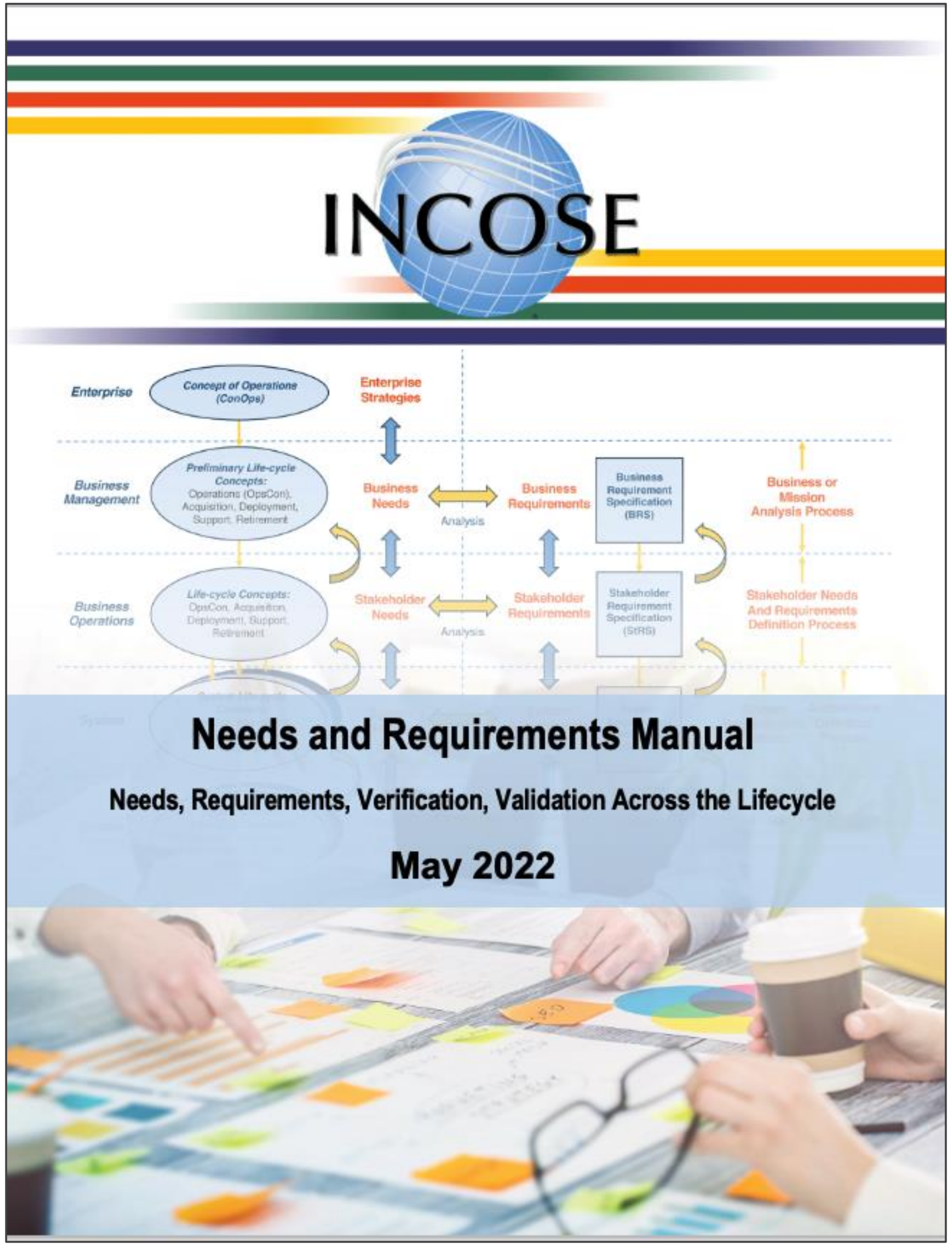
2021
Annual INCOSE
international workshop
Virtual Event
January 29 - 31, 2021

Needs Requirements Manual (NRM)

Needs, Requirements, Verification, & Validation Across the Lifecycle (Updated March 2022)

Overview – Underlying Concepts

Requirements Working Group



INCOSE
Enterprise
Concept of Operations (ConOps)
Enterprise Strategies
Business Management
Preliminary Life-cycle Concepts: Operations (OpsCon), Acquisition, Deployment, Support, Retirement
Business Needs
Analysis
Business Requirements
Business Requirement Specification (BRS)
Business or Mission Analysis Process
Business Operations
Life-cycle Concepts: OpsCon, Acquisition, Deployment, Support, Retirement
Stakeholder Needs
Analysis
Stakeholder Requirements
Stakeholder Requirement Specification (StRS)
Stakeholder Needs And Requirements Definition Process

Needs and Requirements Manual

Needs, Requirements, Verification, Validation Across the Lifecycle

May 2022

The focus of this presentation – Underlying Concepts Discussed in Section 1 & 2

Underlying Concepts - Overview

- Reducing ambiguity
- The SE Vee – left-side vs right-side
- Organizational levels vs. architectural levels
- Integrated, multidisciplined, collaborative, project team – no silos!
- Data-Centric practice of systems engineering
- Needs before requirements
- A more rigorous process for verification and validation

Underlying Concepts - Overview

Needs and Requirements are the common treads that tie all SE lifecycle activities and artifacts together.

This Manual takes a holist view of SE such that needs and requirements are defined and managed in the context of all other SE process areas rather than in a silo distinct from the other process areas.

Underlying Concepts - Overview

Writing needs and requirements is NOT an exercise in writing but an exercise in engineering.

The underlying analysis and maturation of knowledge from which needs and requirements are derived is more important than how well a textual need or requirement statement is written.

Underlying Concepts - Overview

From the INCOSE Guide for Writing Requirements (GfWR):

Characteristics of a well-formed needs and requirements statements:

- *Necessary*
- *Singular*
- *Conforming*
- *Appropriate*
- *Correct*
- *Unambiguous*
- *Complete*
- *Feasible*
- Verifiable
- *Able to be Validated*

Characteristics of a well-formed sets of needs and requirements:

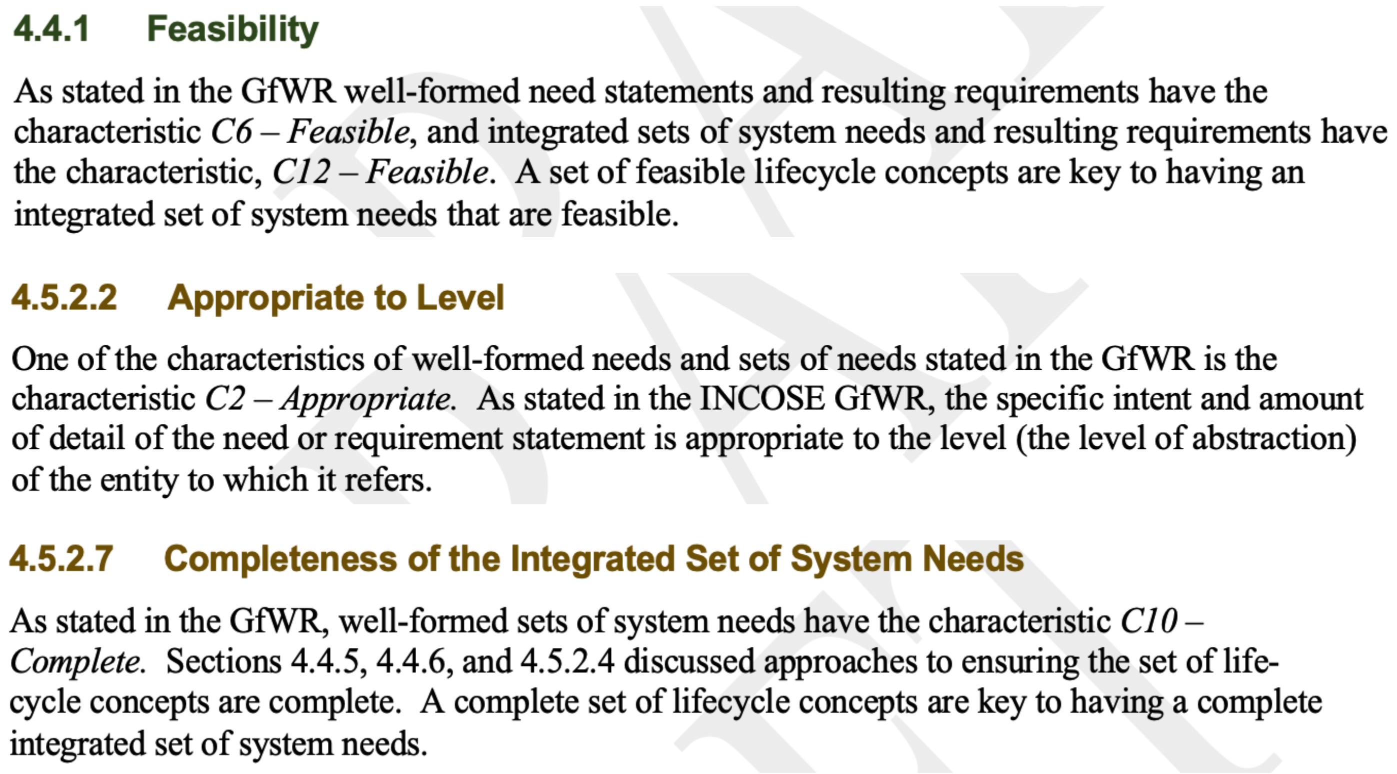
- *Complete*
- *Consistent*
- *Feasible*
- *Comprehensible*
- *Able to be validated*
- *Correct*

Characteristics in red are achieved more by the underlying analysis and maturation of knowledge than by following the rules in the GfWR for writing needs and requirement statements.

Underlying Concepts - Overview

The manual has tight traceability of concepts, activities, and artifacts to the characteristics in the GfWR.

"This activity helps establish the integrated set of system needs is complete."



4.4.1 Feasibility

As stated in the GfWR well-formed need statements and resulting requirements have the characteristic *C6 – Feasible*, and integrated sets of system needs and resulting requirements have the characteristic, *C12 – Feasible*. A set of feasible lifecycle concepts are key to having an integrated set of system needs that are feasible.

4.5.2.2 Appropriate to Level

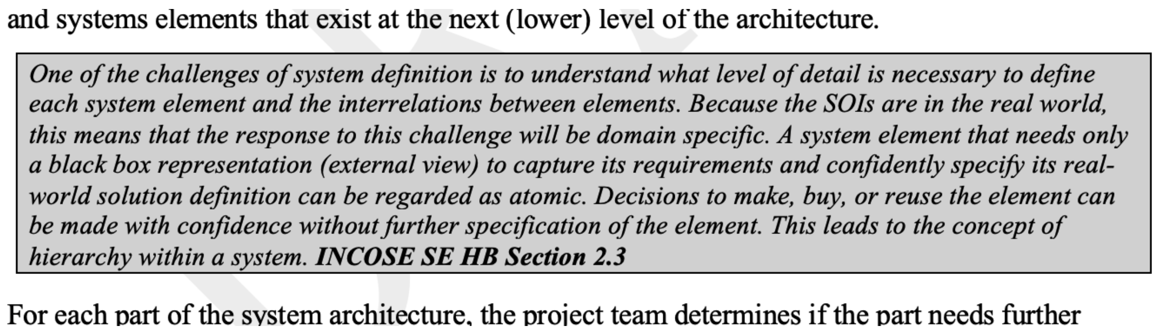
One of the characteristics of well-formed needs and sets of needs stated in the GfWR is the characteristic *C2 – Appropriate*. As stated in the INCOSE GfWR, the specific intent and amount of detail of the need or requirement statement is appropriate to the level (the level of abstraction) of the entity to which it refers.

4.5.2.7 Completeness of the Integrated Set of System Needs

As stated in the GfWR, well-formed sets of system needs have the characteristic *C10 – Complete*. Sections 4.4.5, 4.4.6, and 4.5.2.4 discussed approaches to ensuring the set of life-cycle concepts are complete. A complete set of lifecycle concepts are key to having a complete integrated set of system needs.

Underlying Concepts - Overview

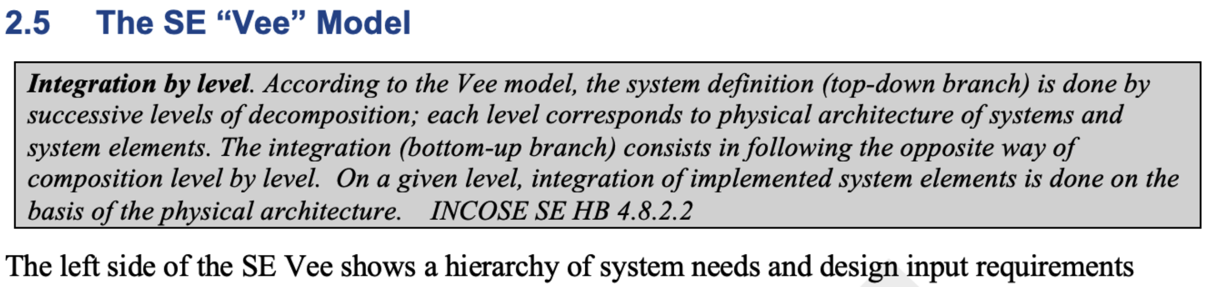
- The manual also has tight traceability of concepts, activities, and artifacts to the INCOSE SE HB.



and systems elements that exist at the next (lower) level of the architecture.

> *One of the challenges of system definition is to understand what level of detail is necessary to define each system element and the interrelations between elements. Because the SOIs are in the real world, this means that the response to this challenge will be domain specific. A system element that needs only a black box representation (external view) to capture its requirements and confidently specify its real-world solution definition can be regarded as atomic. Decisions to make, buy, or reuse the element can be made with confidence without further specification of the element. This leads to the concept of hierarchy within a system.* ***INCOSE SE HB Section 2.3***

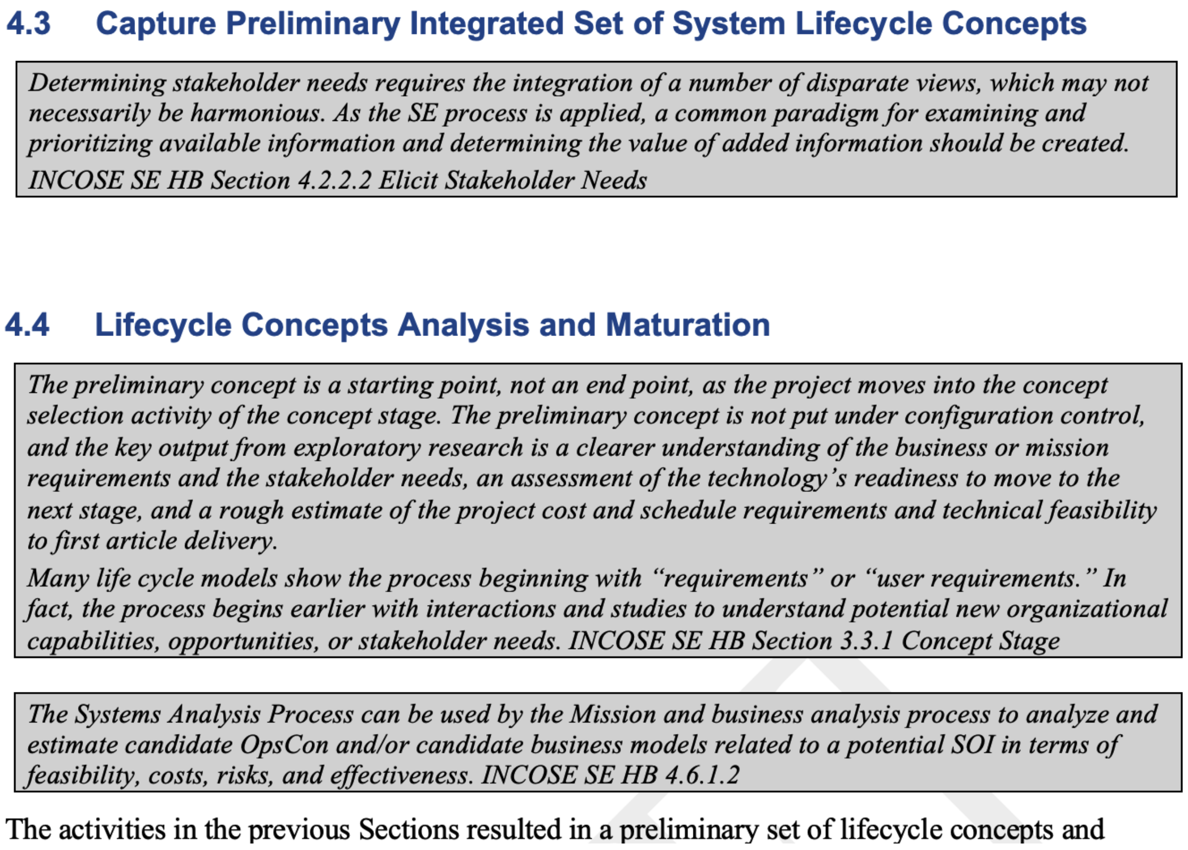
For each part of the system architecture, the project team determines if the part needs further



2.5 The SE "Vee" Model

> ***Integration by level***. *According to the Vee model, the system definition (top-down branch) is done by successive levels of decomposition; each level corresponds to physical architecture of systems and system elements. The integration (bottom-up branch) consists in following the opposite way of composition level by level. On a given level, integration of implemented system elements is done on the basis of the physical architecture. INCOSE SE HB 4.8.2.2*

The left side of the SE Vee shows a hierarchy of system needs and design input requirements



4.3 Capture Preliminary Integrated Set of System Lifecycle Concepts

> *Determining stakeholder needs requires the integration of a number of disparate views, which may not necessarily be harmonious. As the SE process is applied, a common paradigm for examining and prioritizing available information and determining the value of added information should be created.*
>
> *INCOSE SE HB Section 4.2.2.2 Elicit Stakeholder Needs*

4.4 Lifecycle Concepts Analysis and Maturation

> *The preliminary concept is a starting point, not an end point, as the project moves into the concept selection activity of the concept stage. The preliminary concept is not put under configuration control, and the key output from exploratory research is a clearer understanding of the business or mission requirements and the stakeholder needs, an assessment of the technology's readiness to move to the next stage, and a rough estimate of the project cost and schedule requirements and technical feasibility to first article delivery.*
>
> *Many life cycle models show the process beginning with "requirements" or "user requirements." In fact, the process begins earlier with interactions and studies to understand potential new organizational capabilities, opportunities, or stakeholder needs. INCOSE SE HB Section 3.3.1 Concept Stage*

> *The Systems Analysis Process can be used by the Mission and business analysis process to analyze and estimate candidate OpsCon and/or candidate business models related to a potential SOI in terms of feasibility, costs, risks, and effectiveness. INCOSE SE HB 4.6.1.2*

The activities in the previous Sections resulted in a preliminary set of lifecycle concepts and

Reducing Ambiguity

Reducing ambiguity

From the Guide for Writing Requirements: **C3 – UNAMBIGUOUS:**

- Need statements must be written such that the stakeholder intent is clear.
- Requirement statements must be stated such that the requirement can be interpreted in only one way by all the intended readers.
- A need or requirement statement must lend itself to a single interpretation of intent.
- Ambiguity leads to multiple interpretations such that the stakeholder expectations may not be met.
- The intent of a need or requirement must be understood in the same way by the writer, the designer, and those doing verification and validation activities following the "reasonable person" guideline.
- Ambiguity leads to interpretations of a need or requirement not intended by the author, and thence to ensuing problems, including project delay and even perhaps litigation and financial loss.

