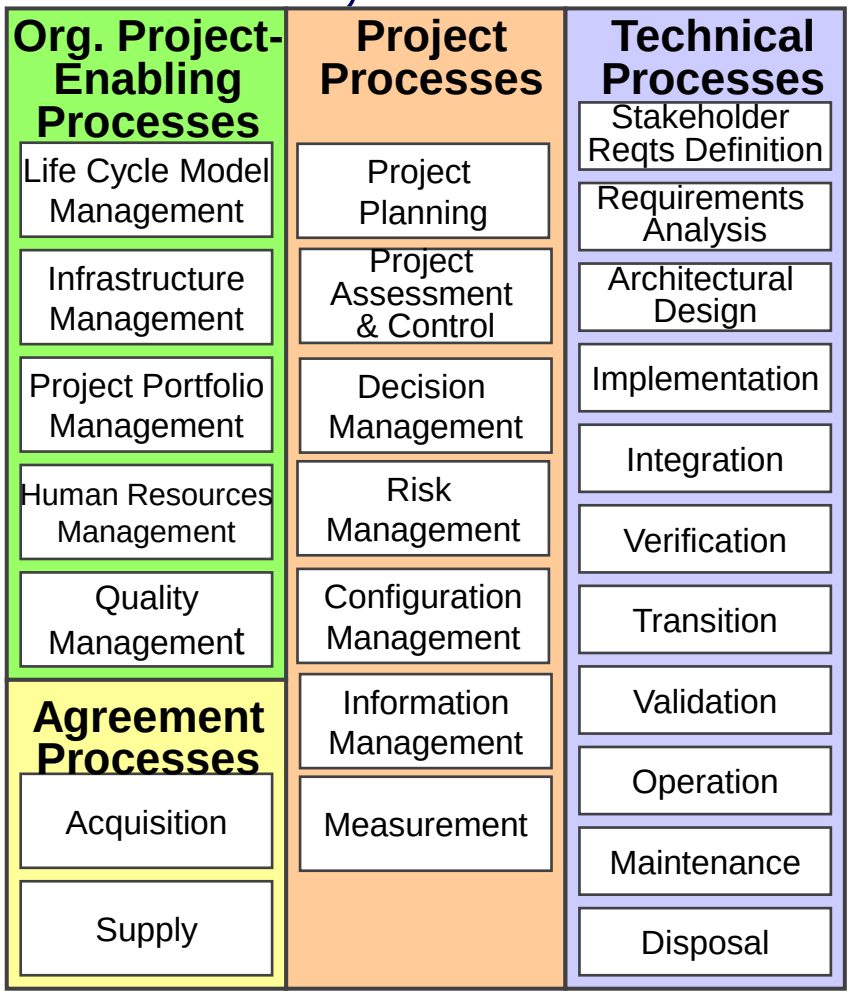
10.13 Usability Analysis/Human Systems Integration

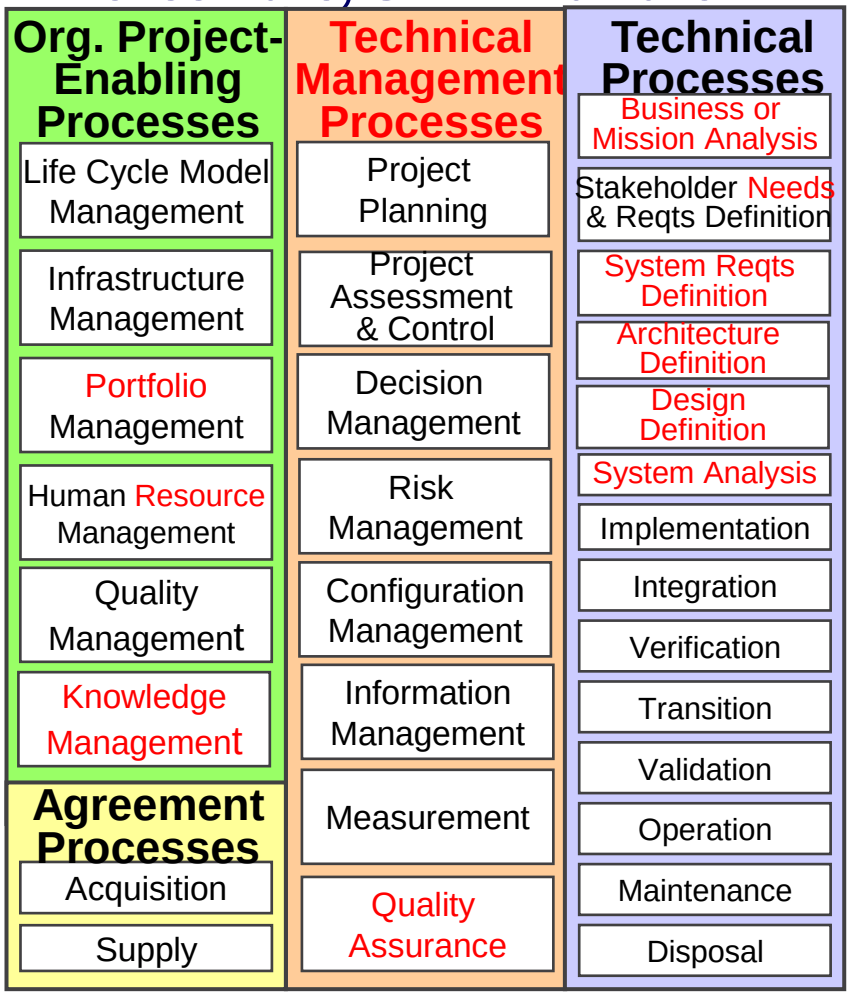
- A key method of HSI is trade studies and analyses.
  - HSI analyses, especially requirements analyses that include human issues and implications, often result in insights not otherwise realized.
  - Trade studies that include human-related issues are critical to determining the design that is the most effective, efficient, suitable (including useful and understandable), usable, safe, and affordable.
  - HSI helps systems engineers focus on long-term costs since much of that cost is directly related to human element areas.
- One example (unfortunately, of many) is the Three Mile Island power plant nuclear incident in the United States:
  - The accident was caused by a combination of personnel error, design deficiencies, and component failures.
  - The problems identified from careful analysis of the events during those days have led to permanent and sweeping changes in how NRC regulates its licensees—which, in turn, has reduced the risk to public health and safety.
- Failure to include HSI within a comprehensive SE frame-work resulted in loss of confidence in nuclear power in the United States and delayed progress in the field for almost 30 years. The cleanup costs, legal liability, and significant resources associated with responding to this near catastrophe trace directly to lack of attention to the human element of a highly complex system, resulting in flawed operations technology and work methods.
- It also emphasized that while human performance includes raw efficiency in terms of tasks accomplished per unit time and accuracy, human performance directly impacts the overall system performance.

V4.0 10.0 Specialty Engineering (cont)
10.12 Training Needs Analysis

- Training needs analyses support the development of products and processes for training the users, main-tainers, and support personnel of a system.
  - Training analysis includes the development of personnel capabil-ities and proficiencies to accomplish tasks at any point in the system life cycle to the level they are tasked.
    - These analyses address initial and follow-on training necessary to execute required tasks associated with system use and maintenance.
  - An effective training analysis begins with a thorough understanding of the concept documents and the requirements for the SOI.
    - A specific list of functions or tasks can be identified from these sources and repre-sented as learning objectives for operators, maintainers, administrators, and other system users.
    - The learning objectives then determine the design and development of the training modules and their means of delivery.
- Important considerations in the design of training include who, what, under what conditions, how well each user must be trained, and what training will meet the objectives.
- Each of the required skills identified must be transformed into a positive learning experience and mapped onto an appropriate delivery mechanism.
- The formal classroom environment is rapidly being replaced with or augmented by simulators, computer-based training, Internet-based distance delivery, and in-systems electronic support, to name a few.
- Updates to training content use feedback from trainees after they have some experience to improve training effectiveness.

15288 and SE Handbook Processes





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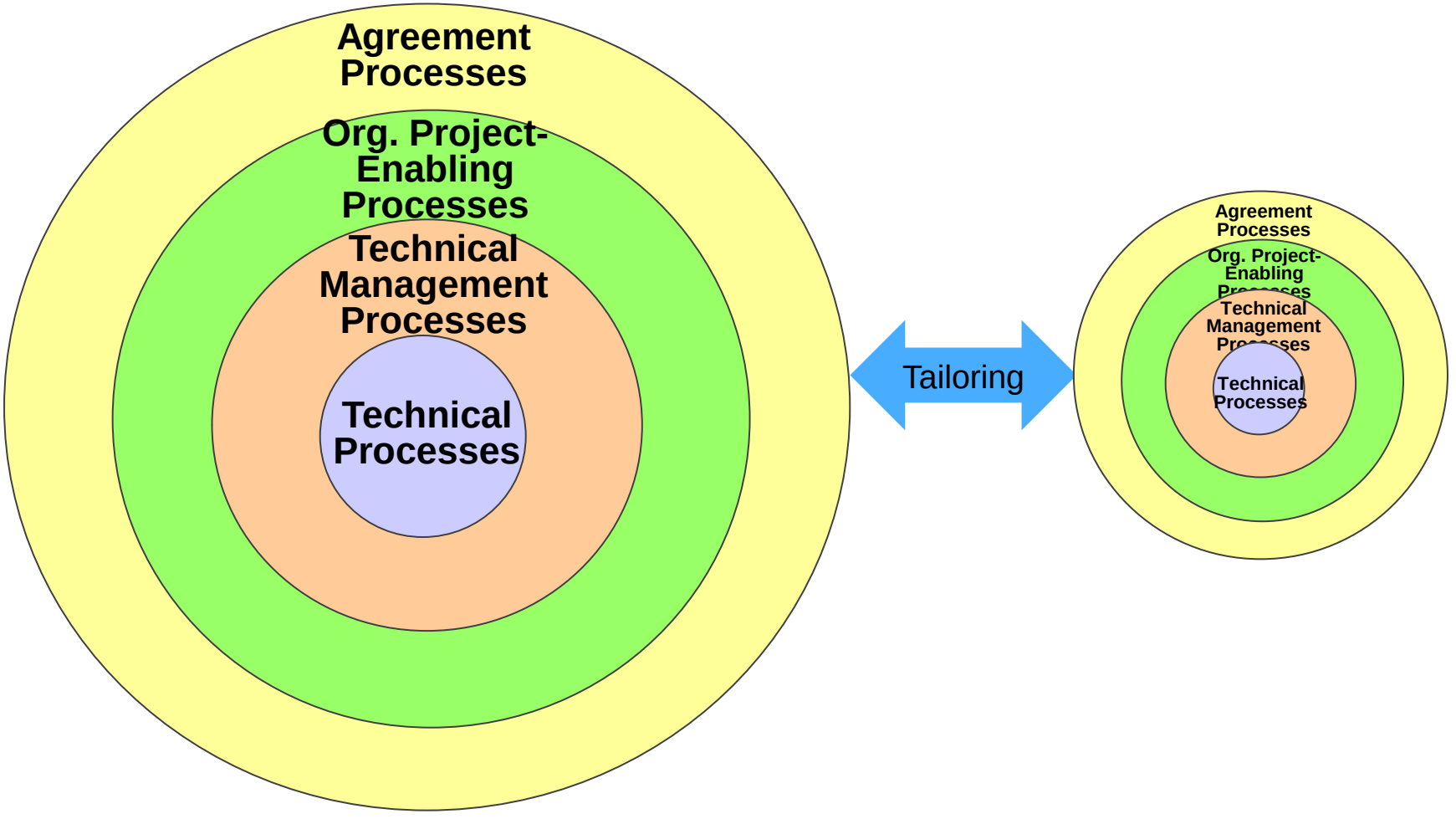
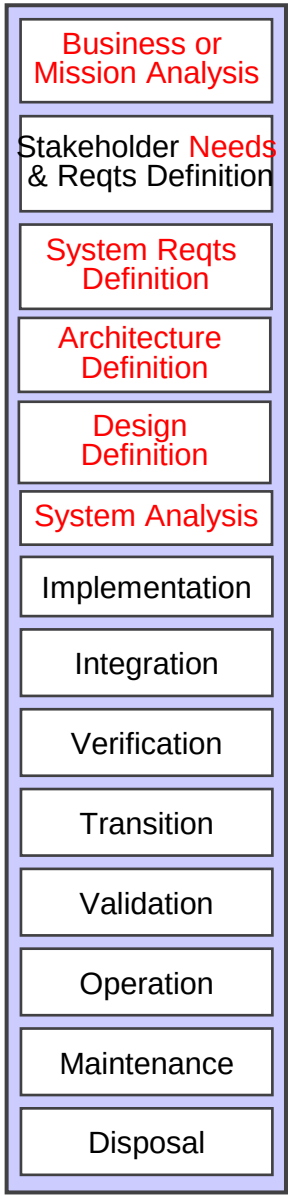
Tailoring