Shouldn't this apply to everything we communicate?

Reducing ambiguity

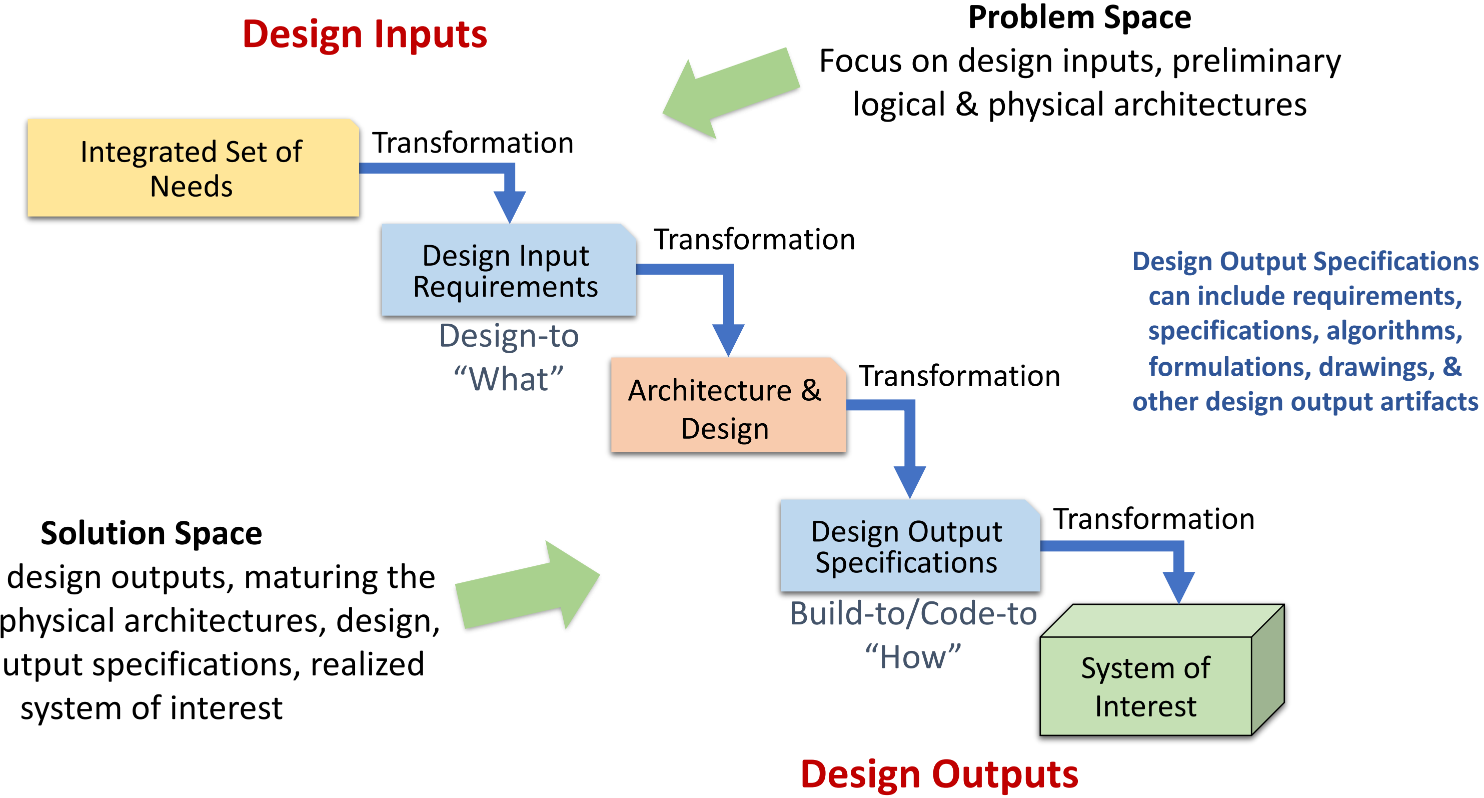
- Inconsistent use of terms
  - Stakeholder needs, user needs, stakeholder expectations, stakeholder requirements, system requirements, technical requirements?
  - Stakeholder requirements vs Stakeholder-owned requirements
  - Requirements vs. specifications
  - Design inputs vs design outputs
  - Verification vs Validation
- Inconsistent naming of the various needs, requirements, and management processes

Reducing ambiguity

Design inputs vs design outputs

Requirements vs. specifications

To reduce ambiguity, the manual refers to requirements as design inputs and specifications as part of the design output artifacts.

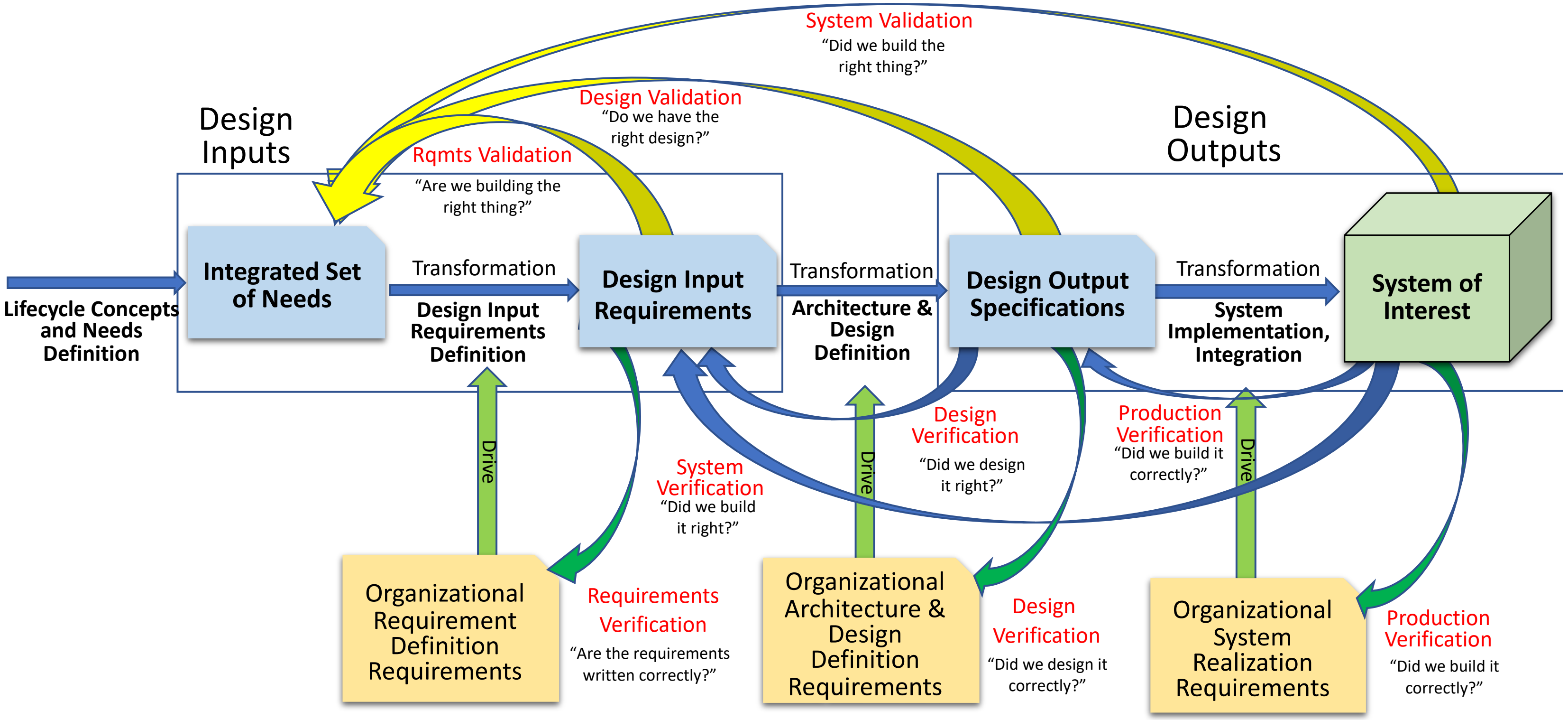


Problem Space
Focus on design inputs, preliminary logical & physical architectures

Design Output Specifications can include requirements, specifications, algorithms, formulations, drawings, & other design output artifacts

Solution Space
Focus on design outputs, maturing the logical & physical architectures, design, design output specifications, realized system of interest

Reducing ambiguity


System Validation
"Did we build the right thing?"
Design Validation
"Do we have the right design?"
Rqmts Validation
"Are we building the right thing?"
Design Inputs
Design Outputs
Lifecycle Concepts and Needs Definition
Integrated Set of Needs
Transformation
Design Input Requirements Definition
Design Input Requirements
Transformation
Architecture & Design Definition
Design Output Specifications
Transformation
System Implementation, Integration
System of Interest
Drive
Drive
Drive
System Verification
"Did we build it right?"
Design Verification
"Did we design it right?"
Production Verification
"Did we build it correctly?"
Organizational Requirement Definition Requirements
Requirements Verification
"Are the requirements written correctly?"
Organizational Architecture & Design Definition Requirements
Design Verification
"Did we design it correctly?"
Organizational System Realization Requirements
Production Verification
"Did we build it correctly?"

Derived from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017

Verification & Validation in Context

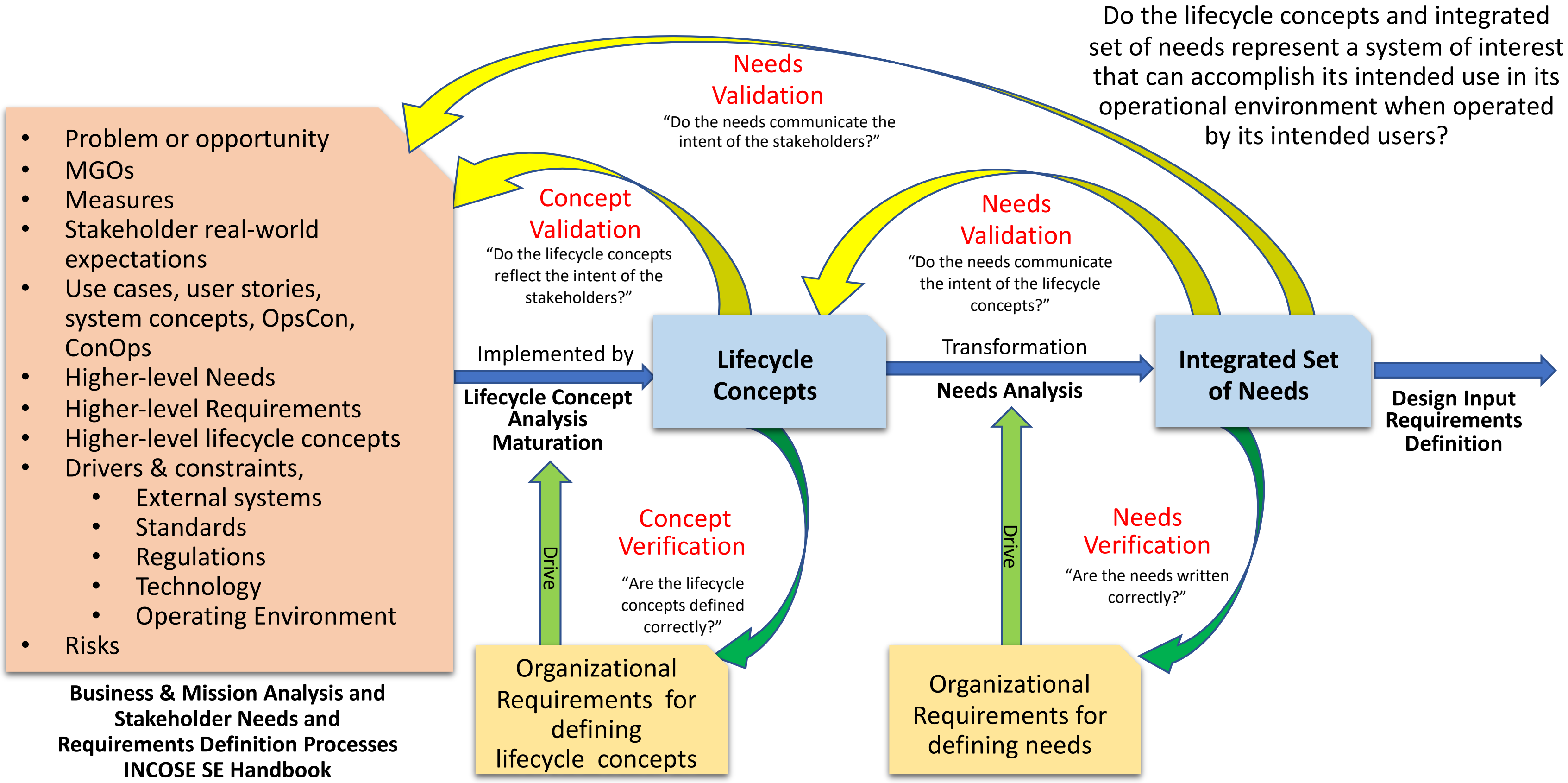
- Verifying requirements vs verifying a system meets the requirements
- Validating needs vs validating a system meets needs
- Requirements Verification vs System Verification

We validate the SOI against the needs, not requirements.

Lifecycle Concepts and Needs Definition

Lifecycle Concept Verification and Validation

Needs Verification and Validation


Do the lifecycle concepts and integrated set of needs represent a system of interest that can accomplish its intended use in its operational environment when operated by its intended users?
Needs Validation
"Do the needs communicate the intent of the stakeholders?"
Problem or opportunity
MGOs
Measures
Stakeholder real-world expectations
Use cases, user stories, system concepts, OpsCon, ConOps
Higher-level Needs
Higher-level Requirements
Higher-level lifecycle concepts
Drivers & constraints,
External systems
Standards
Regulations
Technology
Operating Environment
Risks
Business & Mission Analysis and Stakeholder Needs and Requirements Definition Processes INCOSE SE Handbook
Concept Validation
"Do the lifecycle concepts reflect the intent of the stakeholders?"
Implemented by
Lifecycle Concept Analysis Maturation
Lifecycle Concepts
Needs Validation
"Do the needs communicate the intent of the lifecycle concepts?"
Transformation
Needs Analysis
Integrated Set of Needs
Design Input Requirements Definition
Drive
Concept Verification
"Are the lifecycle concepts defined correctly?"
Drive
Needs Verification
"Are the needs written correctly?"
Organizational Requirements for defining lifecycle concepts
Organizational Requirements for defining needs

Reducing ambiguity

What is meant when we say “Requirements”?

- ***project requirements*** on a project and organizational elements within the enterprise that will be recorded in a project management plan and other plans?
- ***supplier requirements*** that will be recorded in Supplier Agreements (SA) and Statements of Work (SOW)?
- ***design input requirements*** (aka “the requirements”) that communicate what the SOI must do to meet the integrated set of system needs they were transformed from?
- ***design output specifications*** (aka “the design characteristics”) that communicate the design outputs to those that will build or code the SOI?
- **Verification and validation requirements** that communicate what must be included within the verification and validatiopn procedures?

Each has its own purpose and place and should be kept separate and distinct

Reducing ambiguity

- Rather than just “Requirements Definition and Management”

- We should think and say “Needs and Requirements Definition & Management”

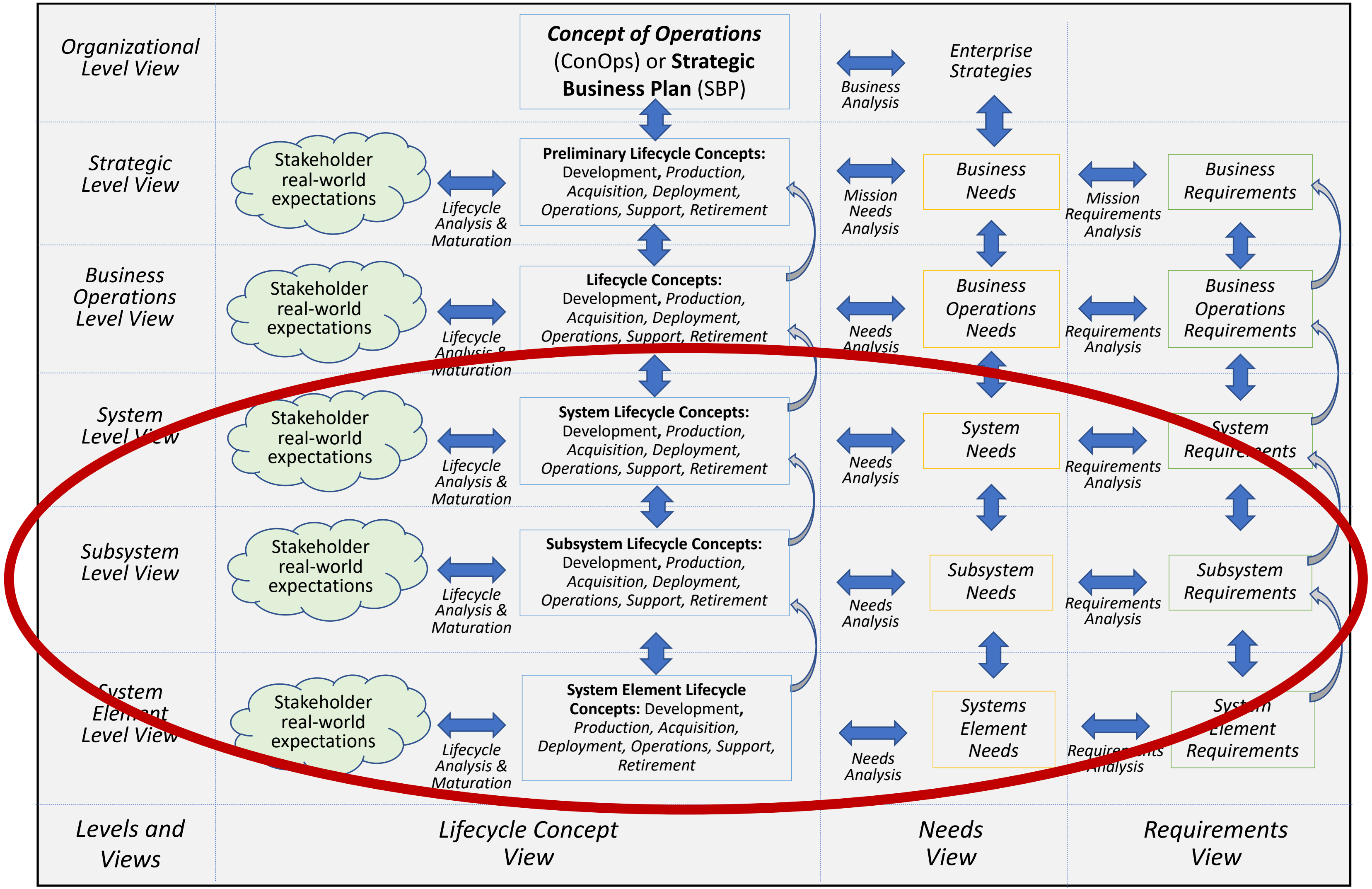
Each are equally important!

Failing to recognize needs, leads to a failure to address system validation

Needs and Requirements Working Group ??????

Needs and Requirements Engineer??

Reducing ambiguity



Levels and Views	Lifecycle Concept View			Needs View		Requirements View	
Organizational Level View			**Concept of Operations** (ConOps) or **Strategic Business Plan** (SBP)	Business Analysis	Enterprise Strategies		
Strategic Level View	Stakeholder real-world expectations	Lifecycle Analysis & Maturation	**Preliminary Lifecycle Concepts:** Development, Production, Acquisition, Deployment, Operations, Support, Retirement	Mission Needs Analysis	Business Needs	Mission Requirements Analysis	Business Requirements
Business Operations Level View	Stakeholder real-world expectations	Lifecycle Analysis & Maturation	**Lifecycle Concepts:** Development, Production, Acquisition, Deployment, Operations, Support, Retirement	Needs Analysis	Business Operations Needs	Requirements Analysis	Business Operations Requirements
System Level View	Stakeholder real-world expectations	Lifecycle Analysis & Maturation	**System Lifecycle Concepts:** Development, Production, Acquisition, Deployment, Operations, Support, Retirement	Needs Analysis	System Needs	Requirements Analysis	System Requirements
Subsystem Level View	Stakeholder real-world expectations	Lifecycle Analysis & Maturation	**Subsystem Lifecycle Concepts:** Development, Production, Acquisition, Deployment, Operations, Support, Retirement	Needs Analysis	Subsystem Needs	Requirements Analysis	Subsystem Requirements
System Element Level View	Stakeholder real-world expectations	Lifecycle Analysis & Maturation	**System Element Lifecycle Concepts:** Development, Production, Acquisition, Deployment, Operations, Support, Retirement	Needs Analysis	Systems Element Needs	Requirements Analysis	System Element Requirements

Stakeholders exist at all levels

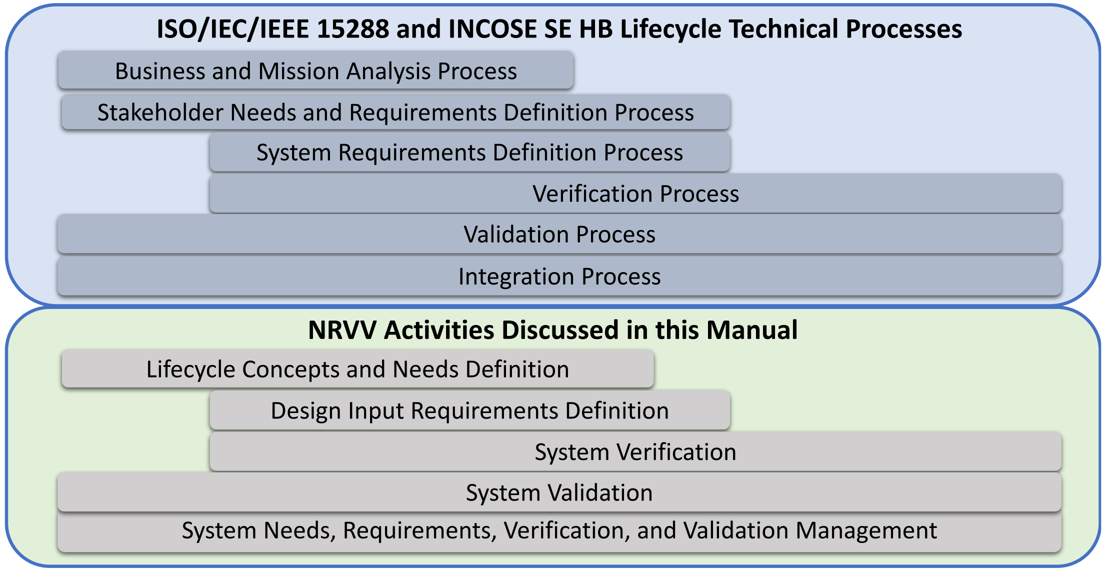
Stakeholders have real-world expectations that drive the development of systems

Focus in this Manual

Triad of lifecycle concepts, needs, and requirements

Reducing ambiguity

- Naming of the various process areas
  - PMI, SEI, CMMI
    - Requirements Development
    - Requirements Management
  - ISO/IEC/IEEE 15288, INCOSE SE HB
    - Business Analysis
    - Stakeholder Needs and Requirements
    - System Requirements
    - Multiple Technical Management Process Areas
  - NASA NPR 7123 and SE HB
    - Stakeholder Expectation Definition
    - Technical Requirements Definition
    - Requirements Management



ISO/IEC/IEEE 15288 and INCOSE SE HB Lifecycle Technical Processes

Business and Mission Analysis Process

Stakeholder Needs and Requirements Definition Process

System Requirements Definition Process

Verification Process

Validation Process

Integration Process

NRVV Activities Discussed in this Manual

Lifecycle Concepts and Needs Definition

Design Input Requirements Definition

System Verification

System Validation

System Needs, Requirements, Verification, and Validation Management

The Manual focus is on elaboration of activities performed within the technical process areas.

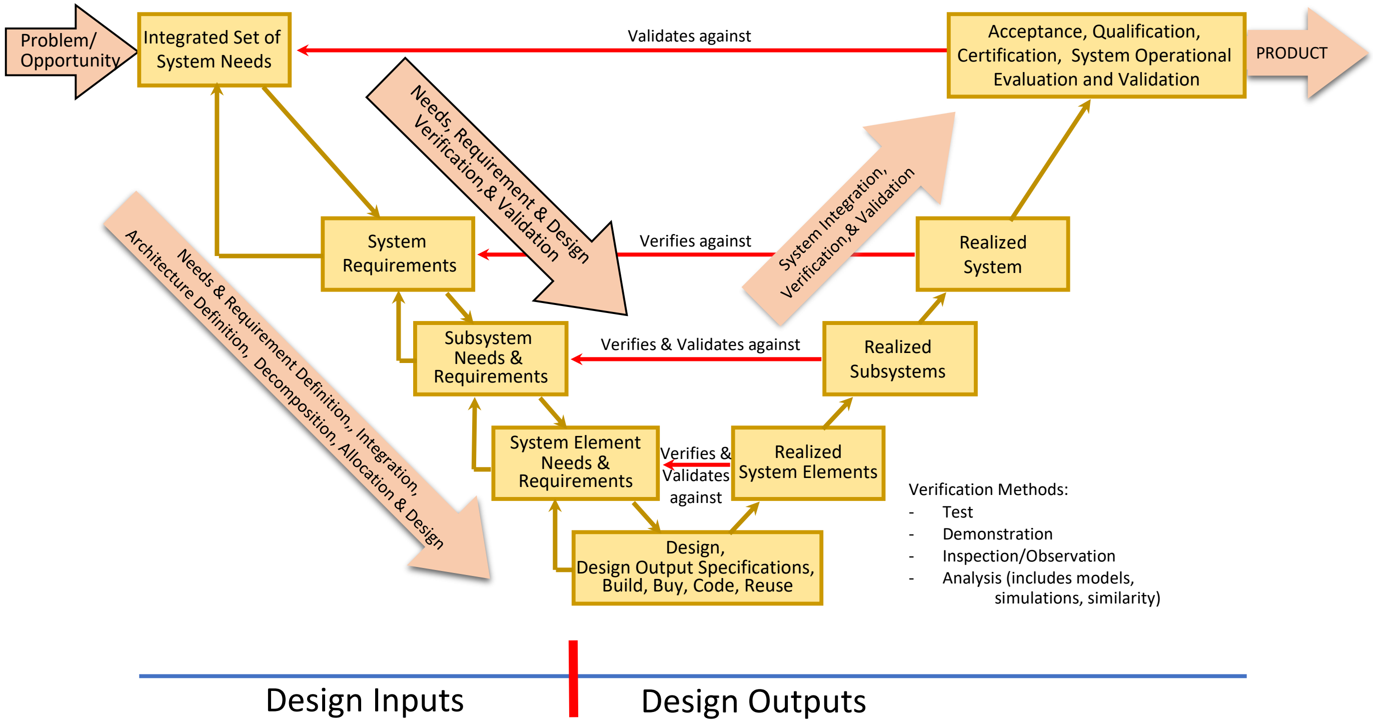
Activity Areas discussed in this Manual

- Lifecycle Concepts and Needs Definition (Sections 4 & 5)
- Design Input Requirements Definition (Section 6 & 7)
- Design Verification & Validation (Section 8)
- Production Verification (Section 9)
- System Verification (Sections 10 & 11)
- System Validation (Sections 10 & 11)
- Needs, Design Input Requirements, and System V&V Management (Section 14)

The SE Vee – Left-side vs Right-side

The SE Vee – Left-side vs Right-side

- Left-side
  - Needs definition & Needs Verification and Validation
  - Requirements definition & Requirements Verification and Validation
  - Integration
  - Architecture definition
  - Decomposition
  - Functional, Architecture, Behavior Modeling
  - Allocation
  - Budgeting
  - Traceability
  - Parent/child relationships
  - Design & Design Verification and Validation
  - Early Verification and Validation
  - Design output specifications

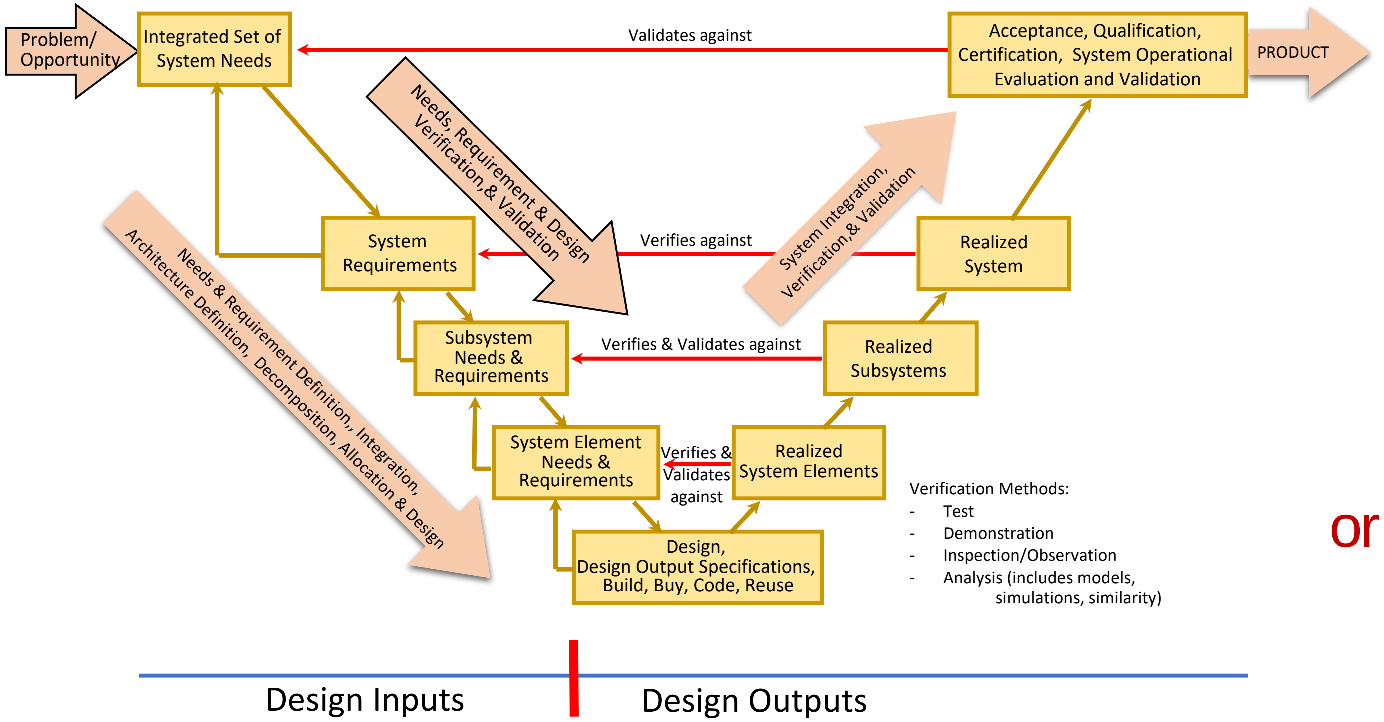


Problem/ Opportunity
Integrated Set of System Needs
Validates against
Acceptance, Qualification, Certification, System Operational Evaluation and Validation
PRODUCT
Needs, Requirement & Design Verification,& Validation
System Integration, Verification,& Validation
System Requirements
Verifies against
Realized System
Subsystem Needs & Requirements
Verifies & Validates against
Realized Subsystems
Needs & Requirement Definition,, Integration, Architecture Definition, Decomposition, Allocation & Design
System Element Needs & Requirements
Verifies & Validates against
Realized System Elements
Design, Design Output Specifications, Build, Buy, Code, Reuse
Design Inputs
Design Outputs

Verification Methods:
- Test
- Demonstration
- Inspection/Observation
- Analysis (includes models, simulations, similarity)

Adapted from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017 and INCOSE SE HB, Version 4, Figures 4.15 & 4.19

The SE Vee – Left-side vs Right-side



Problem/ Opportunity

Integrated Set of System Needs

Validates against

Acceptance, Qualification, Certification, System Operational Evaluation and Validation

PRODUCT

Needs, Requirement & Design Verification, & Validation

System Integration, Verification, & Validation

System Requirements

Verifies against

Realized System

Subsystem Needs & Requirements

Verifies & Validates against

Realized Subsystems

Needs & Requirement Definition, Integration, Architecture Definition, Decomposition, Allocation & Design

System Element Needs & Requirements

Verifies & Validates against

Realized System Elements

Design, Design Output Specifications, Build, Buy, Code, Reuse

Verification Methods:

- Test
- Demonstration
- Inspection/Observation
- Analysis (includes models, simulations, similarity)

Design Inputs

Design Outputs

Adapted from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017 and INCOSE SE HB, Version 4, Figures 4.15 & 4.19

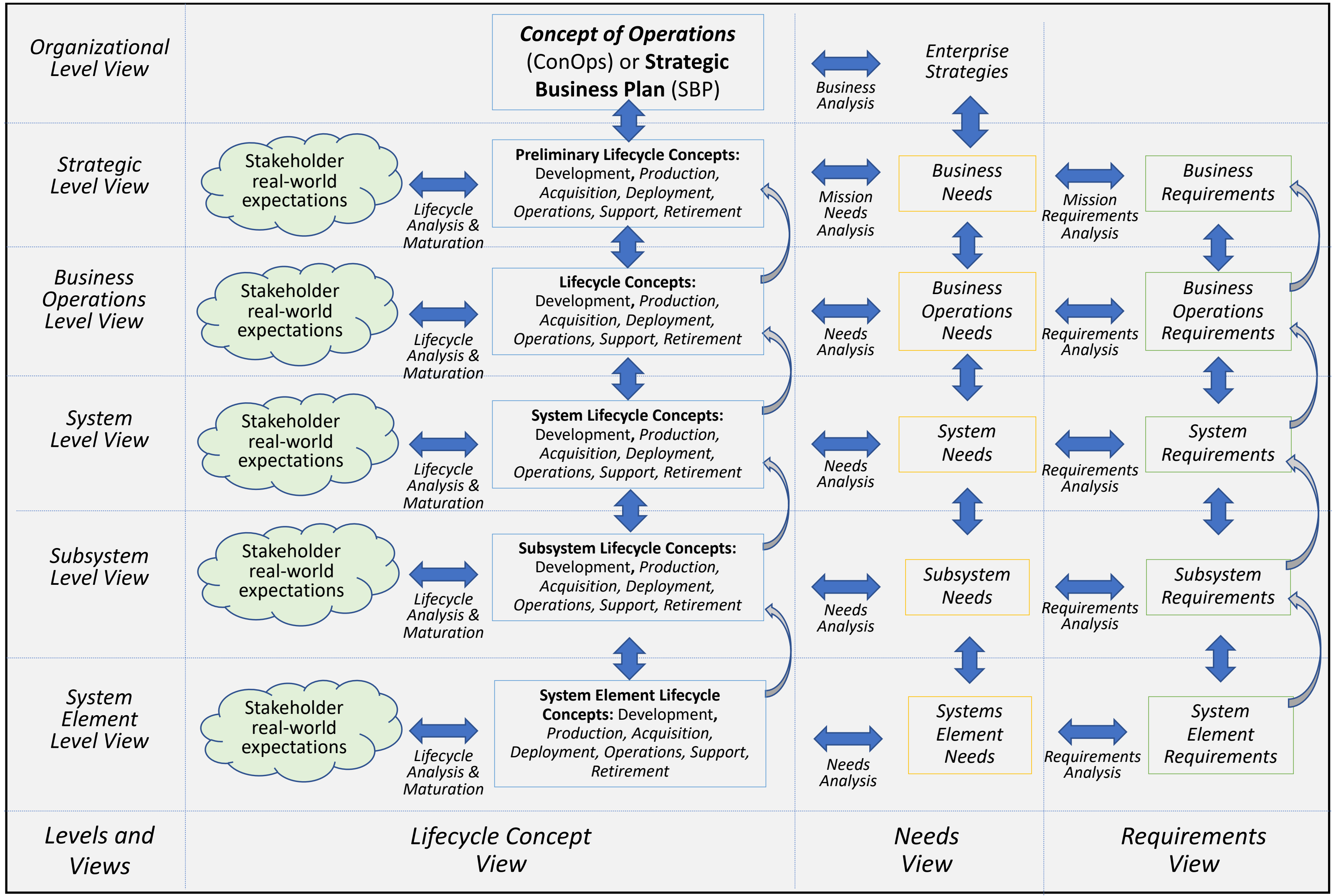
- Right-side
  - Realized physical system elements, subsystems, and the integrated SOI
  - System Verification
  - System Validation
  - System Integration