15288:2015 Processes Context Diagram



Technical Processes – 15288:2015, SEH V4.0:2015



*B*egins with the business vision of the organization or enterprise, the concept of operations (ConOps), and other organization strategic goals and objectives from which business management define business needs (aka mission needs). These needs are supported by preliminary life cycle concepts—acquisition concept, deployment con-cept, operational concept (OpsCon), support con-cept, and retirement concept. Business needs are then elaborated and formalized into business require-ments, which are often captured in a Business Requirements Specification (BRS).

Requirements engineers lead stakeholders from business operations through a structured process to elicit stakeholder needs (in the form of a refined system-level OpsCon and other life cycle con-cepts). Stakeholder needs are then transformed by requirements engineers into a formal set of stake-holder requirements, which are often captured in a Stakeholder Requirements Specification (StRS).

The stake-holder requirements in the StRS are then transformed by requirements engineers into system requirements, which are often contained in a System Requirements Specification (SyRS).

Alternative system architectures are defined and one is selected.

System elements are defined in sufficient detail to enable implementa-tion consistent with the selected system architecture.

Mathematical analysis, modeling, and simulation are used to support the other technical processes

System elements are realized to satisfy system requirements, architecture, and design.

System elements are combined into a realized system

Evidence is provided that the system, the system elements, and the work products in the life cycle meet the specified requirements

The system moves into opera-tions in a planned, orderly manner

Evidence is provided that the system, the system elements, and the work products in the life cycle will achieve their intended use in the intended operational environment.

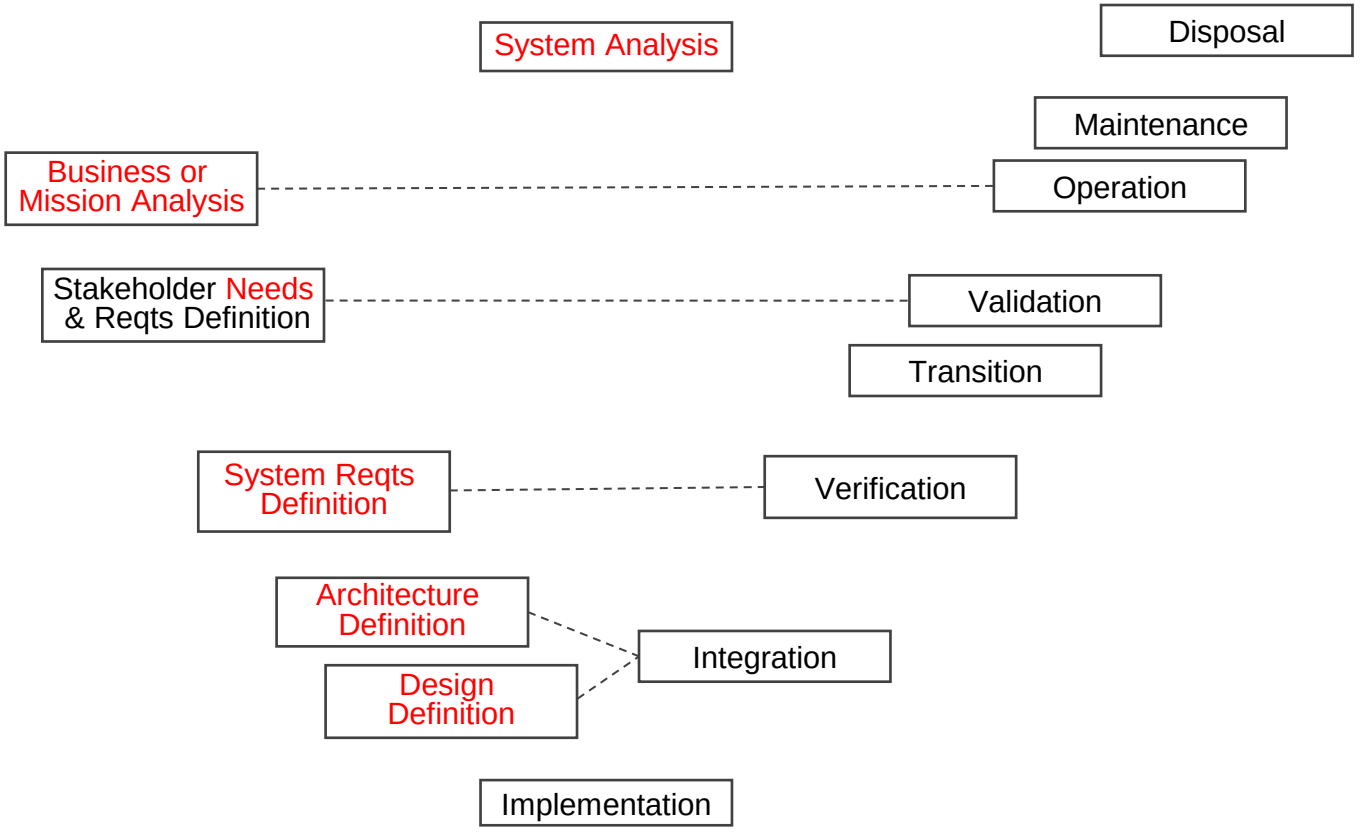
The system is used.

The system is sustained during operations.

The system or system elements are deactivated, disassembled, and removed from operations.