There are no needs, requirements, parent/child relationships, or models on the right side of the SE Vee

System elements, subsystems, and the integrated SOI are verified and validated against the needs and requuirements defined on the left side of the SE Vee

Organizational levels vs architectural levels

Organizational Levels vs Architectural Levels



Levels and Views	*Lifecycle Concept View*				*Needs View*		*Requirements View*
Organizational Level View			***Concept of Operations*** (ConOps) or **Strategic Business Plan** (SBP)	*Business Analysis*	*Enterprise Strategies*		
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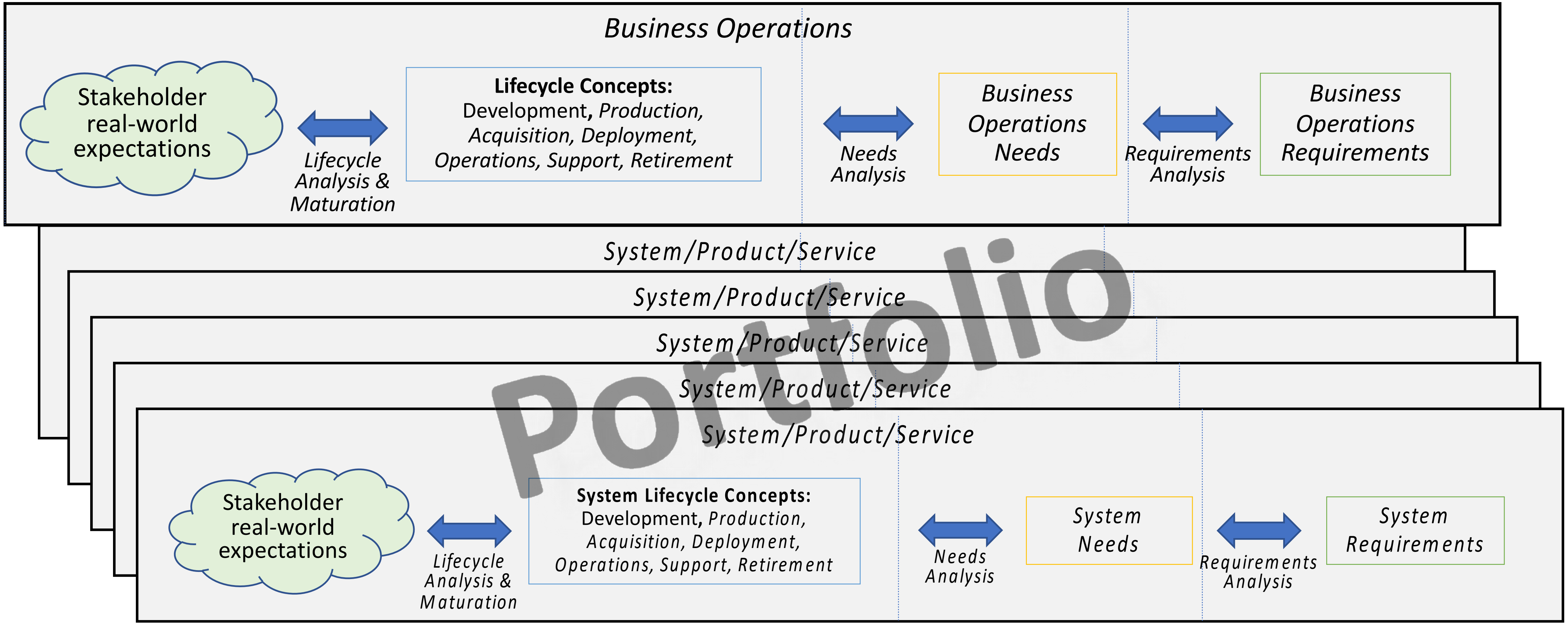
Subsystem Level View	Stakeholder real-world expectations	*Lifecycle Analysis & Maturation*	**Subsystem Lifecycle Concepts:** Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*	*Needs Analysis*	*Subsystem Needs*	*Requirements Analysis*	*Subsystem Requirements*
System Element Level View	Stakeholder real-world expectations	*Lifecycle Analysis & Maturation*	**System Element Lifecycle Concepts:** Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*	*Needs Analysis*	*Systems Element Needs*	*Requirements Analysis*	*System Element Requirements*

Limited discussion in 15288 and SE HB

The Manual provides detailed elaboration on levels

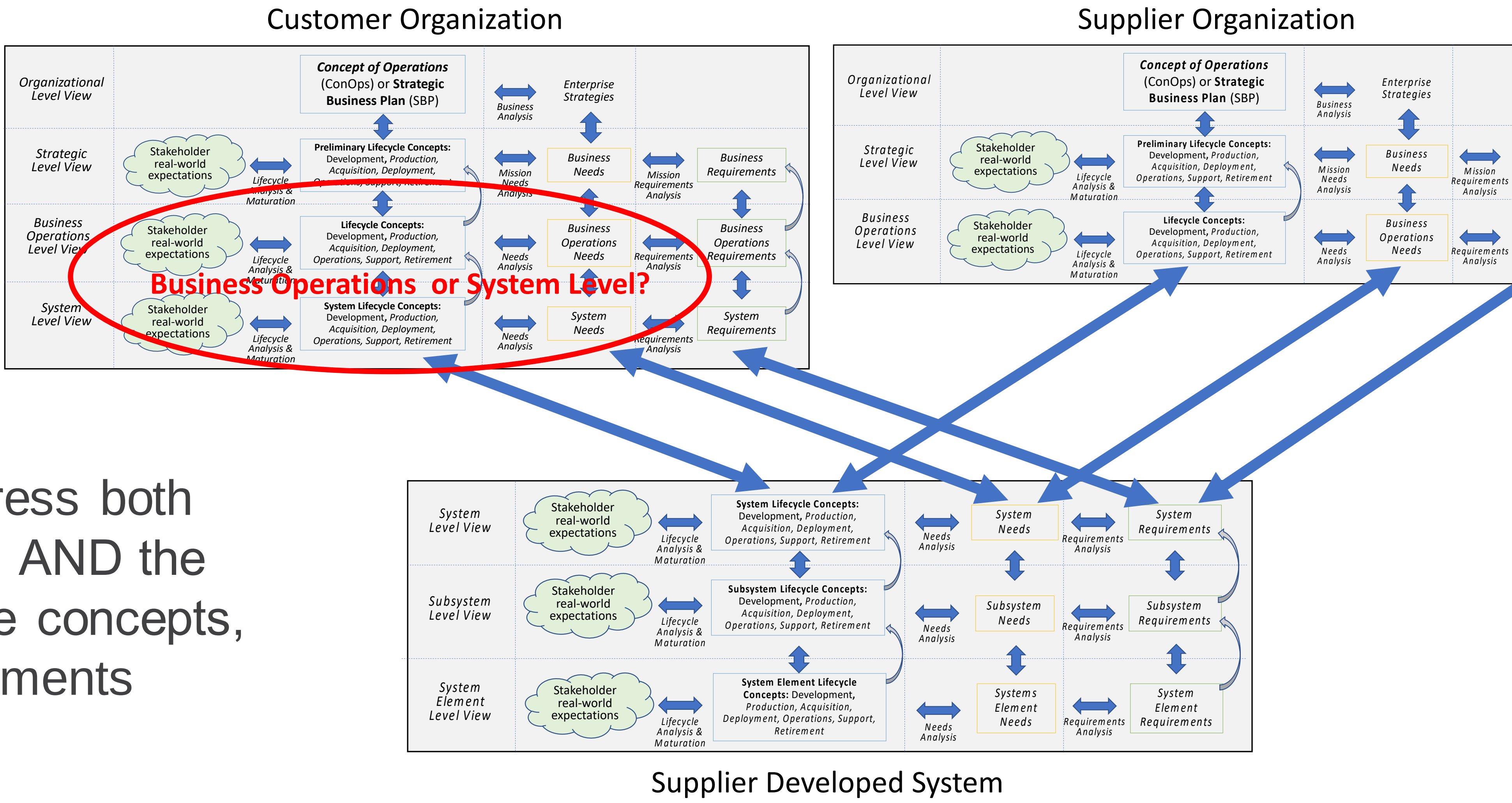
Triad of lifecycle concepts, needs, and requirements at each level

Operational Level Expanded


Business Operations
Stakeholder real-world expectations
Lifecycle Analysis & Maturation
Lifecycle Concepts: Development, Production, Acquisition, Deployment, Operations, Support, Retirement
Needs Analysis
Business Operations Needs
Requirements Analysis
Business Operations Requirements
System/Product/Service
System/Product/Service
System/Product/Service
System/Product/Service
System/Product/Service
Portfolio
Stakeholder real-world expectations
Lifecycle Analysis & Maturation
System Lifecycle Concepts: Development, Production, Acquisition, Deployment, Operations, Support, Retirement
Needs Analysis
System Needs
Requirements Analysis
System Requirements

Portfolio of products and services

Supplier Developed Systems



Customer Organization

Organizational Level View

Concept of Operations (ConOps) or **Strategic Business Plan** (SBP)

Business Analysis

Enterprise Strategies

Strategic Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

Preliminary Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Mission Needs Analysis

Business Needs

Mission Requirements Analysis

Business Requirements

Business Operations Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Needs Analysis

Business Operations Needs

Requirements Analysis

Business Operations Requirements

Business Operations or System Level?

System Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

System Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Needs Analysis

System Needs

Requirements Analysis

System Requirements

Supplier Organization

Organizational Level View

Concept of Operations (ConOps) or **Strategic Business Plan** (SBP)

Business Analysis

Enterprise Strategies

Strategic Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

Preliminary Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Mission Needs Analysis

Business Needs

Mission Requirements Analysis

Business Operations Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Needs Analysis

Business Operations Needs

Requirements Analysis

System Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

System Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Needs Analysis

System Needs

Requirements Analysis

System Requirements

Subsystem Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

Subsystem Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Needs Analysis

Subsystem Needs

Requirements Analysis

Subsystem Requirements

System Element Level View

Stakeholder real-world expectations

Lifecycle Analysis & Maturation

System Element Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Needs Analysis

Systems Element Needs

Requirements Analysis

System Element Requirements

Supplier Developed System

Supplier must address both their organization's AND the customer's lifecycle concepts, needs, and requirements

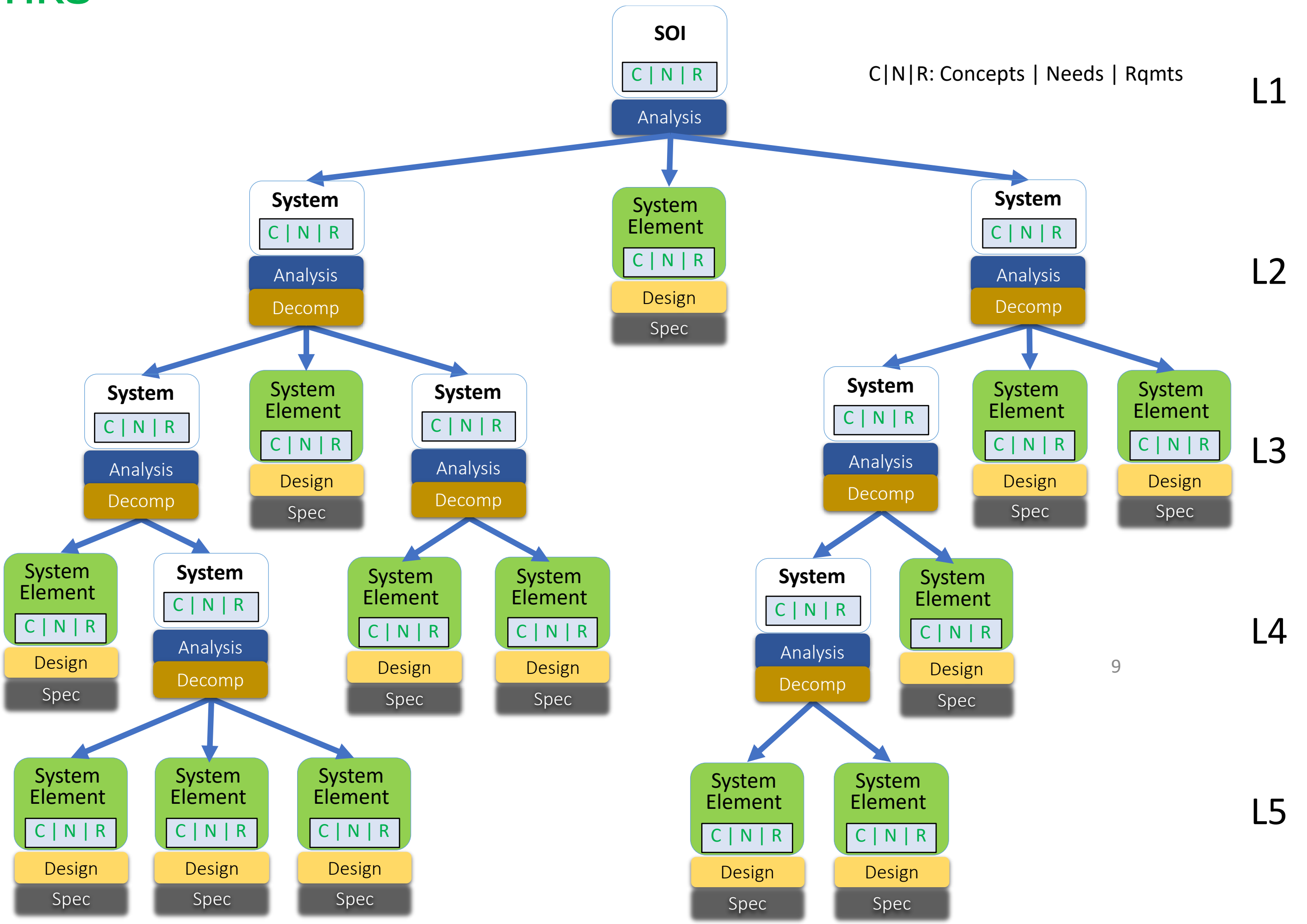
Levels of a System – Hierarchical View

Focus on decomposition making it easier to develop the SOI in bite sized chunks across multiple organizational units (internal and external) based on specialize knowledge and expertise

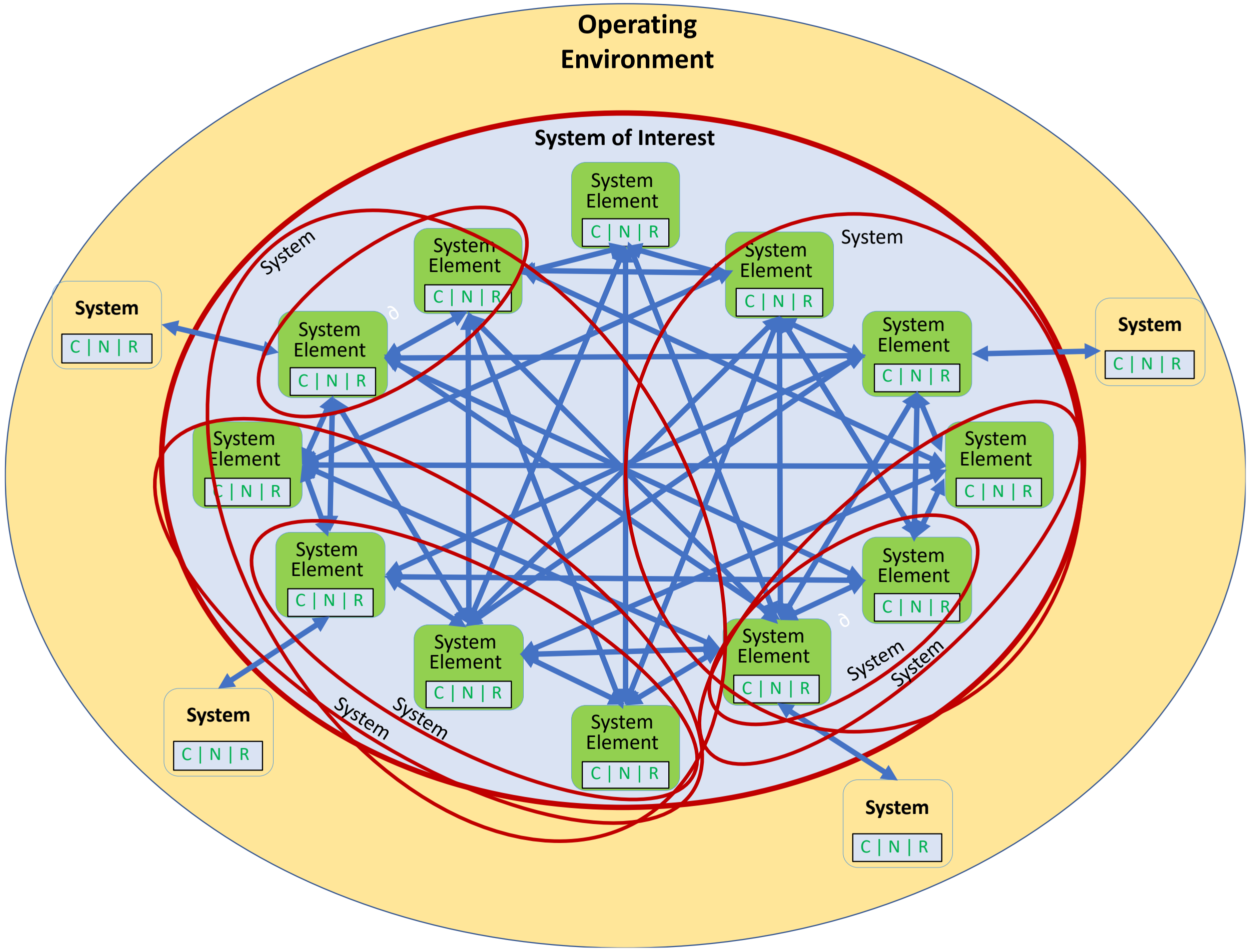
Interactions (Interfaces) not shown in this view