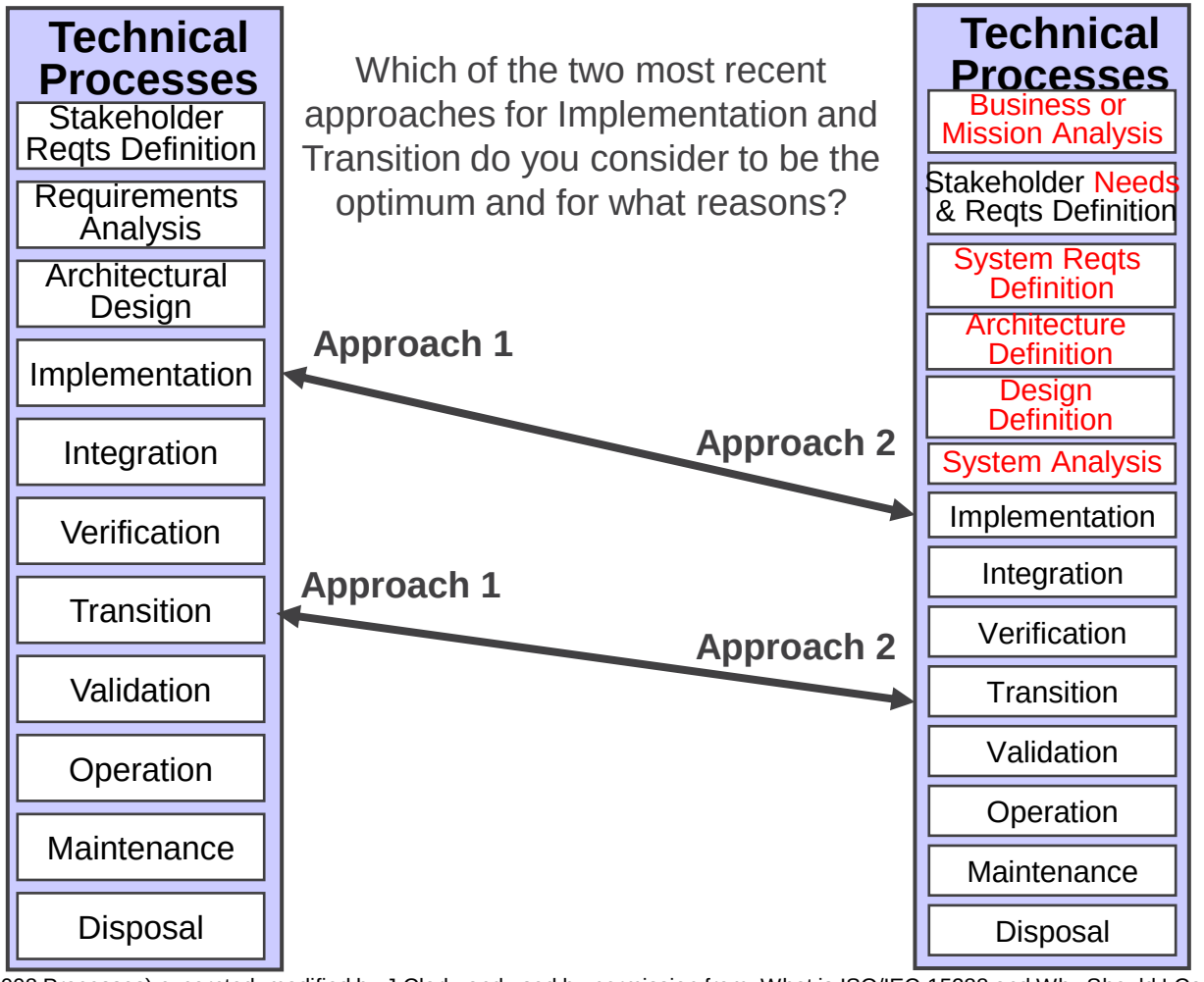
Technical Processes V-Model

15288:2015, SEH V4.0:2015
Technical Processes



Two Alternative Approaches

15288:2008, SEH V3.2.2:2011 ***15288:2015, SEH V4.0:2015***



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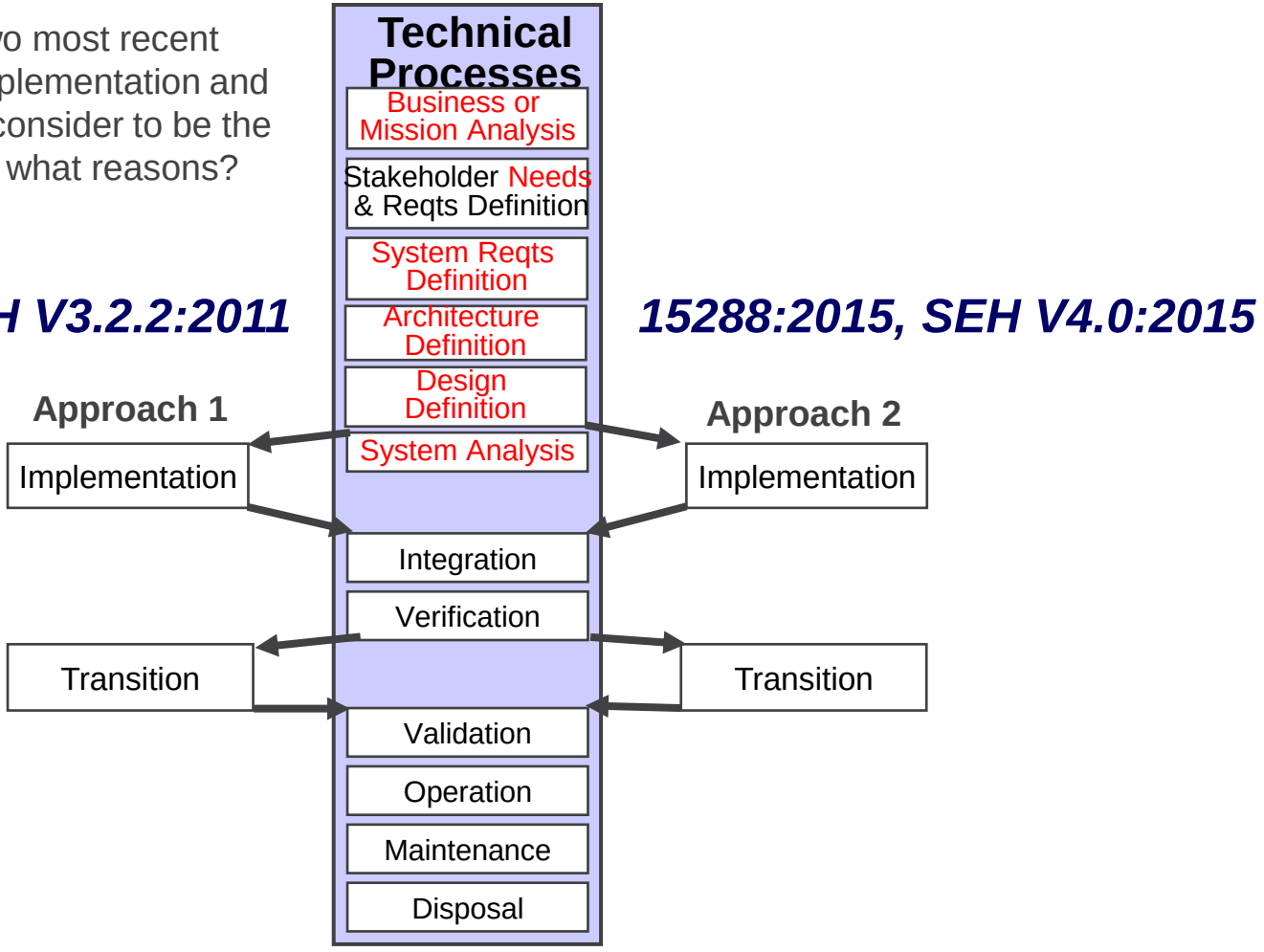
Two Alternative Approaches (cont)

Which of the two most recent approaches for Implementation and Transition do you consider to be the optimum and for what reasons?



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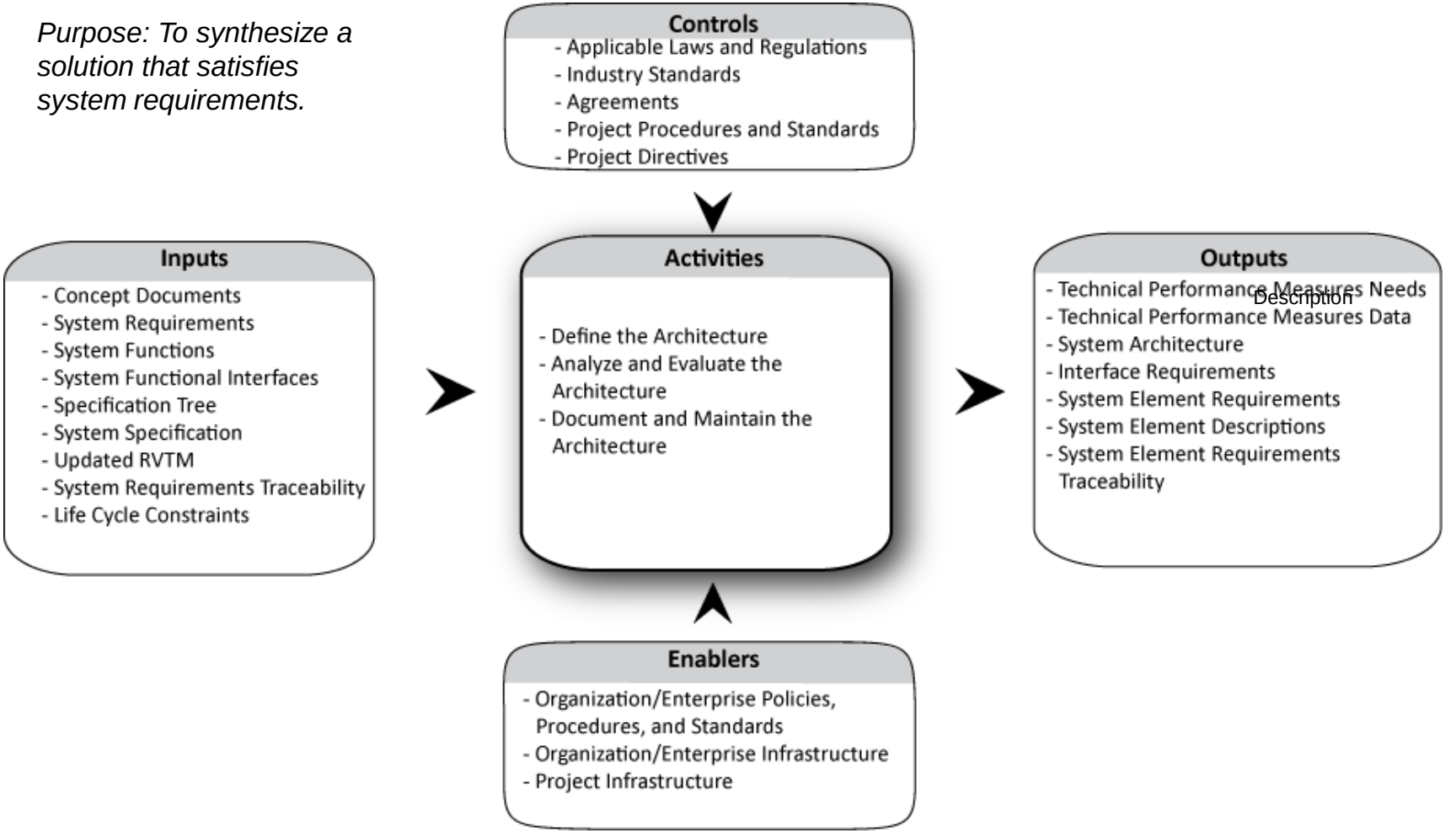
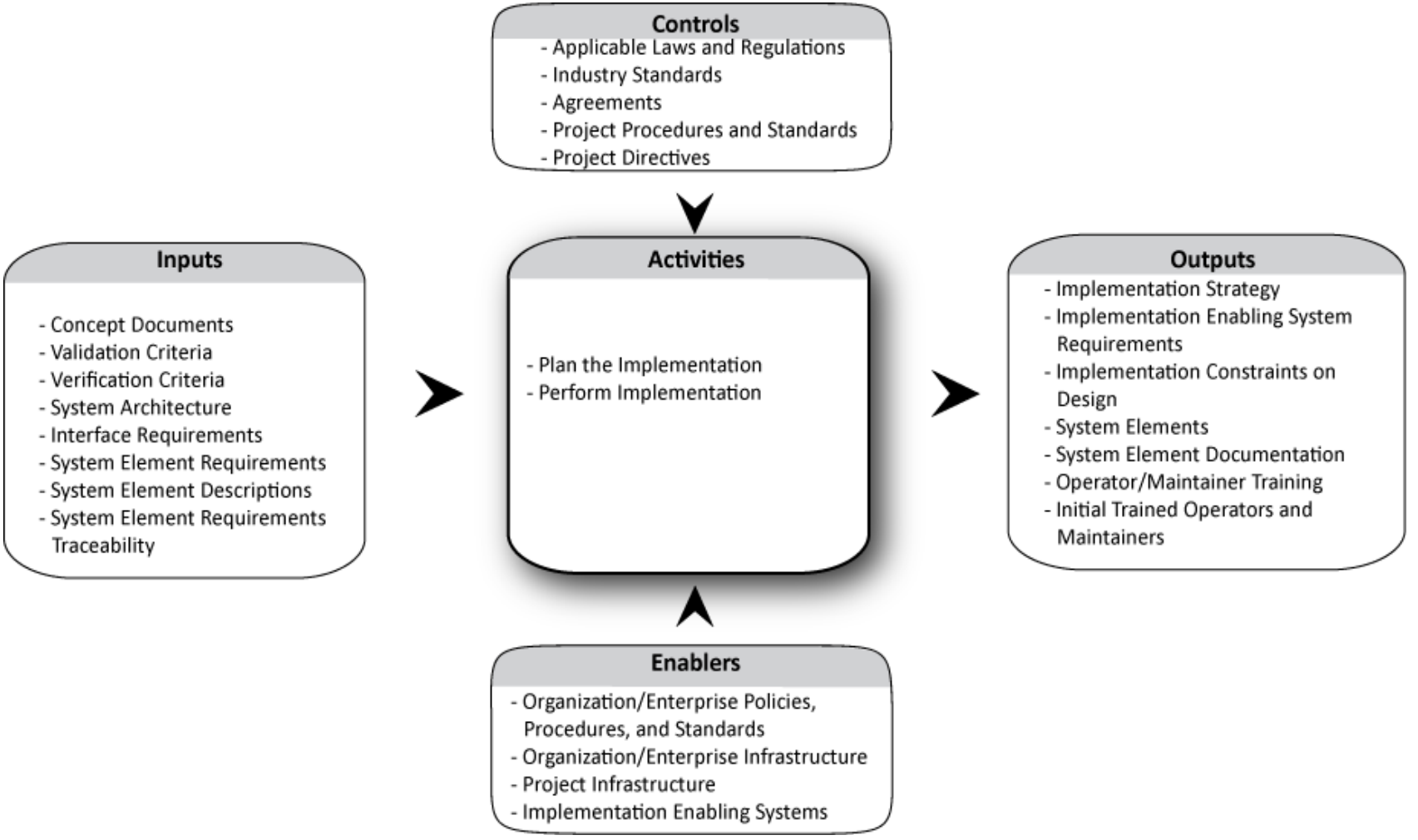
V3.2.2 Architectural Design Process