Focus tends to be more on the systems and system elements that make up the SOI than the integrated SOI

Leads to development in silos and system and system optimization rather than optimization of the integrated SOI



Holistic View of the SOI



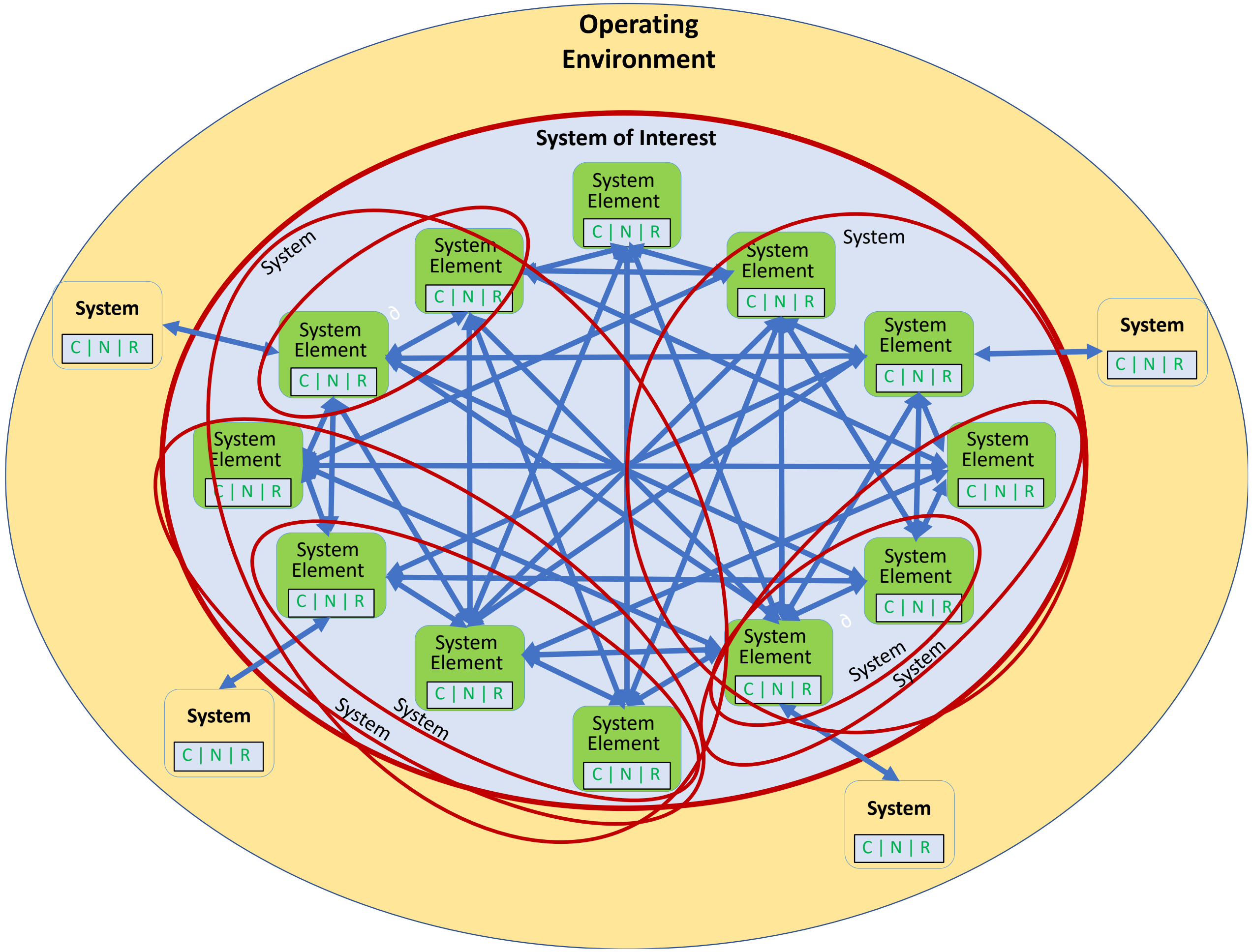
Focus on behavior and emerging properties of the integrated SOI based on interactions between the systems and system elements that make up the SOI, as well as interactions with external systems and the operational environment.

To optimize the integrated SOI, systems and system elements within its architecture may not be optimized.

Holist View of System Validation

System Validation is more than just validating the system meets the needs.

The **ultimate purpose** of system validation is to identify and assess the behavior and emerging properties of the realized physical, integrated SOI in its actual operational environment by its intended users and validates that the SOI does not enable/allow unintended users to negatively impact the intended use of the system.

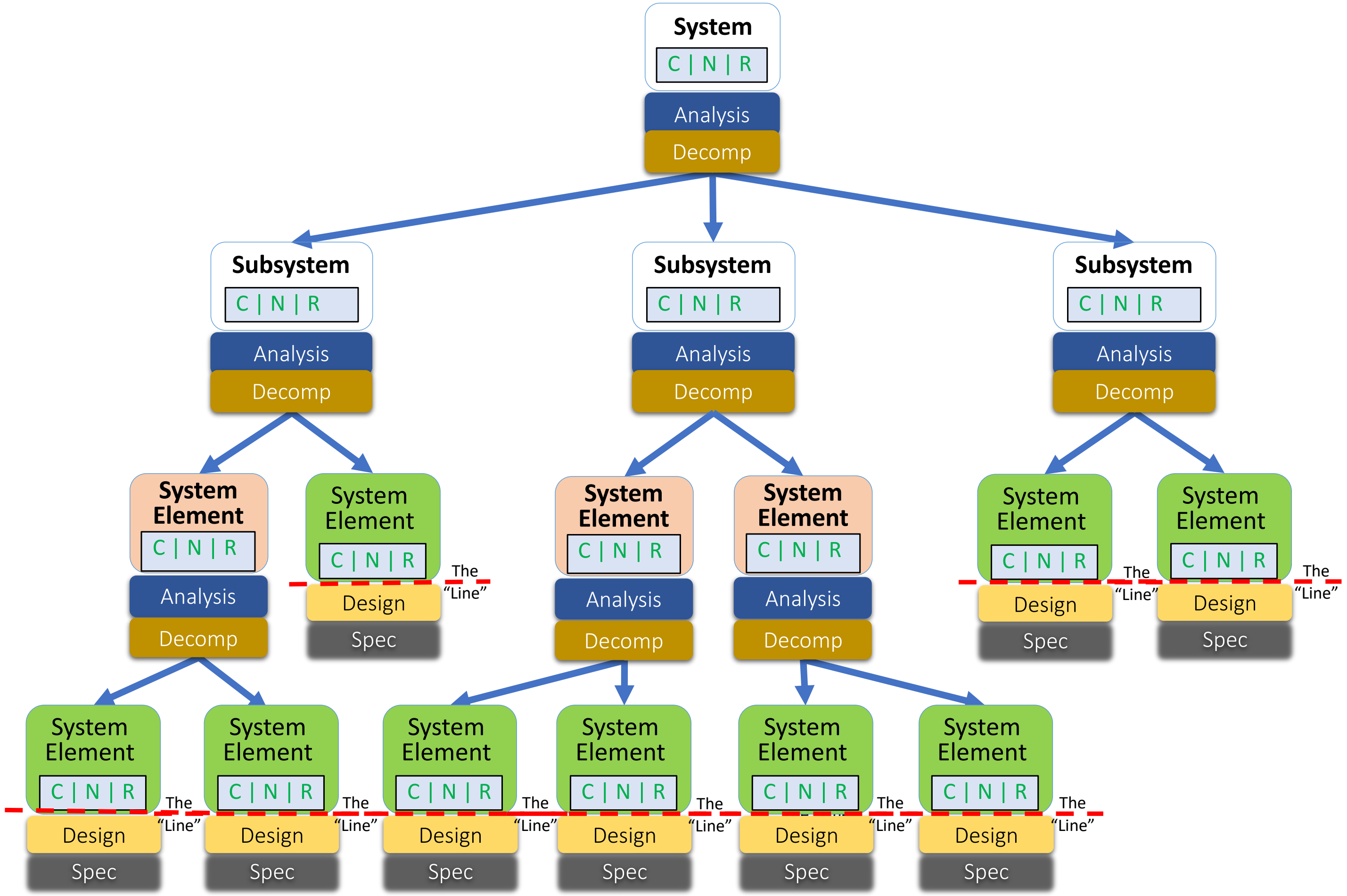


The Concept of "The Line"

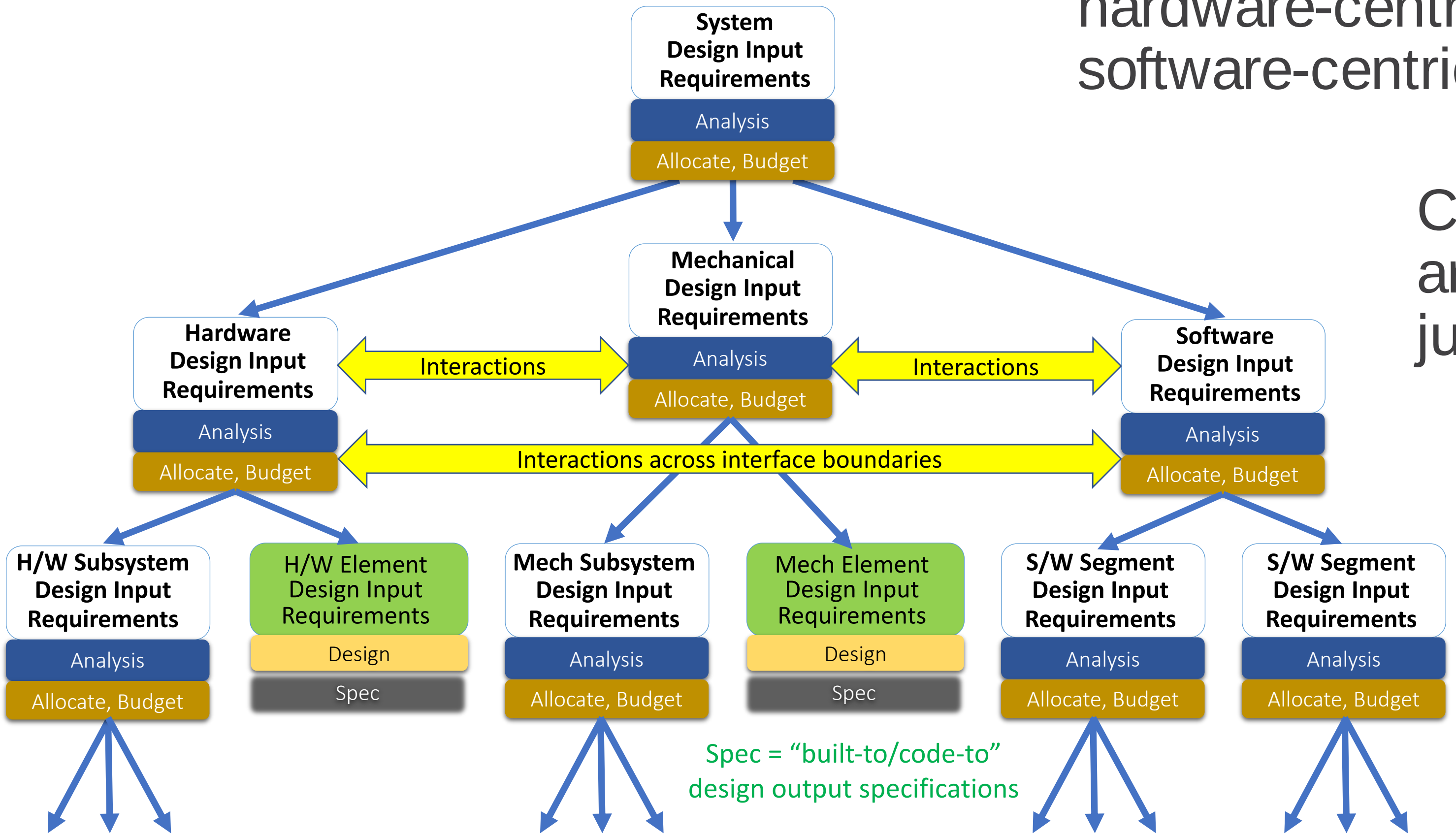
A SOI is decomposed into sub systems and system elements.

Systems are further decomposed by the developing organization into lower-level systems and system elements.

Decomposition by the developing organization ends when all that are left are system elements that will not be further decomposed and a build, code, buy, or reuse decision is made – "The Line".



Architecture for software-centric systems


System Design Input Requirements
Analysis
Allocate, Budget
Hardware Design Input Requirements
Analysis
Allocate, Budget
Interactions
Mechanical Design Input Requirements
Analysis
Allocate, Budget
Interactions
Software Design Input Requirements
Analysis
Allocate, Budget
Interactions across interface boundaries
H/W Subsystem Design Input Requirements
Analysis
Allocate, Budget
H/W Element Design Input Requirements
Design
Spec
Mech Subsystem Design Input Requirements
Analysis
Allocate, Budget
Mech Element Design Input Requirements
Design
Spec
S/W Segment Design Input Requirements
Analysis
Allocate, Budget
S/W Segment Design Input Requirements
Analysis
Allocate, Budget

Spec = "built-to/code-to" design output specifications

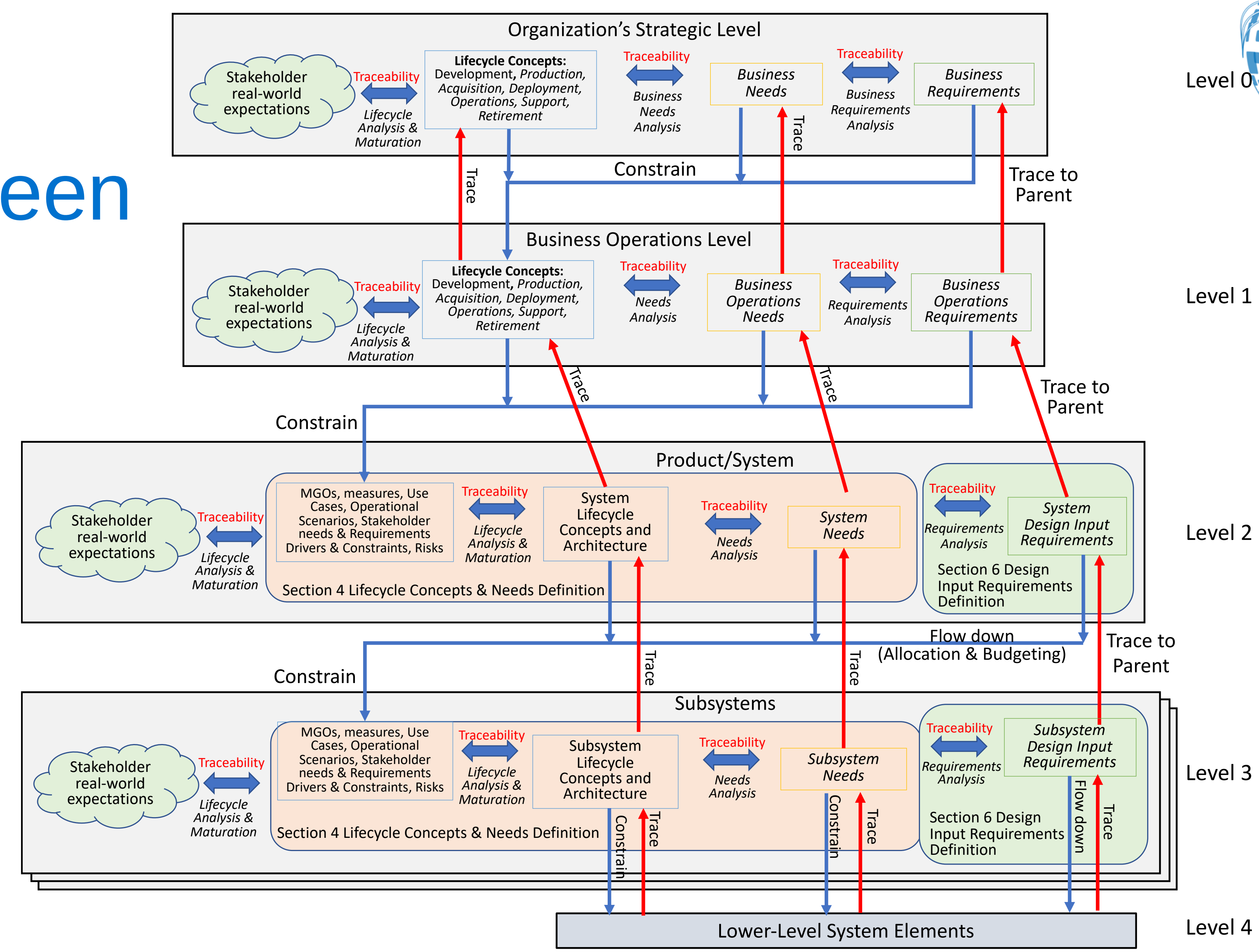
Classical decomposition and architecture for hardware-centric systems not well suited for software-centric systems.

Critical functionality and performance are in the software – the hardware is just a "wrapper".

SOI requirement allocations to software needs to be done at the first level of decomposition.

Enables software to be developed and managed as an integrated system.

Moving Between Levels



Organization's Strategic Level

Stakeholder real-world expectations

Traceability

Lifecycle Analysis & Maturation

Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Traceability

Business Needs Analysis

Business Needs

Traceability

Business Requirements Analysis

Business Requirements

Trace

Constrain

Trace

Trace to Parent

Level 0

Business Operations Level

Stakeholder real-world expectations

Traceability

Lifecycle Analysis & Maturation

Lifecycle Concepts: Development, *Production, Acquisition, Deployment, Operations, Support, Retirement*

Traceability

Needs Analysis

Business Operations Needs

Traceability

Requirements Analysis

Business Operations Requirements

Level 1

Trace

Trace

Constrain

Trace to Parent

Product/System

Stakeholder real-world expectations

Traceability

Lifecycle Analysis & Maturation

MGOs, measures, Use Cases, Operational Scenarios, Stakeholder needs & Requirements Drivers & Constraints, Risks

Traceability

Lifecycle Analysis & Maturation

System Lifecycle Concepts and Architecture

Traceability

Needs Analysis

System Needs

Section 4 Lifecycle Concepts & Needs Definition

Traceability

Requirements Analysis

System Design Input Requirements

Section 6 Design Input Requirements Definition

Level 2

Flow down (Allocation & Budgeting)

Trace

Trace

Constrain

Trace to Parent

Subsystems

Stakeholder real-world expectations

Traceability

Lifecycle Analysis & Maturation

MGOs, measures, Use Cases, Operational Scenarios, Stakeholder needs & Requirements Drivers & Constraints, Risks

Traceability

Lifecycle Analysis & Maturation

Subsystem Lifecycle Concepts and Architecture

Traceability

Needs Analysis

Subsystem Needs

Section 4 Lifecycle Concepts & Needs Definition

Traceability

Requirements Analysis

Subsystem Design Input Requirements

Section 6 Design Input Requirements Definition

Constrain

Trace

Constrain

Trace

Flow down

Trace

Level 3

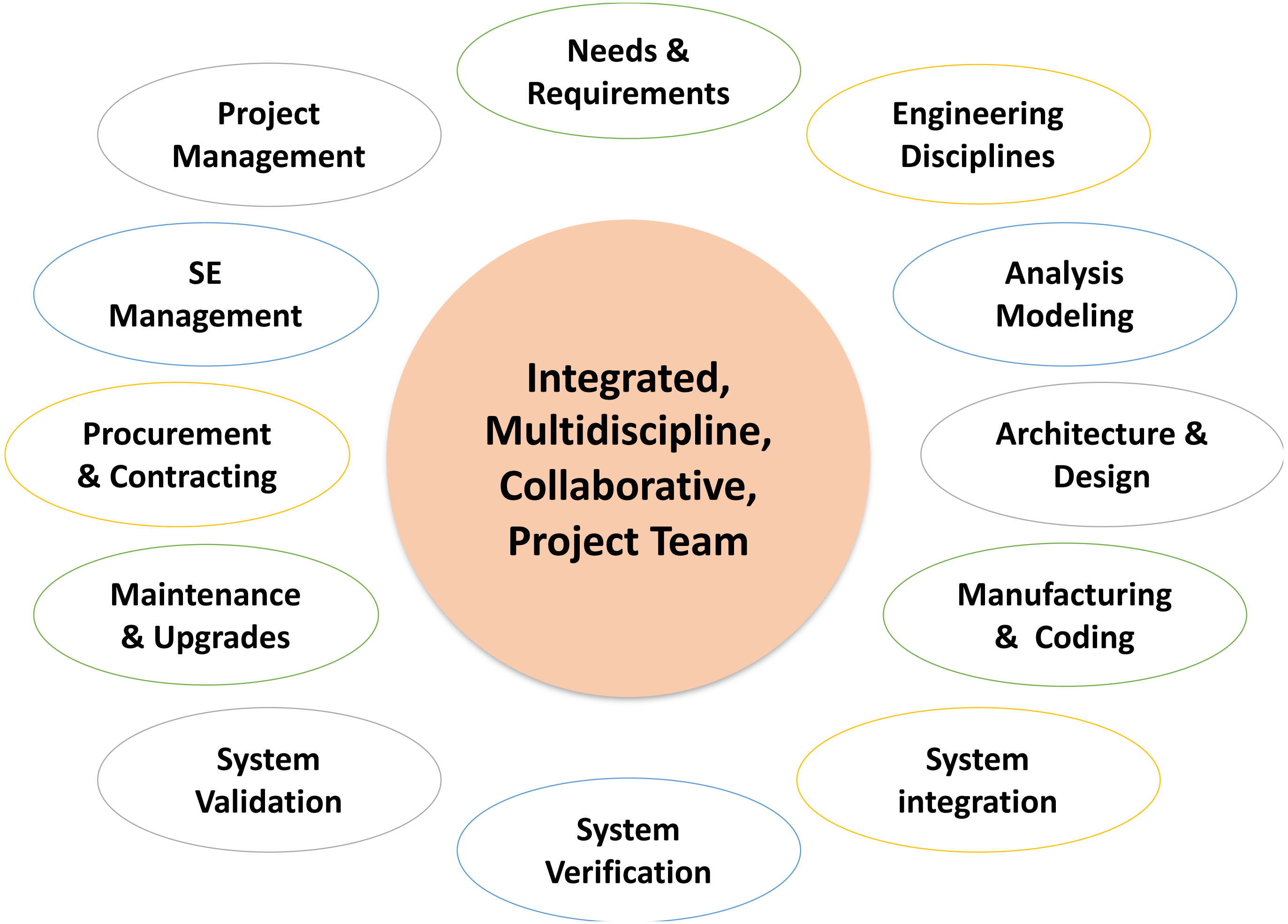
Lower-Level System Elements

Level 4

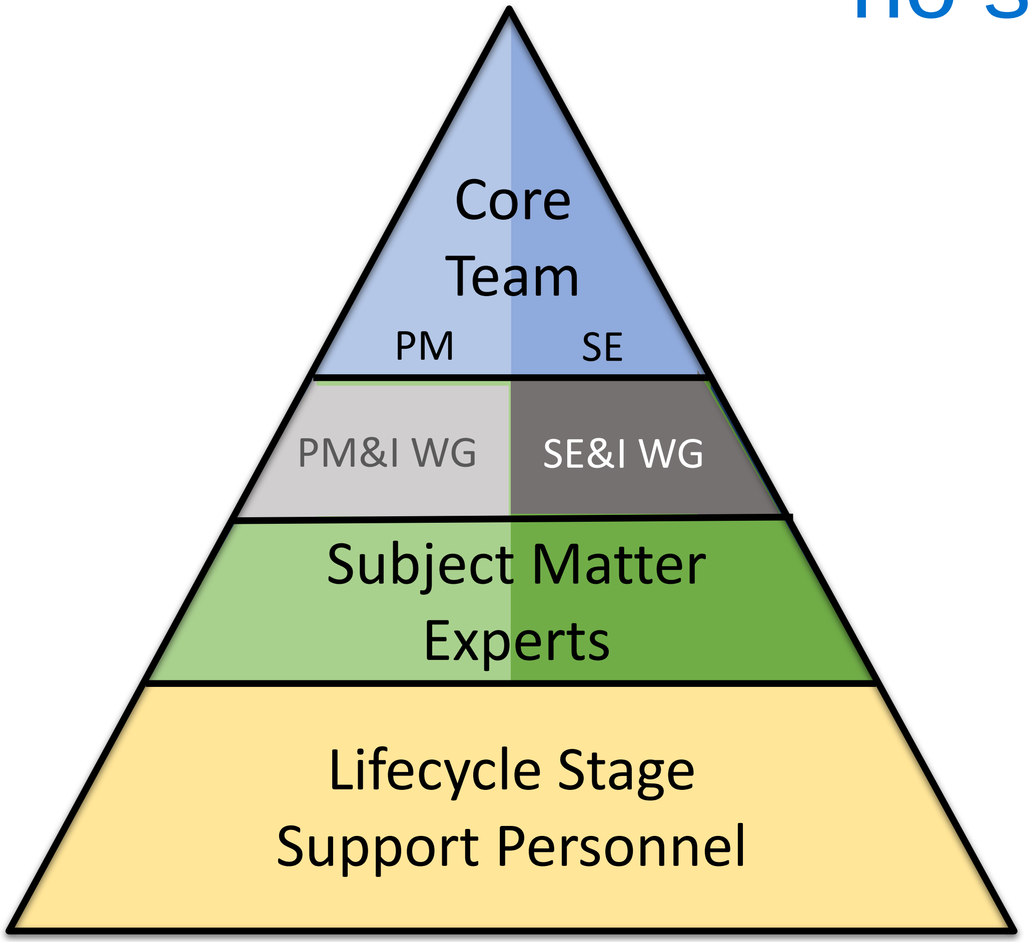
Integrated, collaborative, multidisciplined project team – no silos!

Integrated, Multidisciplined, Collaborative, Project team – no silos!

The team is made up of both PM and SE personnel as both are tightly dependent

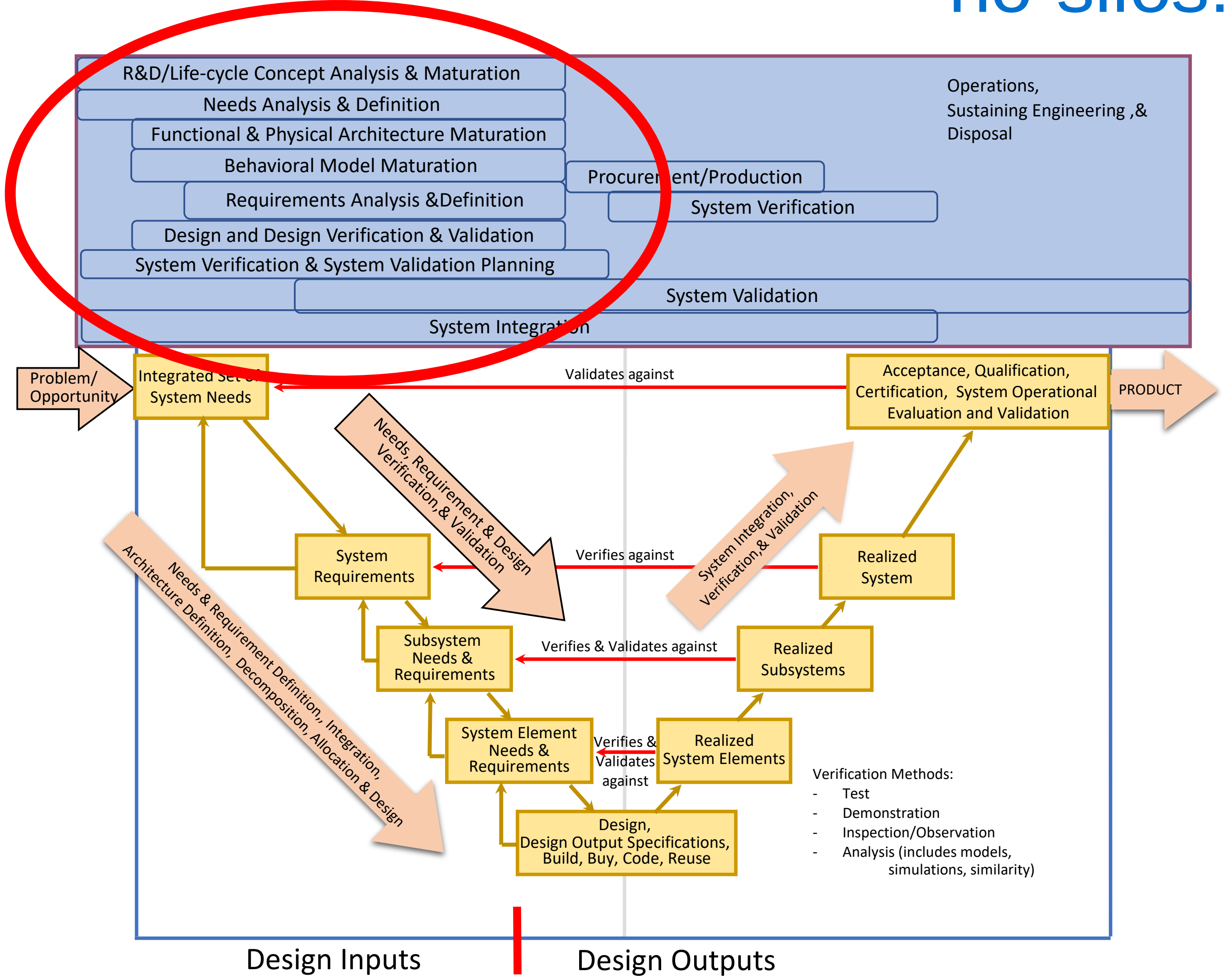


Integrated, collaborative, multidisciplined project team – no silos!



Project Team Organization

Integrated, collaborative, multidisciplined project team – no silos!



R&D/Life-cycle Concept Analysis & Maturation

Needs Analysis & Definition

Functional & Physical Architecture Maturation

Behavioral Model Maturation

Requirements Analysis &Definition

Design and Design Verification & Validation

System Verification & System Validation Planning

Procurement/Production

System Verification

Operations,
Sustaining Engineering ,&
Disposal

System Validation

System Integration

Problem/ Opportunity

Integrated Set of System Needs

Validates against

Acceptance, Qualification, Certification, System Operational Evaluation and Validation

PRODUCT

Needs, Requirement & Design Verification, & Validation

System Integration, Verification,& Validation

System Requirements

Verifies against

Realized System

Needs & Requirement Definition, Integration, Architecture Definition, Decomposition, Allocation & Design

Subsystem Needs & Requirements

Verifies & Validates against

Realized Subsystems

System Element Needs & Requirements

Verifies & Validates against

Realized System Elements

Design, Design Output Specifications, Build, Buy, Code, Reuse

Verification Methods:
- Test
- Demonstration
- Inspection/Observation
- Analysis (includes models, simulations, similarity)

Design Inputs

Design Outputs

Adapted from Ryan, M. J.; Wheatcraft, L.S., “On the Use of the Terms Verification and Validation”, February 2017 and INCOSE SE HB, Version 4, Figures 4.15 & 4.19

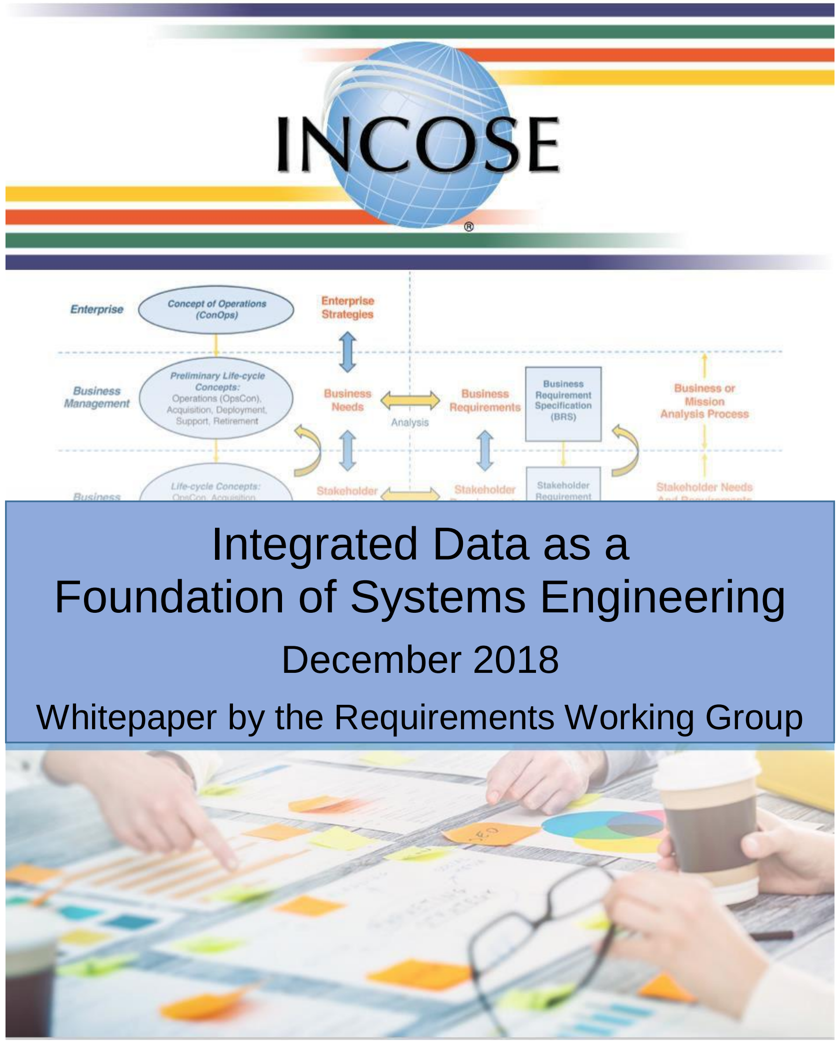
Concurrent Analysis, Maturation, Definition

Faster and cheaper than classical waterfall/serial, document-centric process, with silos

Aids in correctness, completeness, consistency, and feasibility of all SE artifacts

Data-Centric practice of Systems Engineering

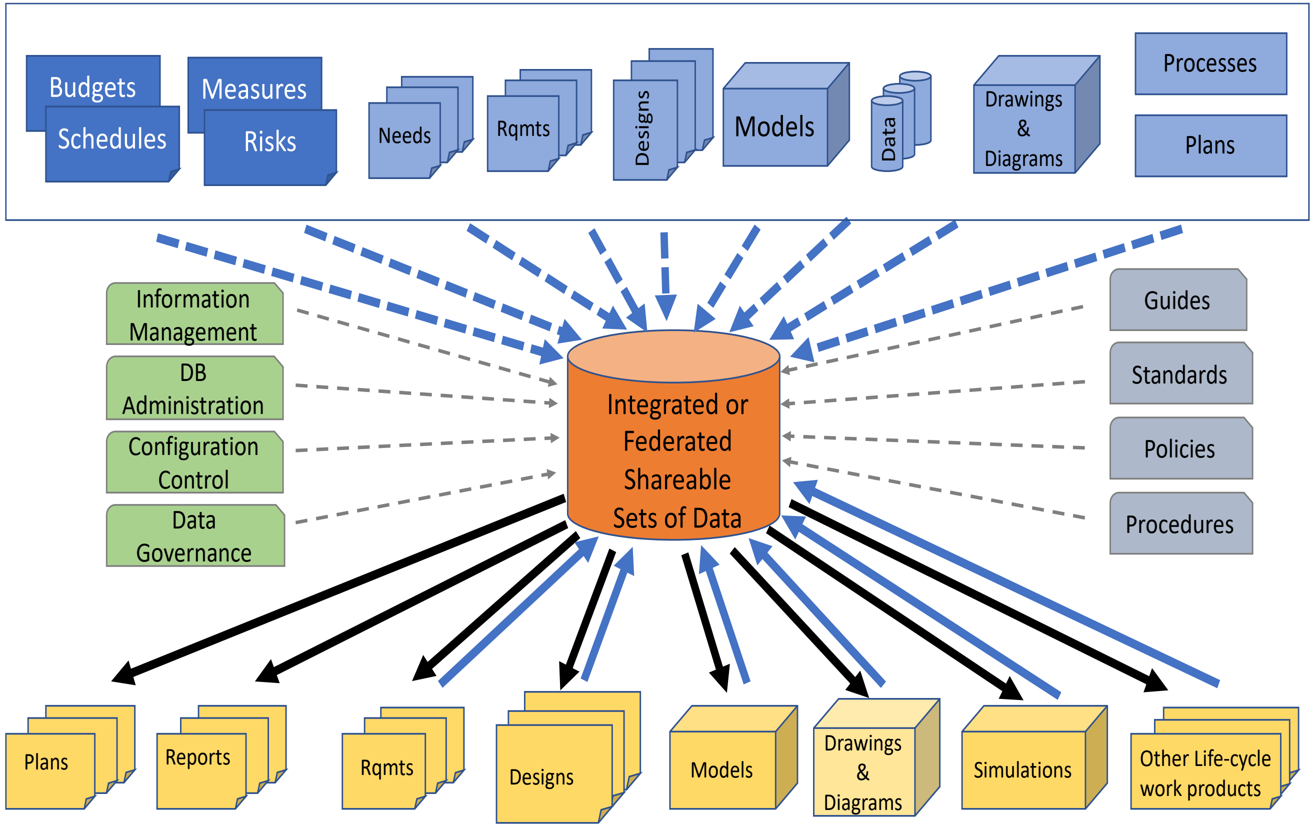
Data-Centric practice of Systems Engineering