Purpose: To synthesize a solution that satisfies system requirements.



V3.2.2 Implementation Process Approach 1



V3.2.2 Transition Process

Approach 1

Purpose: To establish a capability to provide services specified by stakeholder requirements in the operational environment.

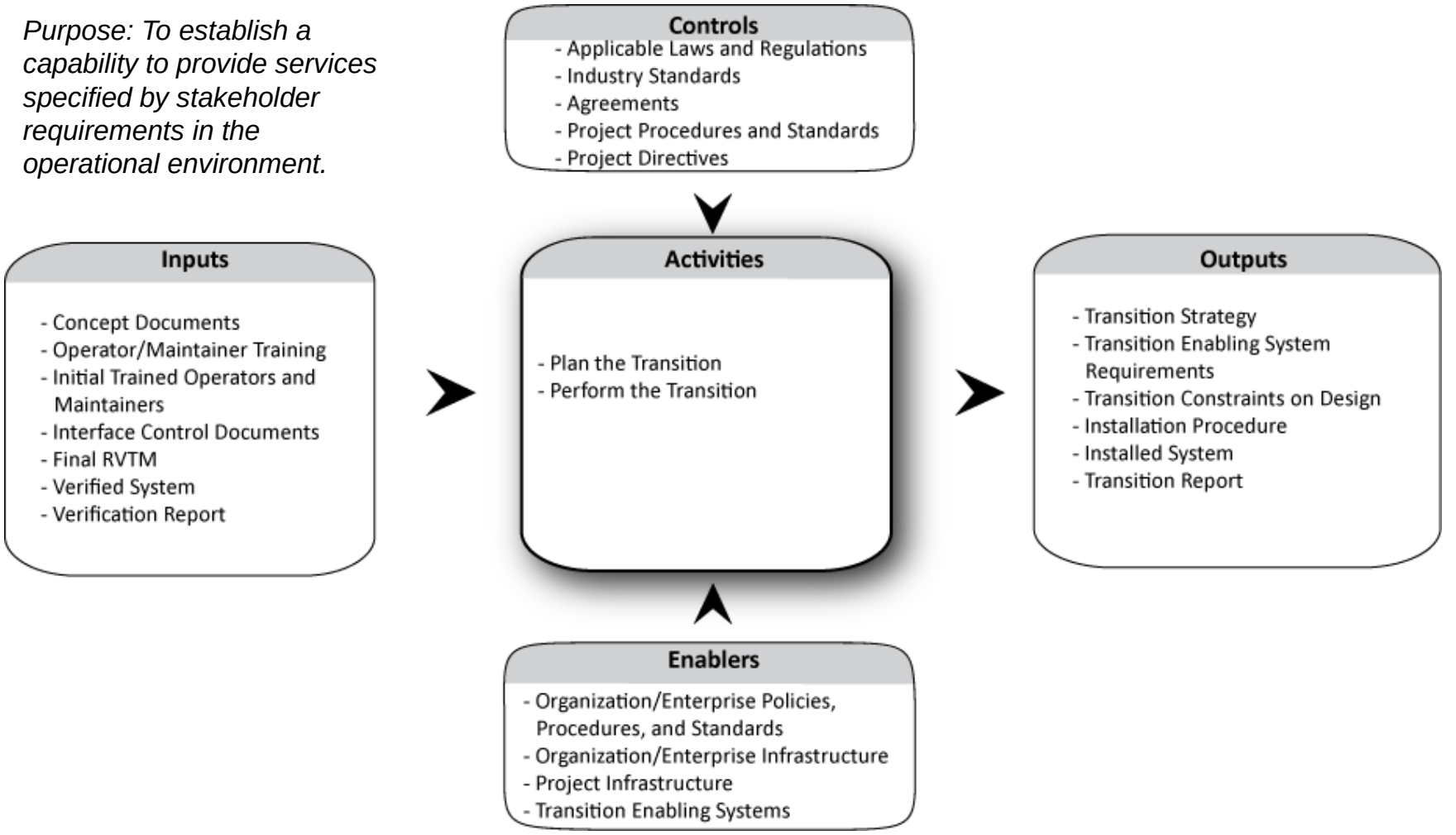


Figure 4-16 Context Diagram for the Transition Process

V4.0 Design Definition Process

Purpose – To provide sufficient detailed data and information about the system and its elements to enable the imple-mentation consistent with architectural entities as defined in models and views of the system architecture. (15288)

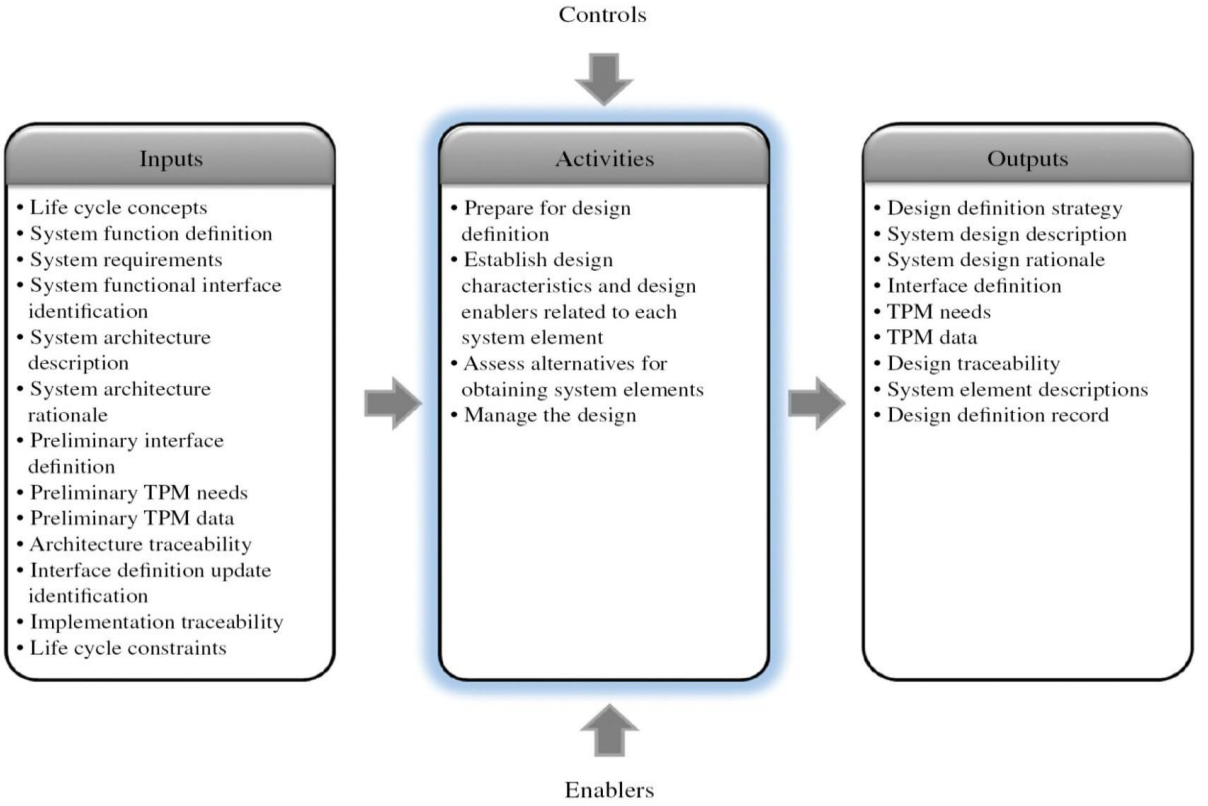


FIGURE 4.9 IPO diagram for the design definition process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Implementation Process – Approach 2

- Purpose (per 15288) – To:
  - Realize a specified system element.
- The IMPL Process creates or fabricates a system element conforming to that element's detailed description (requirements, architecture, design, including interfaces).
  - The element is constructed employing appro-priate technology and industry practices.
- During the IMPL Process, engineers follow the requirements allocated to the system element to fabricate, code, or build each individual element using specified materials, processes, physical or logical arrangements, standards, technol-ogies, and/or information flows outlined in detailed drawings or other design documentation.
  - System requirements are verified and stakeholder requirements are validated.
  - If subsequent configuration audits reveal discrepancies, recursive interactions occur with prede-cessor activities or processes, as required, to correct them.

System Element - member of a set of elements that constitutes a system (15288 & INCOSE)… These elements include products (hardware, software, firmware), processes, people, informa-tion, techniques, facilities, services, and other support elements (INCOSE)… Example: Hardware, software, data, humans, processes (e.g., processes for providing service to users), procedures (e.g., operator instructions), facilities, materials, and naturally occurring entities or any combination... A system element is a discrete part of a system that can be implemented to fulfill specified requirements… Humans can be viewed as both users external to a system and as system elements (i.e., operators) within a system (15288).

V4.0 Implementation Process – Approach 2

Purpose – To realize a specified system element (15288).

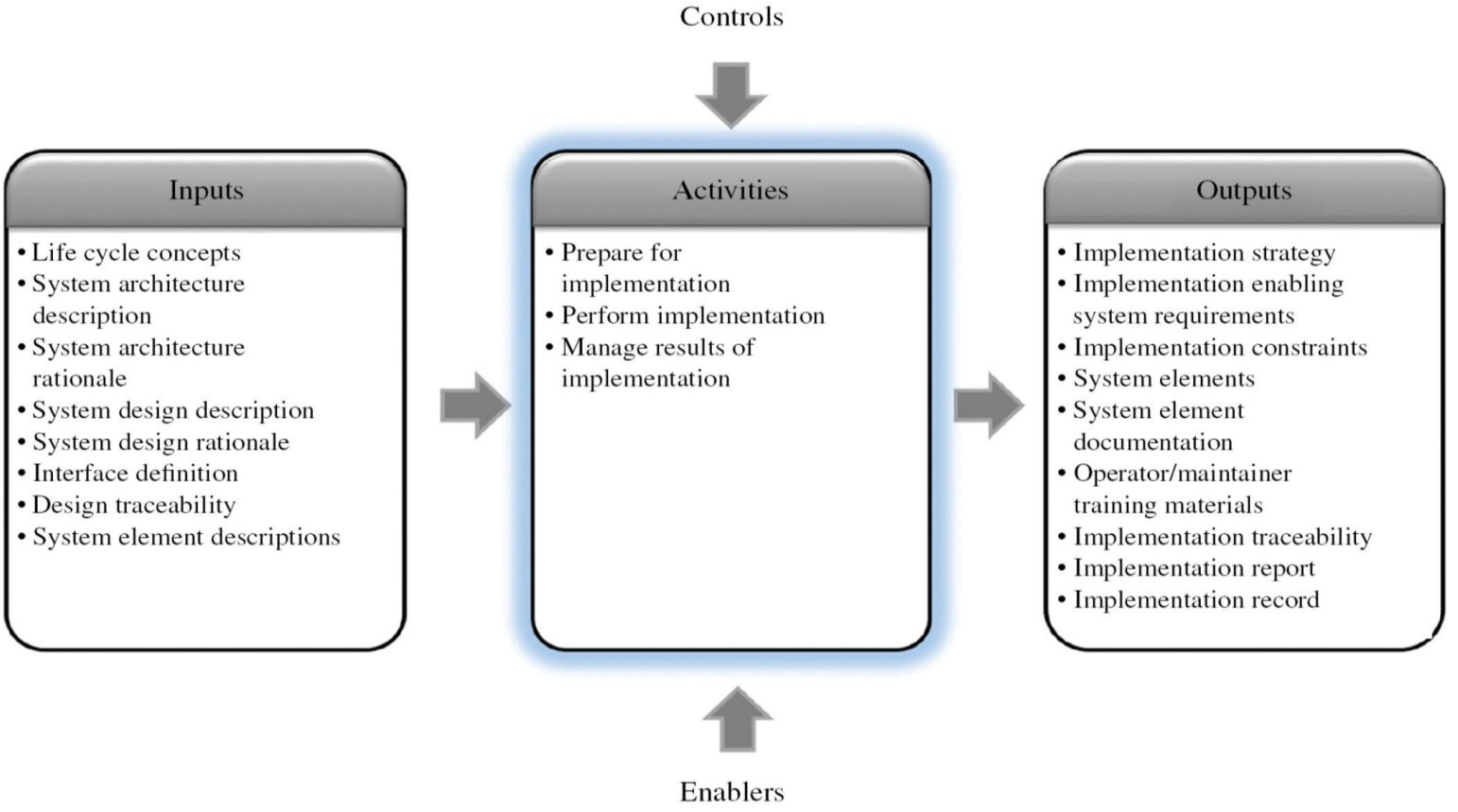

FIGURE 4.11 IPO diagram for the implementation process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Integration Process – Approach 2

Purpose– To syn-thesize a set of system elements into a realized system (product or service) that satisfies system requirements, architecture, and design. (15288)

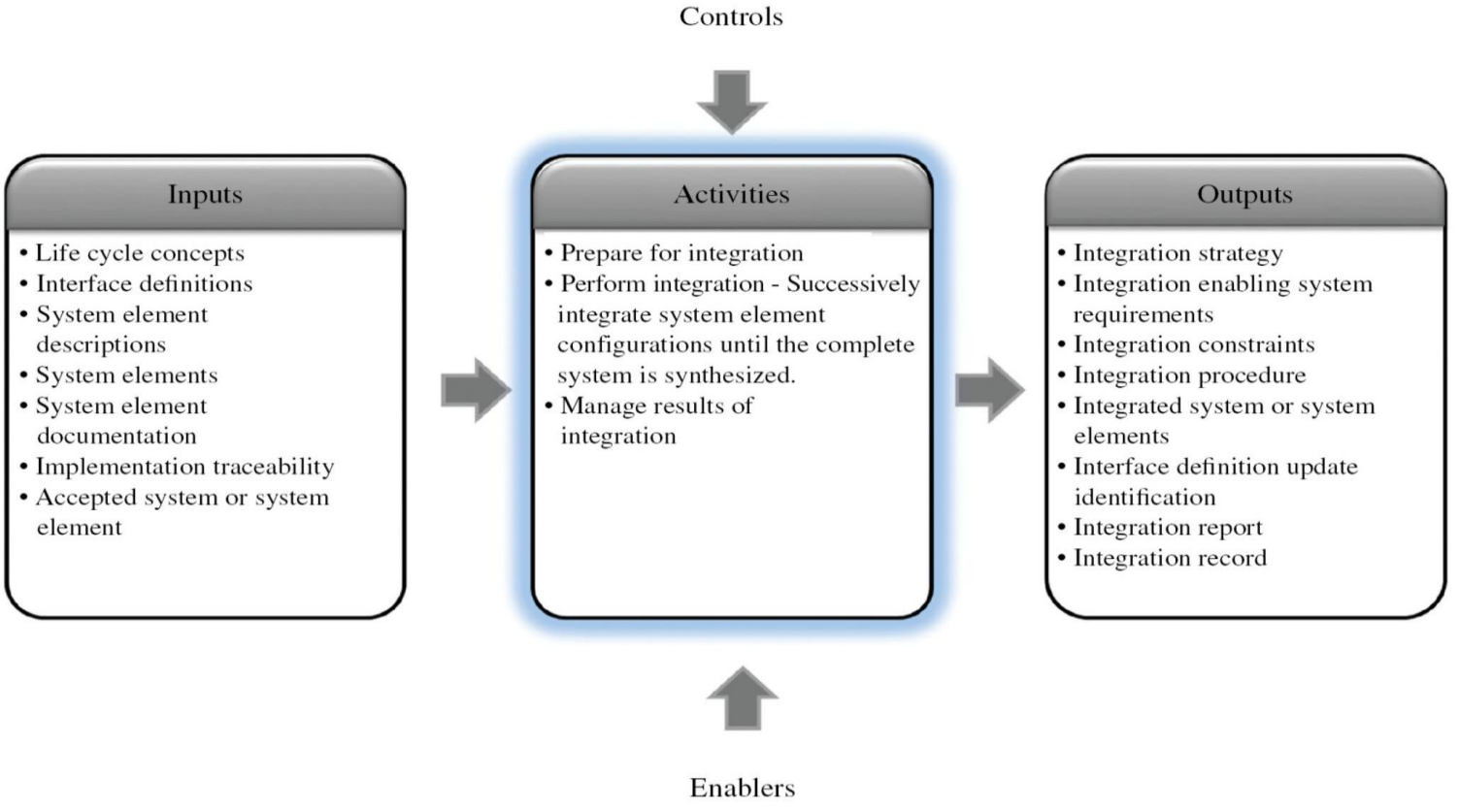

FIGURE 4.12 IPO diagram for the integration process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Verification Process

Purpose– To pro-vide objective evidence that a system or system element fulfils its specified requirements and characteristics. (15288)