INCOSE
Enterprise
Concept of Operations (ConOps)
Enterprise Strategies
Business Management
Preliminary Life-cycle Concepts: Operations (OpsCon), Acquisition, Deployment, Support, Retirement
Business Needs
Analysis
Business Requirements
Business Requirement Specification (BRS)
Business or Mission Analysis Process
Life-cycle Concepts
Stakeholder
Stakeholder Needs

Integrated Data as a
Foundation of Systems Engineering

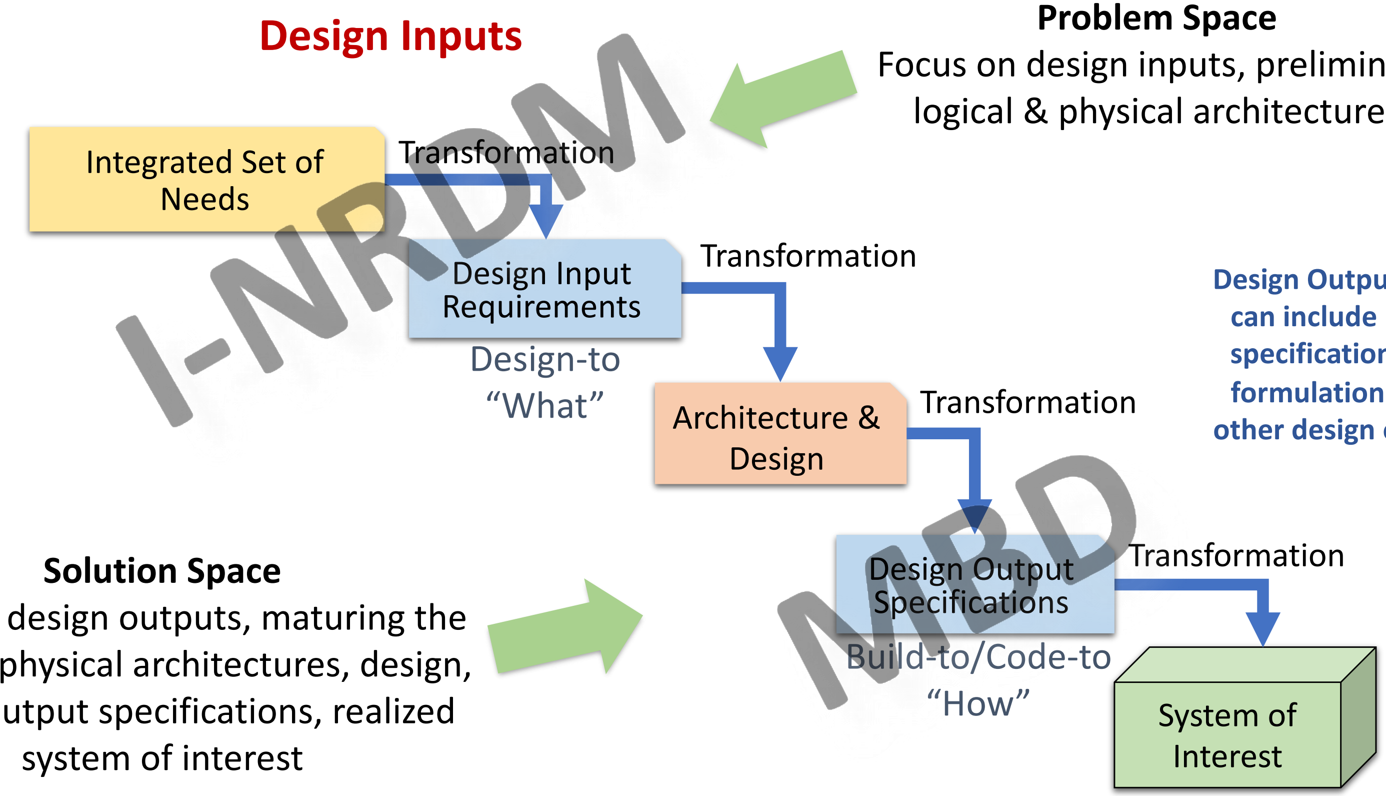
December 2018

Whitepaper by the Requirements Working Group



Original Developed by INCOSE RWG at IW 2017

Data-Centric practice of Systems Engineering



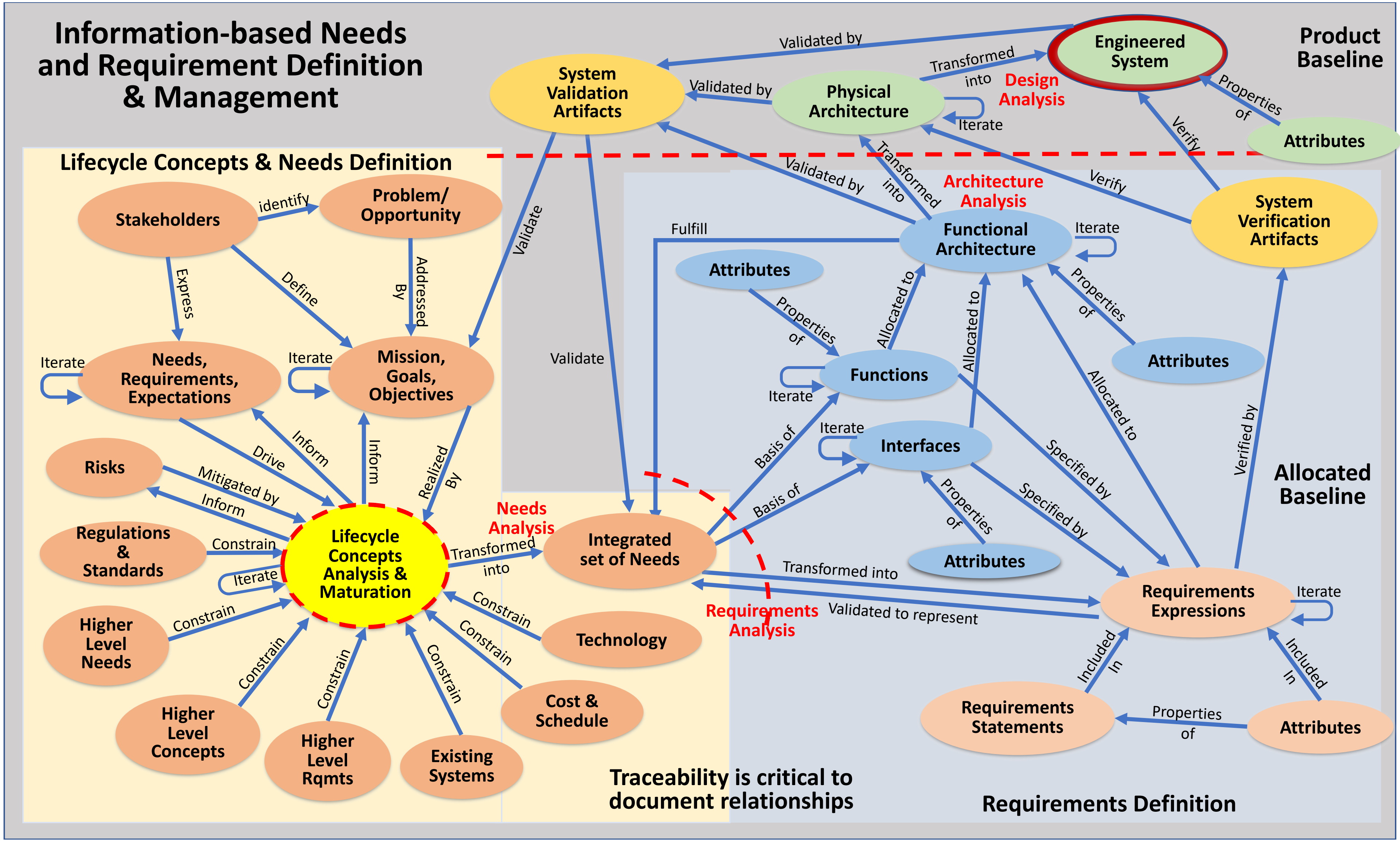
Problem Space
Focus on design inputs, preliminary
logical & physical architectures

Design Output Specifications can include requirements, specifications, algorithms, formulations, drawings, & other design output artifacts

Solution Space
Focus on design outputs, maturing the
logical & physical architectures, design,
design output specifications, realized
system of interest

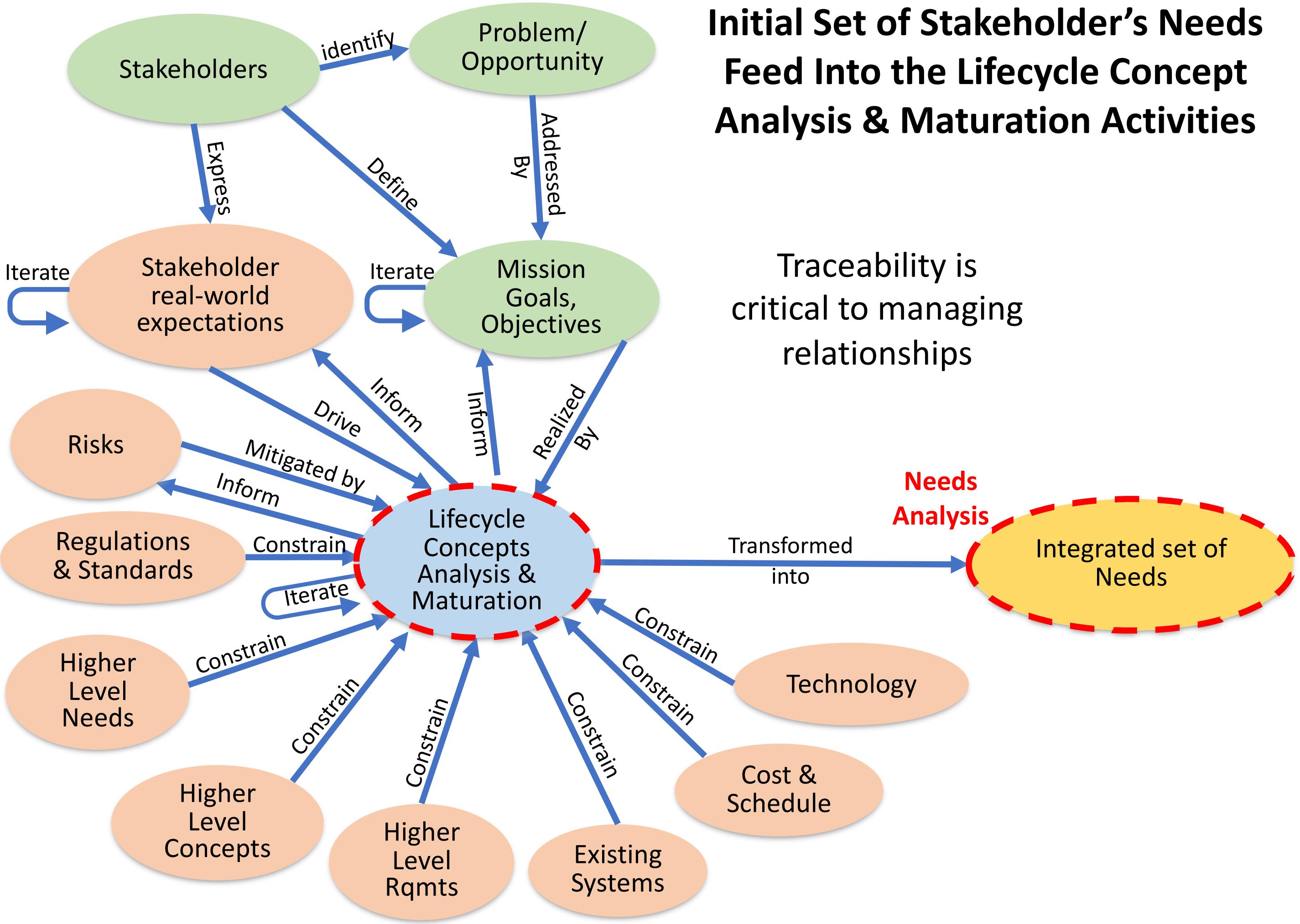
I-NRDM + MBD = MBSE

Data-Centric practice of Systems Engineering



Needs before Requirements

Needs before Requirements



Initial Set of Stakeholder's Needs Feed Into the Lifecycle Concept Analysis & Maturation Activities

Traceability is critical to managing relationships

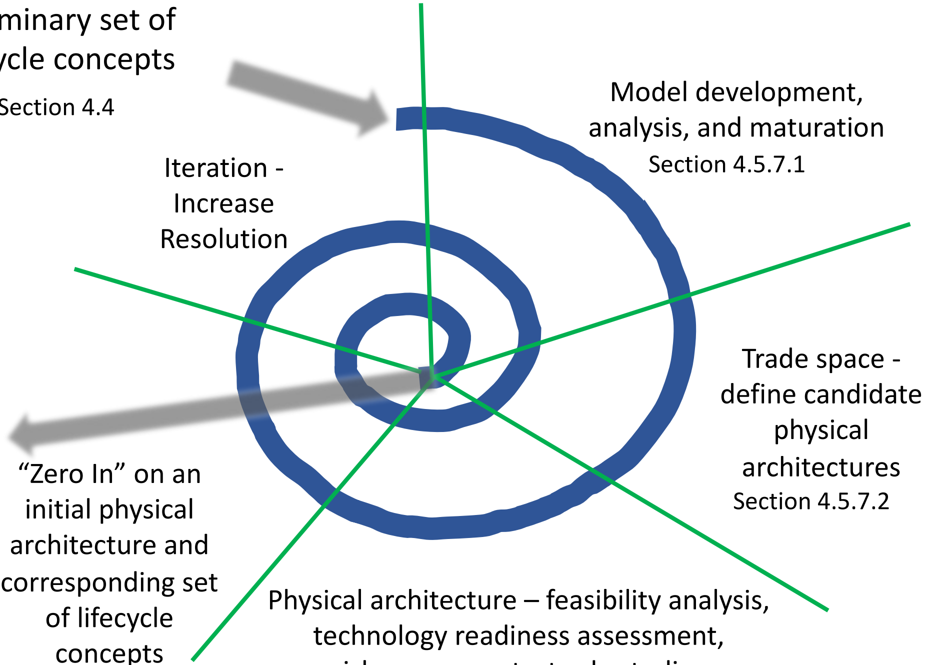
Establish completeness, consistency, correctness, and feasibility before defining needs and transforming them into the design input requirements

Needs before Requirements

Lifecycle Analysis and Maturation

Iterative set of activities zeroing in on a feasible set of lifecycle concepts

Doctrine of Successive Refinement: Needs & Requirement Definition (design inputs)



Preliminary set of lifecycle concepts
Section 4.4

Model development, analysis, and maturation
Section 4.5.7.1

Iteration - Increase Resolution

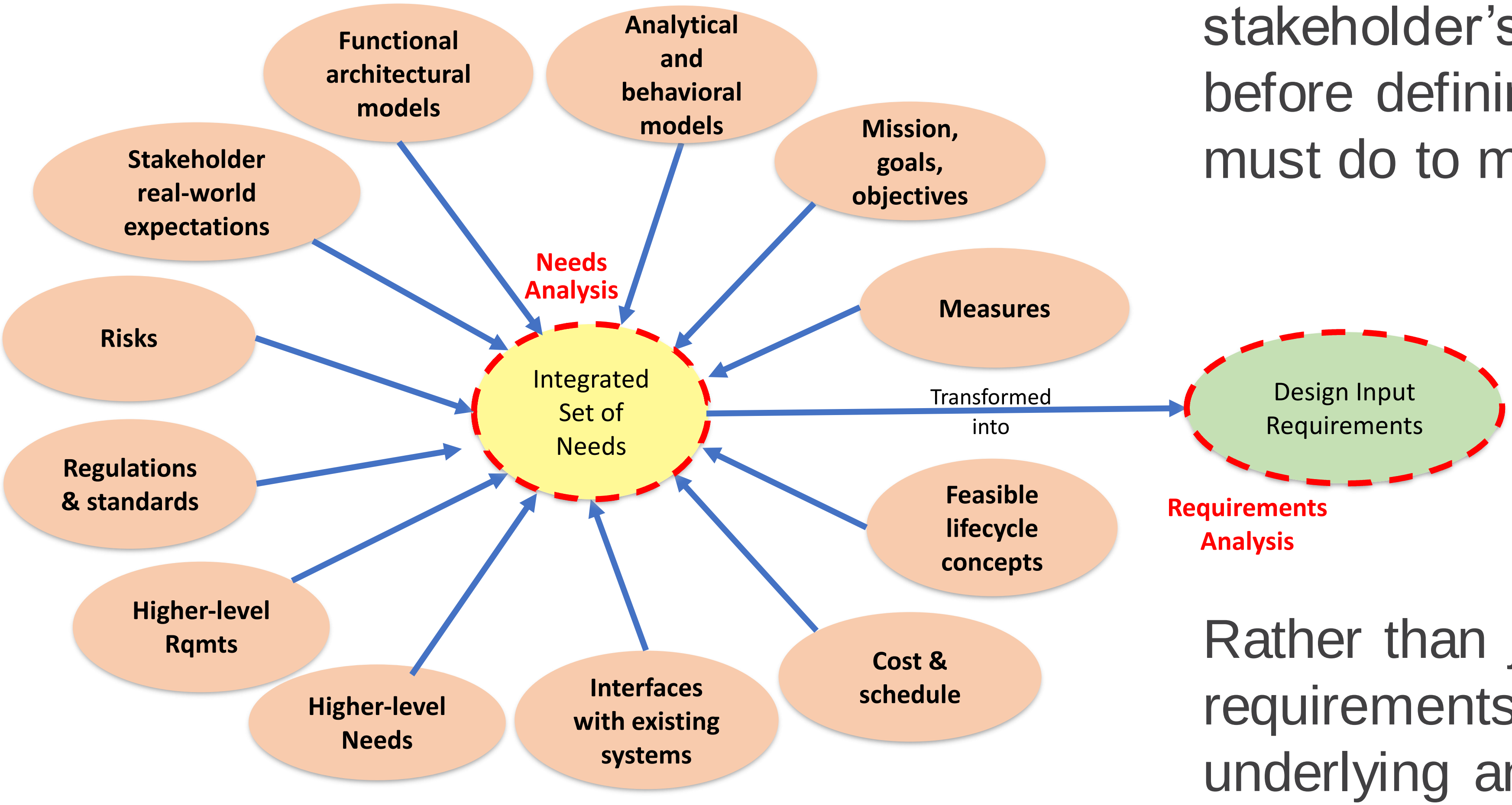
Trade space - define candidate physical architectures
Section 4.5.7.2

Physical architecture – feasibility analysis, technology readiness assessment, risk assessments, trade studies
Section 4.5.7.3

“Zero In” on an initial physical architecture and corresponding set of lifecycle concepts
Section 4.5.7.4

Feasible lifecycle concepts, integrated set of needs, preliminary physical architecture, models, plans, budgets, schedules

Needs before Requirements


Functional architectural models
Analytical and behavioral models
Mission, goals, objectives
Stakeholder real-world expectations
Needs Analysis
Measures
Risks
Integrated Set of Needs
Transformed into
Design Input Requirements
Regulations & standards
Feasible lifecycle concepts
Requirements Analysis
Higher-level Rqmts
Cost & schedule
Higher-level Needs
Interfaces with existing systems

Must understand the stakeholder’s needs for the SOI before defining what the SOI must do to meet those needs.