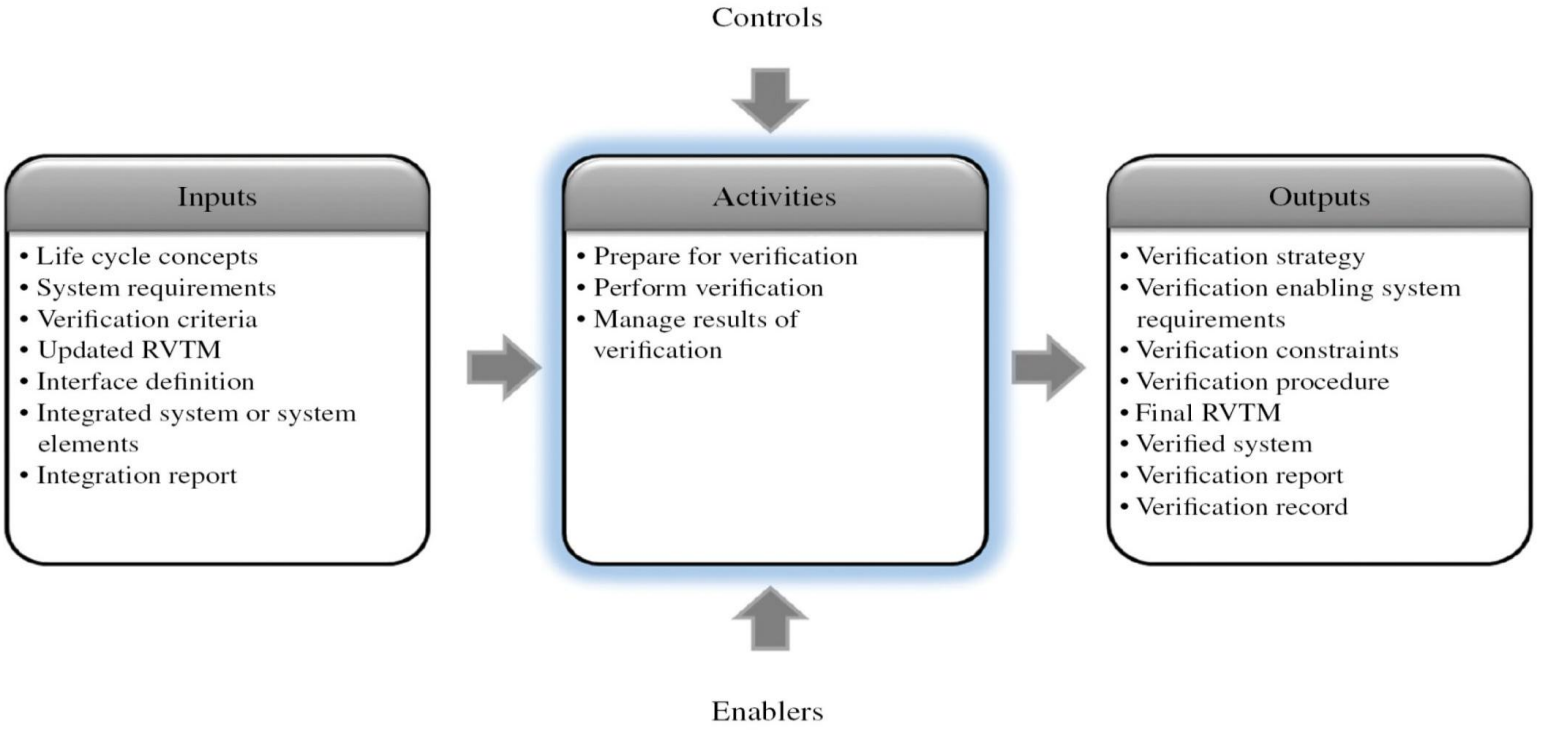

FIGURE 4.13 IPO diagram for the verification process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Transition Process – Approach 2

- Purpose (per 15288) – To establish a capability for a system to provide services specified by stakeholder requirements in the operational environment.
- Ultimately, the TRAN Process enables the transfer of custody of the system and responsibility for system support from one organizational entity to another.
  - This includes, but is not limited to, transfer of custody from the development team to the organizations that will subsequently operate and support the system.
  - Successful conclusion of the TRAN Process typically marks the beginning of the utilization stage of the SOI.
- The TRAN Process installs a verified system in the operational environment along with relevant enabling systems, products, or services, such as operator training systems, as defined in the agreement.
- Using successful results from the VER Process, the acquirer accepts that the system meets the specified system requirements in the intended operational environment prior to allowing a change in control, ownership, and/or custody.
  - While this is a relatively short process, it should be carefully planned to avoid surprises and recrimination on either side of the agreement.
- Additionally, transition plans should be tracked and monitored to ensure all activities are completed to both parties' satisfaction, including resolution of any issues arising during transition.

V4.0 Transition Process – Approach 2

- Purpose– To establish a capability for a system to provide services specified by stakeholder requirements in the operational environment. (15288)

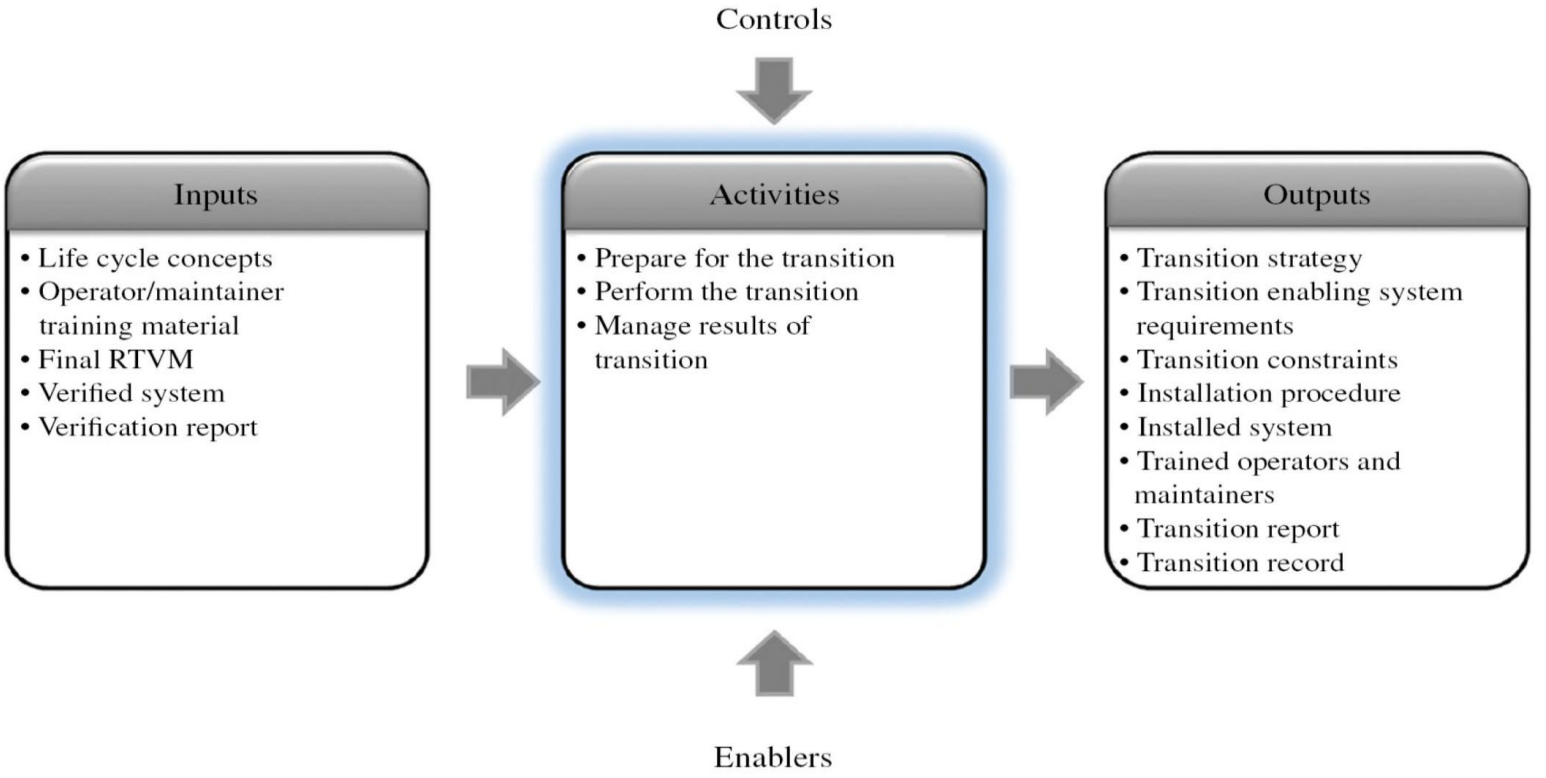

FIGURE 4.16 IPO diagram for the transition process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Validation Process

Purpose – To provide objective evidence that the system, when in use, fulfills its business or mission objectives and stake-holder requirements, achieving its intended use in its intended operational environment. (15288)

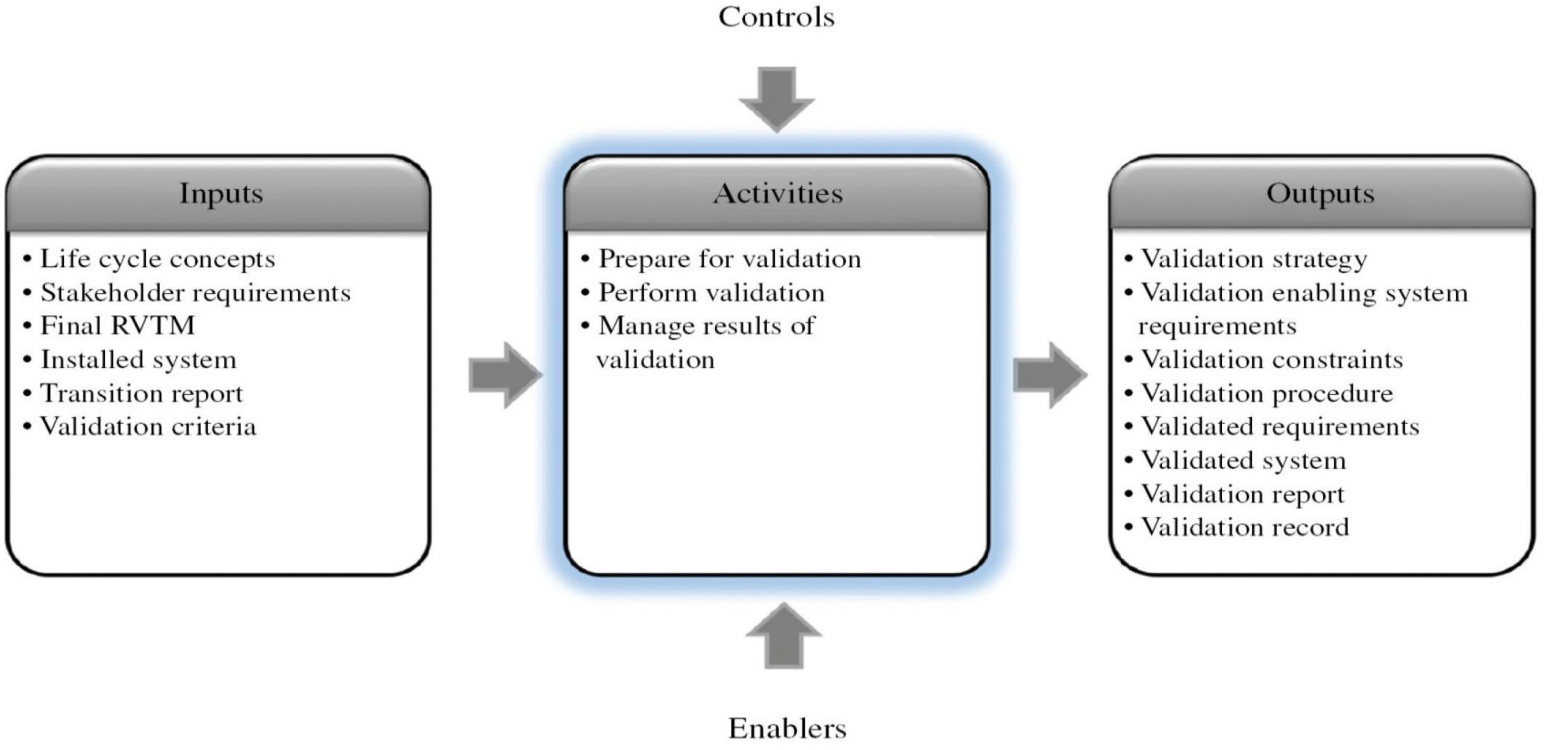

FIGURE 4.17 IPO diagram for the validation process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Operation Process

Purpose – To use the system to deliver its services. (15288)

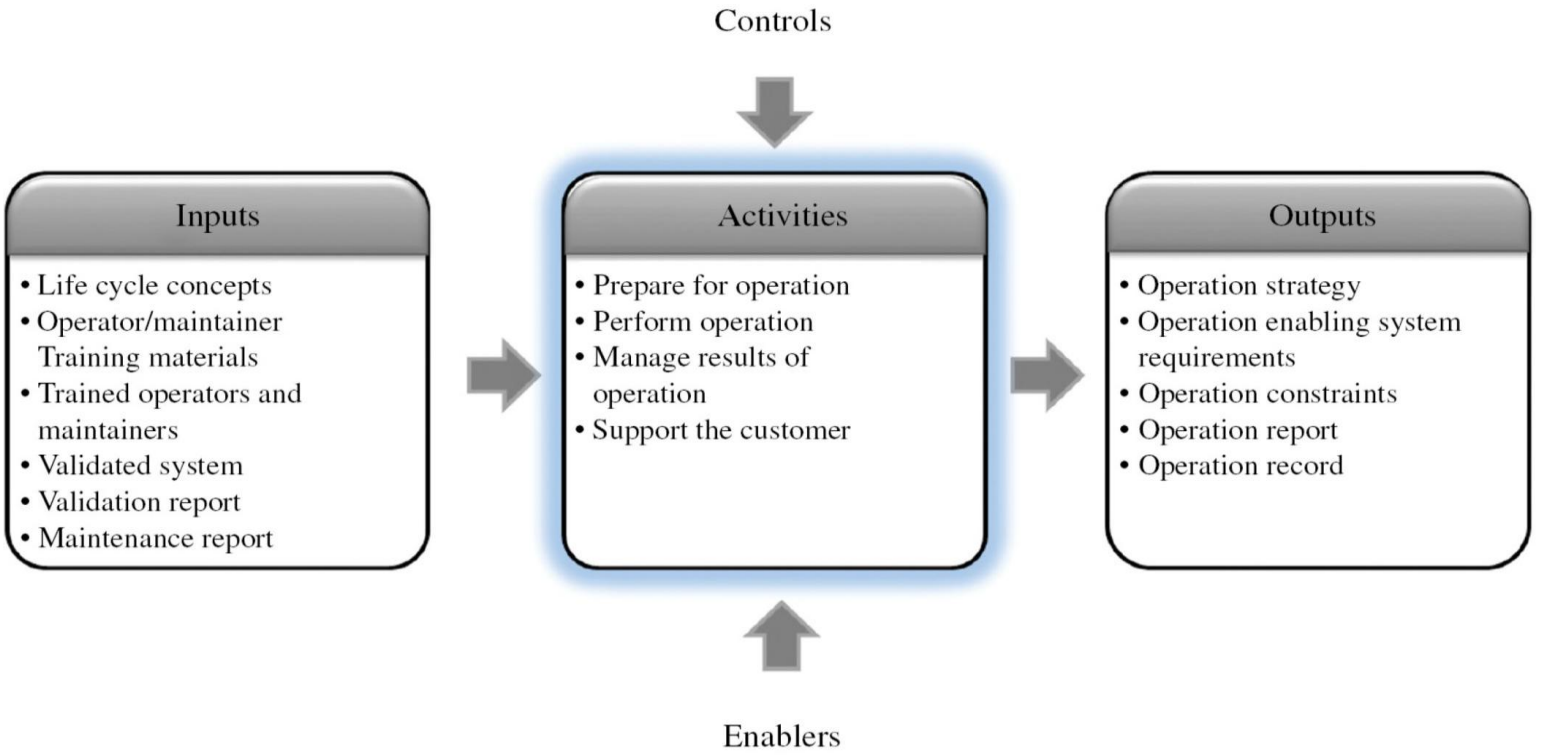

FIGURE 4.20 IPO diagram for the operation process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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V4.0 Maintenance Process

Purpose – To sustain the capability of the system to provide a service. (15288)

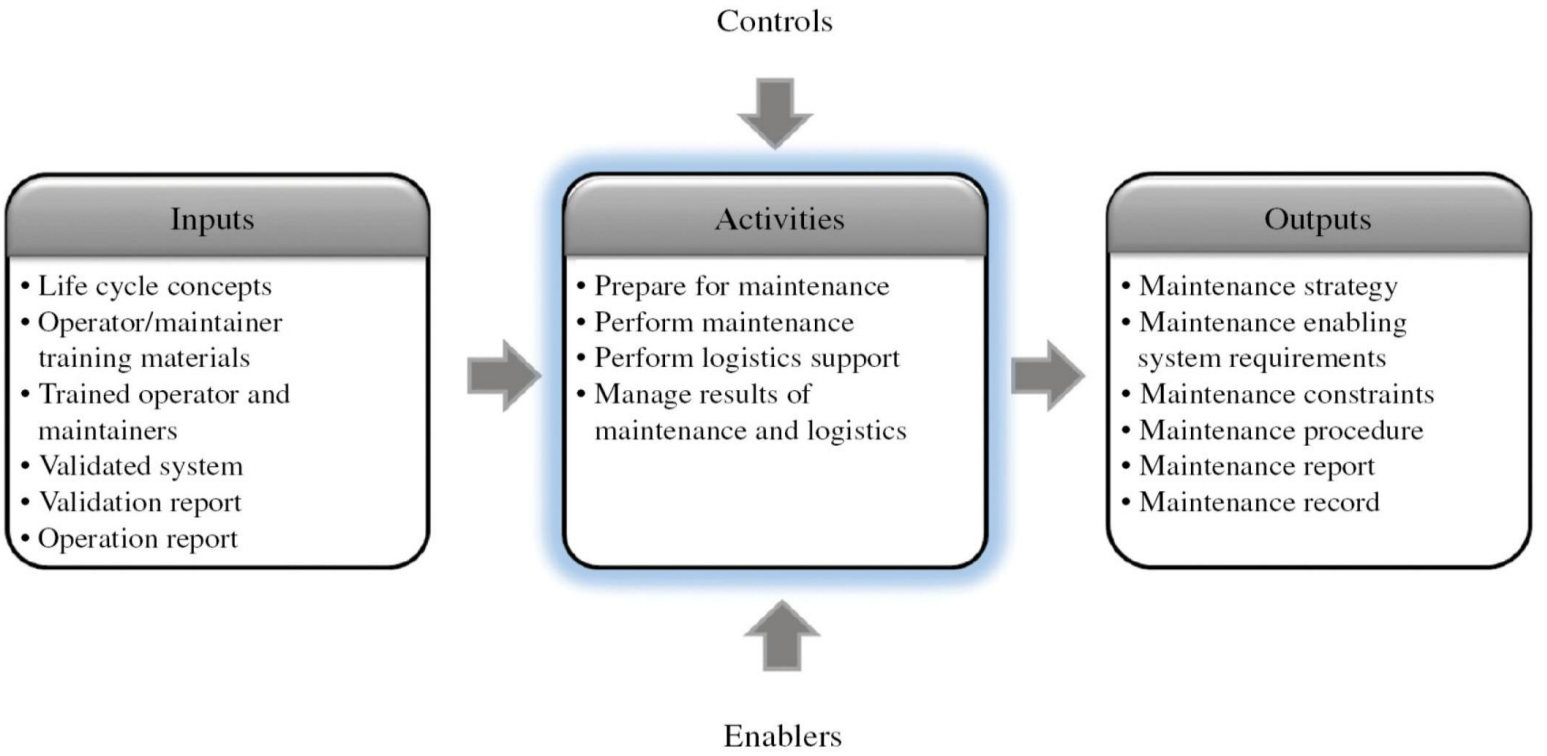

FIGURE 4.21 IPO diagram for the maintenance process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

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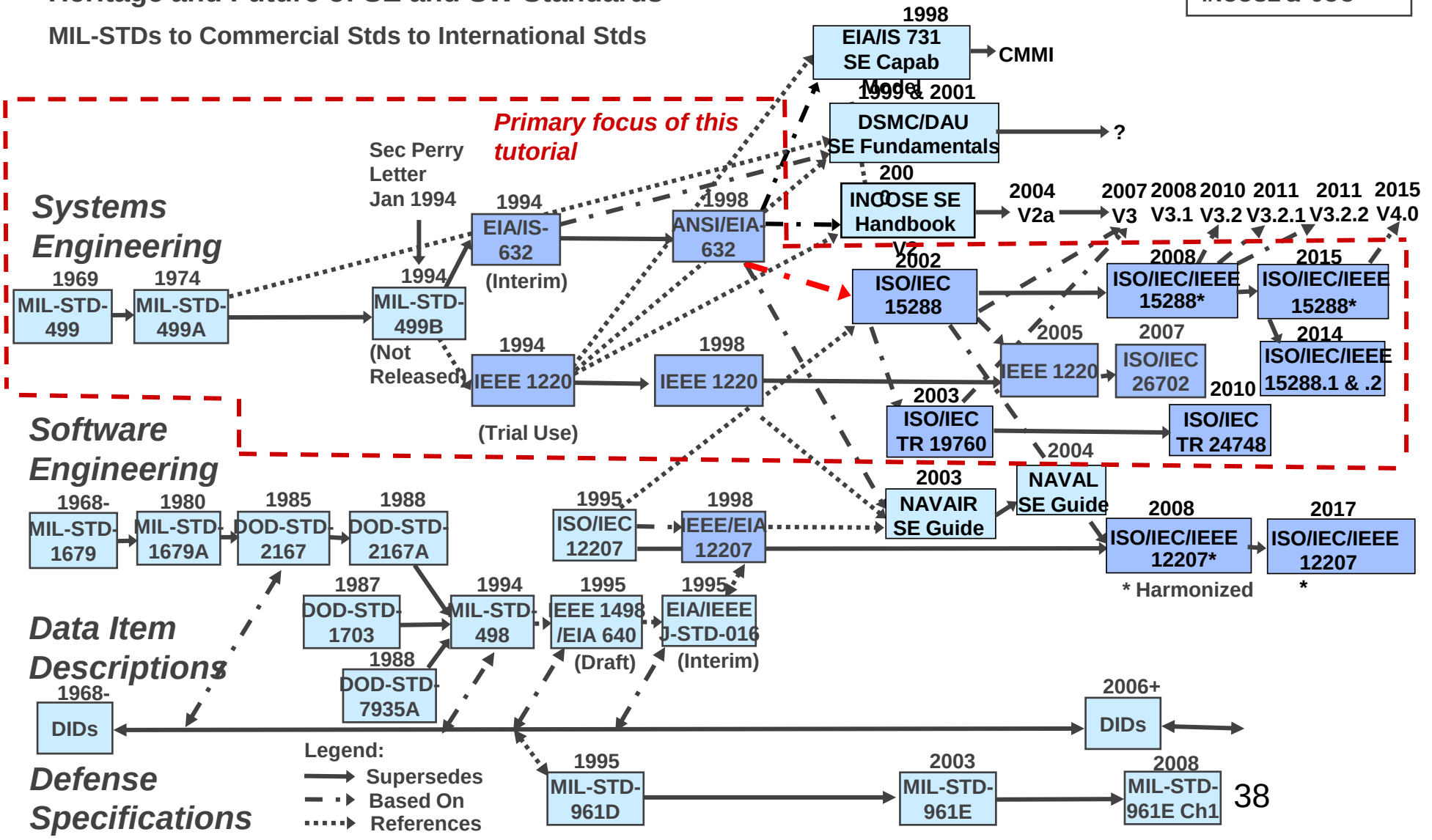
Review of SE Standards Discussed in this Tutorial