Rather than just having a set of requirements, we also have the underlying analysis from which they were derived.

A more rigorous process for verification and validation

A more rigorous process for verification and validation

What’s more important?
System Verification or System Validation?????

What do you validate against?
Where is it defined?

A more rigorous process for verification and validation

Validation:

Validating that a SOI that meets its intended purpose

in its operational environment

when operated by its intended users

and does not enable unintended users to negatively impact the intended use of the system

as defined in the integrated set of needs.

A more rigorous process for verification and validation

Must think of system validation as an equal, if not more important, activity than system verification!

Passing system verification but failing system validation results in a failed project…….

A more rigorous process for verification and validation

- **Necessary for acceptance**.
  - The focus of the System Lifecycle Concepts and Needs Definition Process (Section 4) is to clearly define what is "***necessary for acceptance***" early in the development lifecycle.
  - The result is an integrated set of system needs for the SOI which will drive all SOI lifecycle development activities, the design input requirements, architecture, design, and system validation.
- The goal of all development projects is that their product is accepted by the customer(s) or accepted by some regulatory agency for use by the public.
- System validation is key to addressing questions concerning what is "**necessary for acceptance**".
  - It is critical that system verification and system validation Success Criteria (Section 10) are stated that defines what is ***necessary for acceptance*** for each system need – when the need is written.
  - It is the system verification and system validation Success Criteria that determines what is ***necessary for acceptance***.

A more rigorous process for verification and validation

- Attributes that address system validation that should be defined as each need statement is written just as system verification must be addressed as each design input requirement statement is written

  A6 – System verification and system validation Success Criteria

  A7 – System verification and system validation Strategy

  A8 – System verification and system validation Method

  A9 – System verification and system validation Responsible organization.

  A10 – System verification and system validation Level

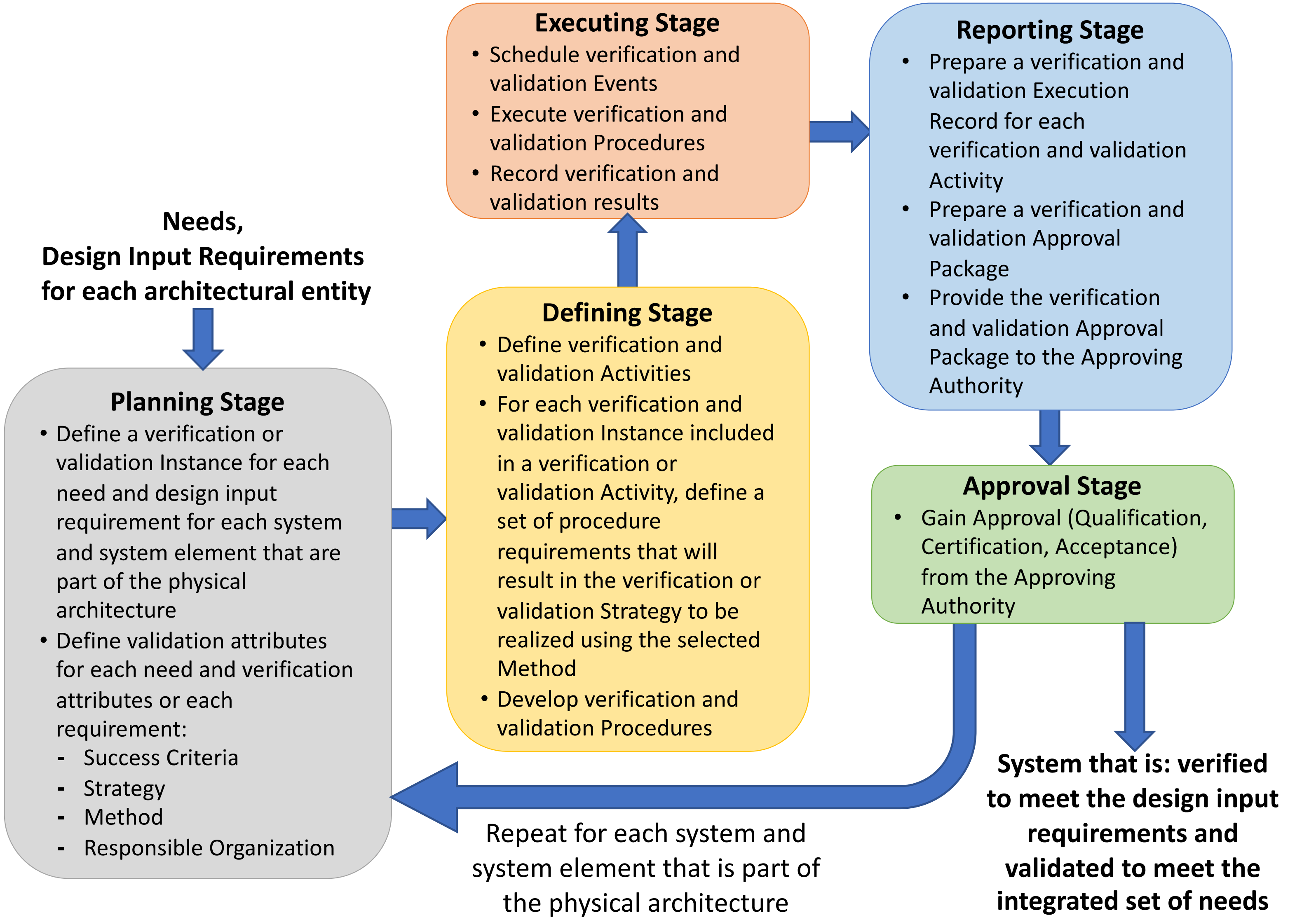
  A11 – System verification and system validation Phase

  A12 – Condition of Use

  A13 – System verification and system validation Results

  A14 – System verification and system validation Status

A more rigorous process for verification and validation



Needs, Design Input Requirements for each architectural entity

Planning Stage

- Define a verification or validation Instance for each need and design input requirement for each system and system element that are part of the physical architecture
- Define validation attributes for each need and verification attributes or each requirement:
  - Success Criteria
  - Strategy
  - Method
  - Responsible Organization

Defining Stage

- Define verification and validation Activities
- For each verification and validation Instance included in a verification or validation Activity, define a set of procedure requirements that will result in the verification or validation Strategy to be realized using the selected Method
- Develop verification and validation Procedures

Executing Stage

- Schedule verification and validation Events
- Execute verification and validation Procedures
- Record verification and validation results

Reporting Stage

- Prepare a verification and validation Execution Record for each verification and validation Activity
- Prepare a verification and validation Approval Package
- Provide the verification and validation Approval Package to the Approving Authority

Approval Stage

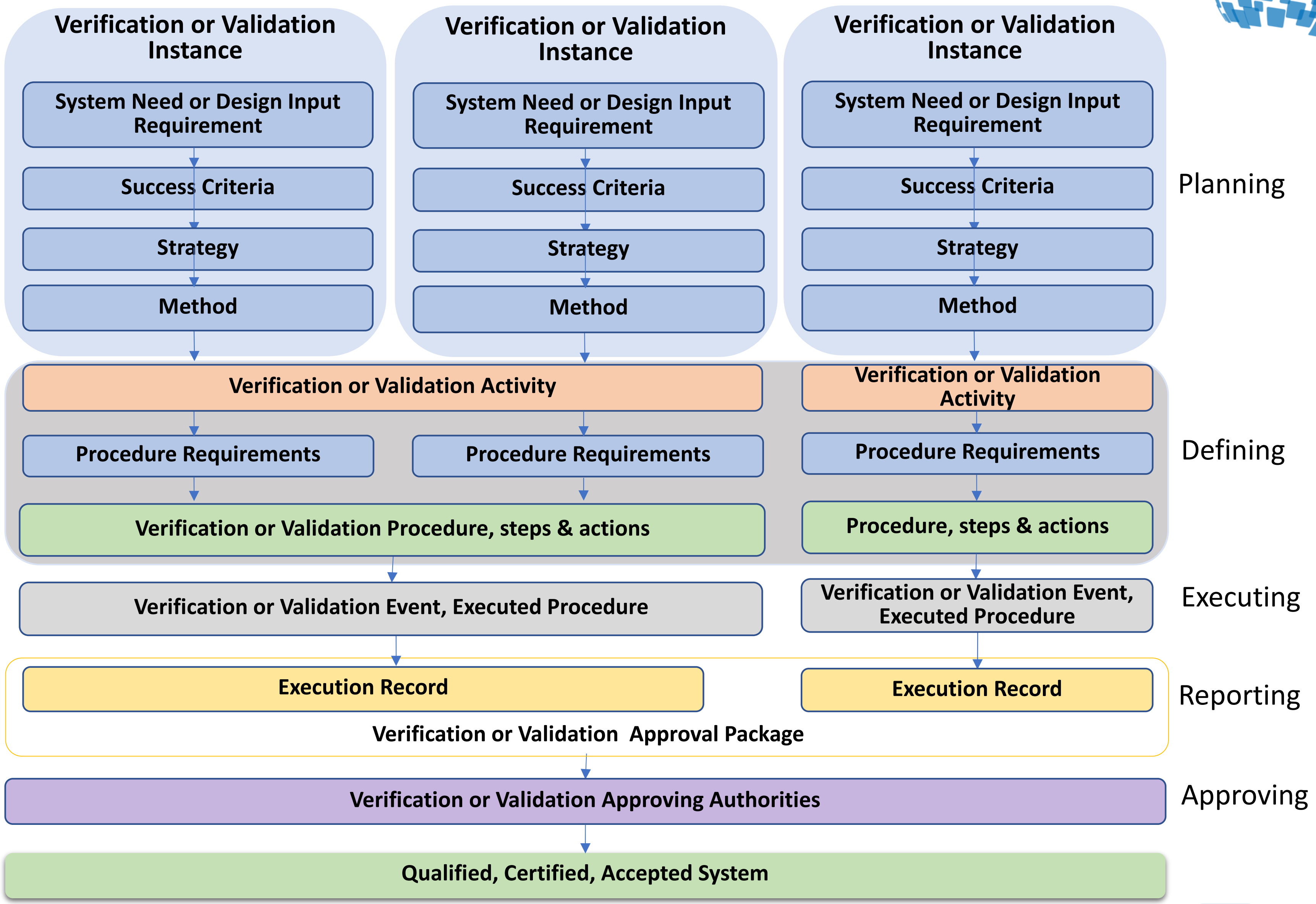
- Gain Approval (Qualification, Certification, Acceptance) from the Approving Authority

Repeat for each system and system element that is part of the physical architecture

System that is: verified to meet the design input requirements and validated to meet the integrated set of needs

A more rigorous process for verification and validation

Includes a specific and well-defined set of activities, artifacts, and terminology



Verification or Validation Instance

System Need or Design Input Requirement

Success Criteria

Strategy

Method

Verification or Validation Instance

System Need or Design Input Requirement

Success Criteria

Strategy

Method

Verification or Validation Instance

System Need or Design Input Requirement

Success Criteria

Strategy

Method

Planning

Verification or Validation Activity

Procedure Requirements

Procedure Requirements

Verification or Validation Procedure, steps & actions

Verification or Validation Activity

Procedure Requirements

Procedure, steps & actions

Defining

Verification or Validation Event, Executed Procedure

Verification or Validation Event, Executed Procedure

Executing

Execution Record

Execution Record

Verification or Validation Approval Package

Reporting

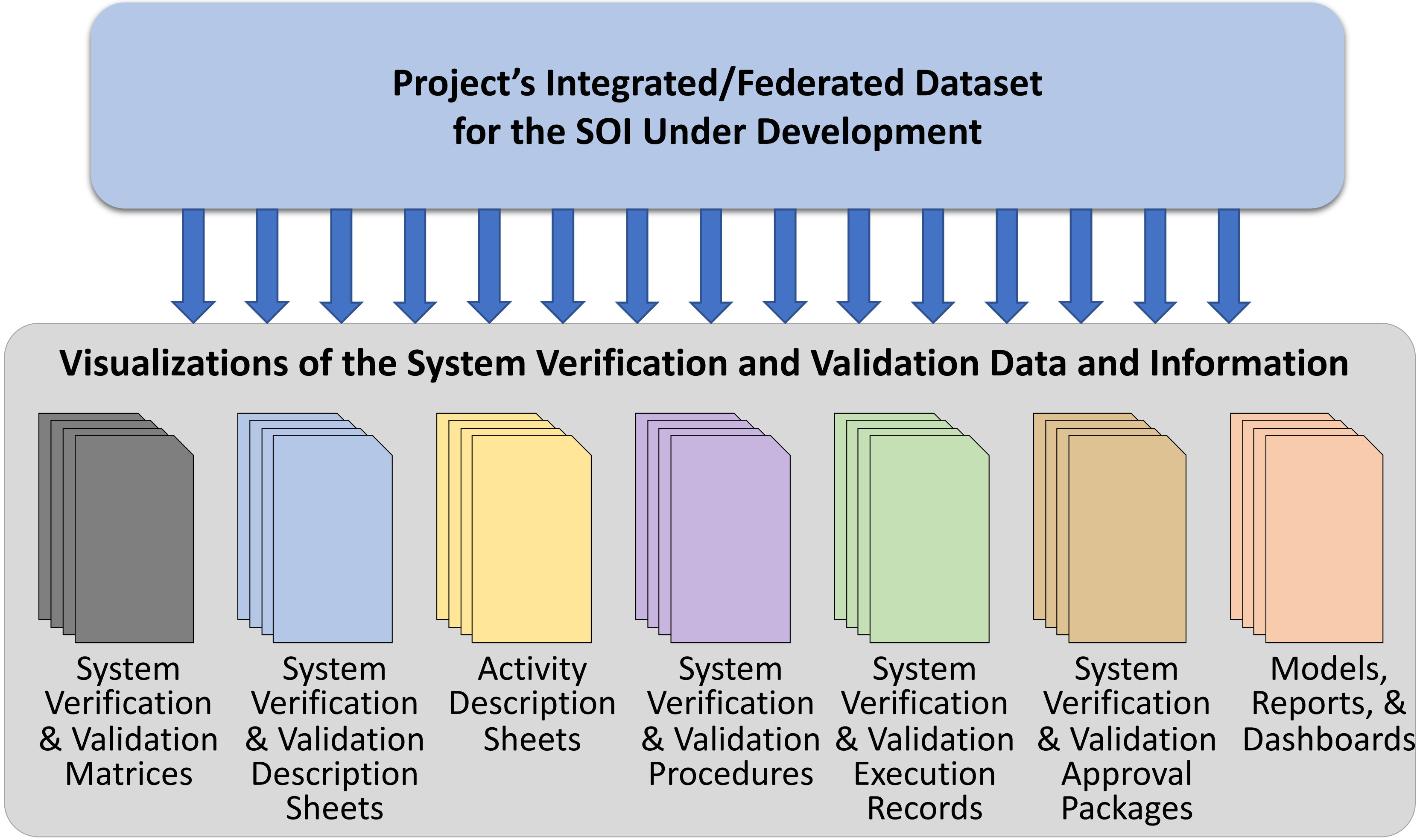
Verification or Validation Approving Authorities

Approving

Qualified, Certified, Accepted System

A more rigorous process for verification and validation

All data, information, and artifacts recorded within the project's integrated/federated dataset



Project's Integrated/Federated Dataset for the SOI Under Development
Visualizations of the System Verification and Validation Data and Information
System Verification & Validation Matrices
System Verification & Validation Description Sheets
Activity Description Sheets
System Verification & Validation Procedures
System Verification & Validation Execution Records
System Verification & Validation Approval Packages
Models, Reports, & Dashboards

Questions and Discussion

2021

Annual INCOSE

international workshop

Virtual Event

January 29 - 31, 2021

www.incose.org/IW2021