Heritage and Future of SE and SW Standards

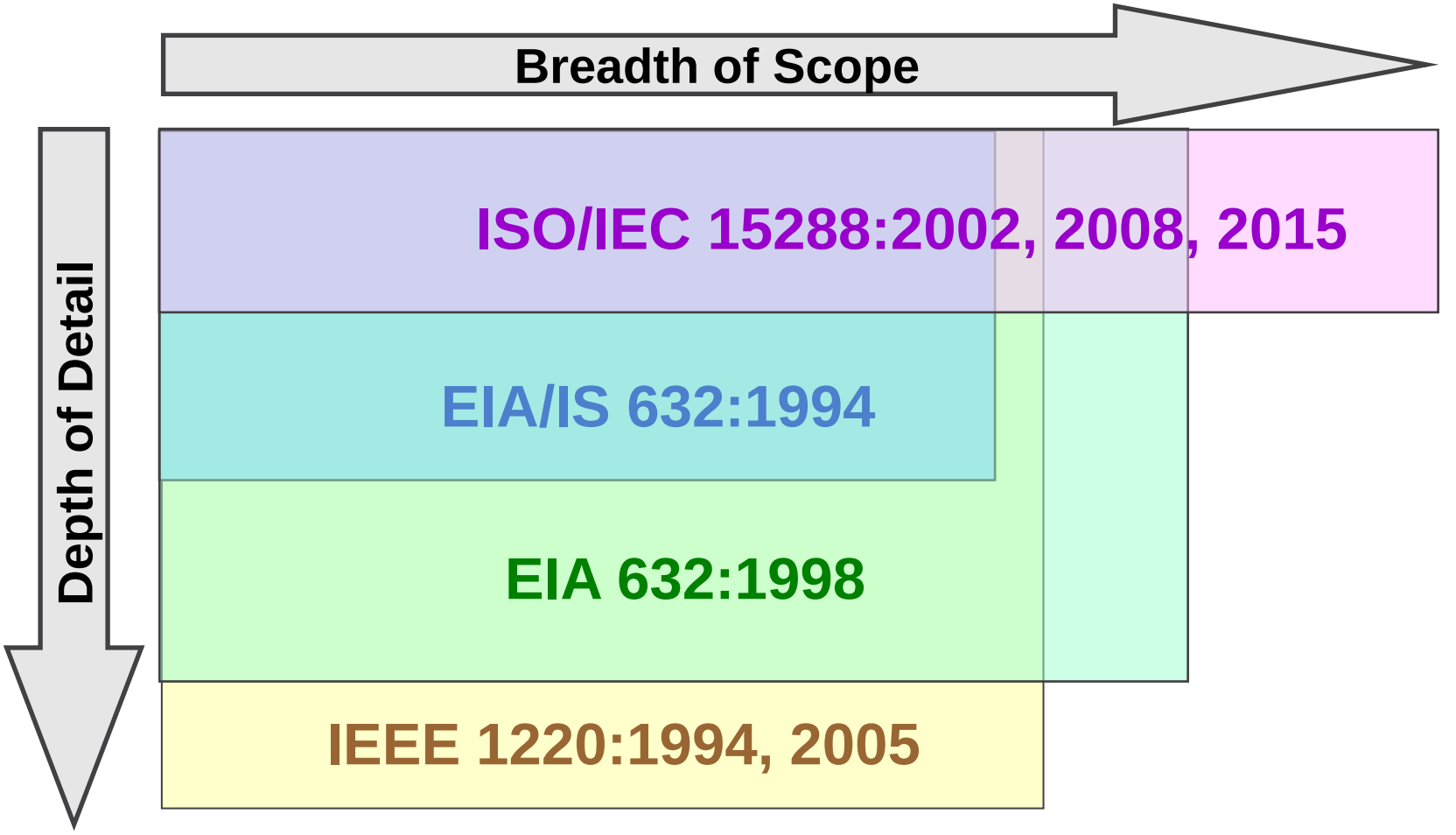
MIL-STDs to Commercial Stds to International Stds

INCOSE & JOC



Breadth and Depth of SE Standards

Sheard and Lake



Provided and modified by John Clark with the permission of Sarah Sheard from
Sheard, Sarah A., Software Productivity Consortium (SPC), and
Lake, Jerome G., Systems Management international (SMi),
Systems Engineering Standards and Models Compared, July 1998.

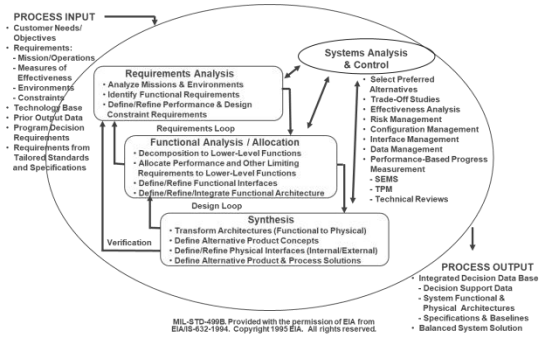
Breadth and Depth of SE Standards (cont)

ISO/IEC TR 19760

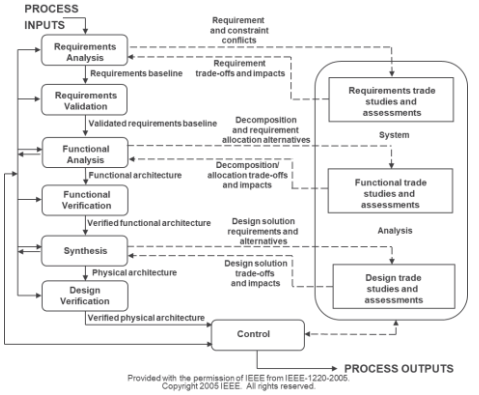
Refer to ISO/IEC TR 19760 Figure A.1 —
ISO/IEC 15288 and other engineering standards

Breadth and Depth of SE Standards (cont)

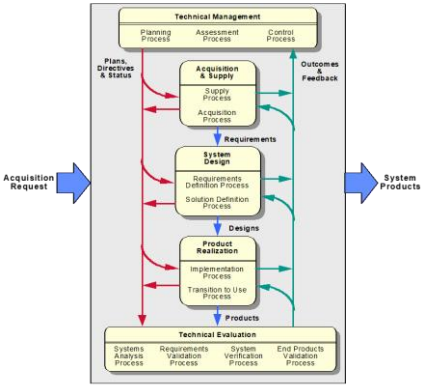
MIL-STD-499B
EIA/IS-632



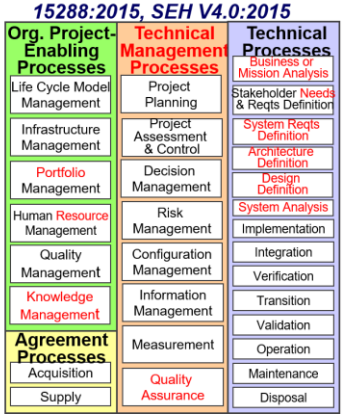
IEEE 1220



EIA-632

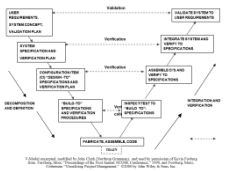


ISO/IEC/IEEE 15288

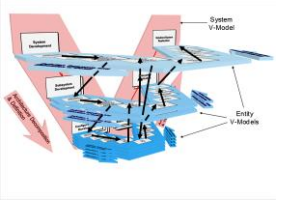


Developed by John Clark based on INCOSE SE Handbook V4.0, October 8, 2015.

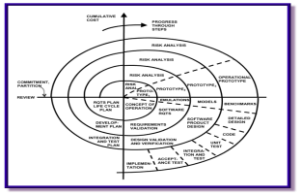
V-Model



Dual-V

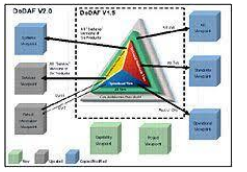


Spiral/ICM

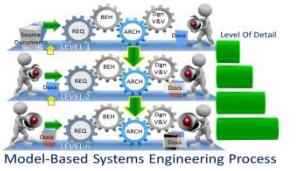


SYS-ML

DODAF



MBSE



Breadth and Depth of SE Models

Summary

- The SE Standards and Handbooks have evolved since 1969 from MIL to Commercial to International Standards and Handbooks, and they include SE of humans.
- The Process scope has increased.
- The Process depth has changed:
  - The Non-Technical Process depth has increased
  - The Technical Process depth has decreased.
  - The Human SE Process depth has decreased
- We need to get back to the basics to restore the depth.

Conclusion

- We do systems engineer humans.
- We do engineer systems that include humans.
- All systems include humans
  - We summarized which humans, and how they are included in a system.
  - We do perform systems engineering on them.
  - Humans are elements of the system like hardware and software.
  - We have hardware, software, and humanware.
  - We can model the behavior of humans
- There are no systems that do not include humans in any way whatsoever.
- We discussed these questions from the SE Standards and INCOSE SE Handbook perspectives, going back to their earlier versions and coming up to date, including the two most recent approaches.
- At the end of this presentation we asked you to answer the question: Which of the two most recent approaches do you consider to be the optimum and for what reasons?

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- **Mica Endsley** Former US Air Force Chief Scientist, President of SA Technologies
- **General Frédéric Parisot** French Air Force State Staff
- **David Sirkin** Stanford University

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Top Domains
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Top Topics
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The End!

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INCOSE Training WG
Founder & Co-Chair
john.clark@incose.org