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

Needs & Requirements Lifecycle Manual (Day 1)

Overview – Underlying Concepts

Requirements Working Group

www.incose.org/IW2021

Planned Sessions for IW2021

RWG Sessions IW2021

Link to IW2021 Platform: https://conference.conflr.com/IW2021

Monday January 25, 2021:

8 am - 9 am (Central Standard Time Zone, UTC-6) - Overview of RWG efforts, Introduction to the *Needs and Requirements Lifecycle Manual*.

9 am - noon (Central Standard Time Zone, UTC-6) - Introduction to the *Needs and Requirements Lifecycle Manual*, overview and concepts.

We are here

Monday session Zoom link: https://incose-org.zoom.us/j/95946486622?pwd=K3NpOUxlRHIwNFkzTFZmL0VtcjM0UT09

Tuesday January 26, 2021:

9 am - 10:00 am (Central Standard Time Zone, UTC-6) - Continuation of the *Needs and Requirements Lifecycle Manual* discussion, overview of the document contents and structure.

10 am - 11:30 am (Central Standard Time Zone, UTC-6) - **Update from IW schedule** Overview and discussion for the *Guideline to Verification and Validation* (moved from Wednesday).

Tuesday session Zoom link: https://incose-org.zoom.us/j/92163636000?pwd=Sm44MFpLcmFmeTJ0UUJNeVJrQjgvZz09

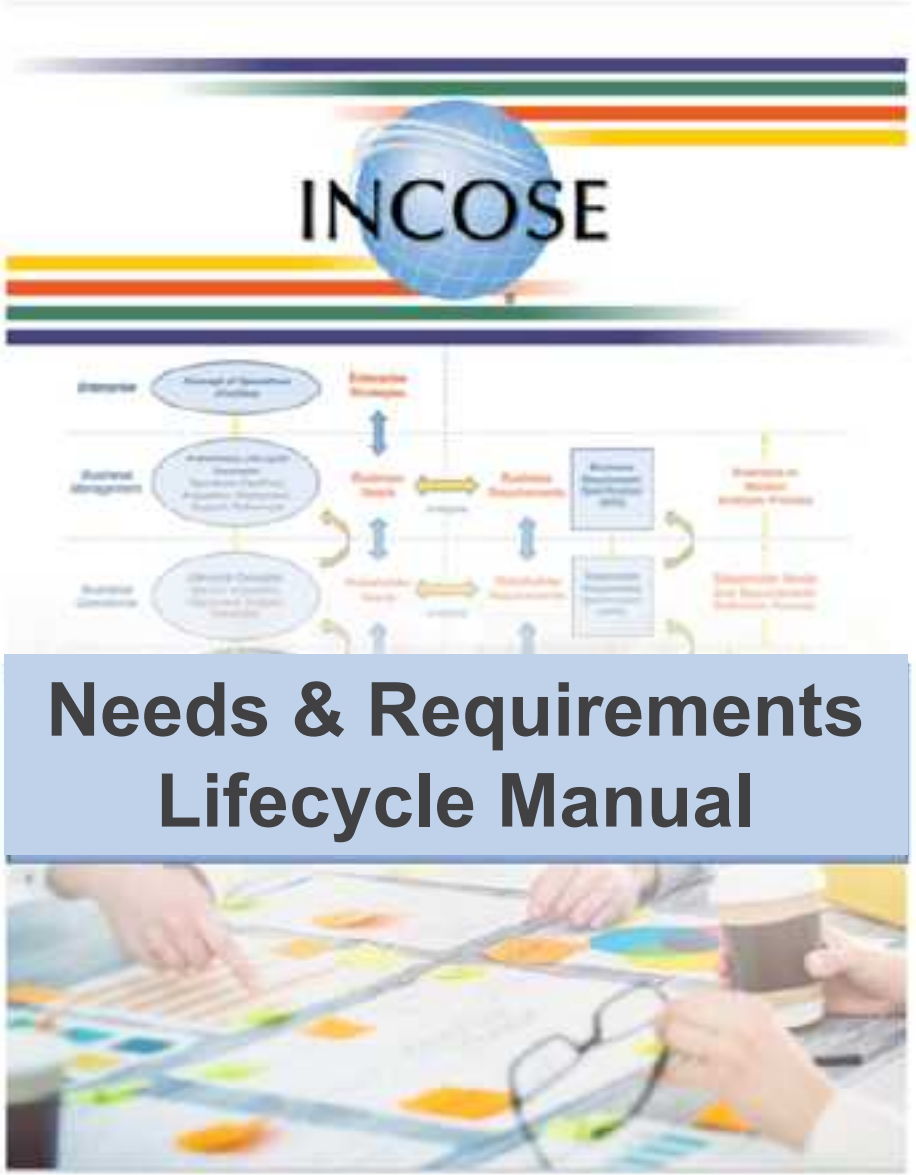
Wednesday January 27, 2021:

10 am - 11:30 am (Central Standard Time Zone, UTC-6) - Overview of new RWG Guidelines to *Needs and Requirements Development and Management*.

11:30 am - 1 pm (Central Standard Time Zone, UTC-6) - General discussion and feedback session of all of the RWG products in work.

Wednesday session Zoom link: https://incose-org.zoom.us/j/92722611138?pwd=ZnVxQWpLZ0d0RUc4VUpCYkd2S3pGZz09

Links to the Zoom Sessions on our Connect Site, RWG Sessions at IW2021



The focus of this presentation –

Underlying Concepts

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*

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?

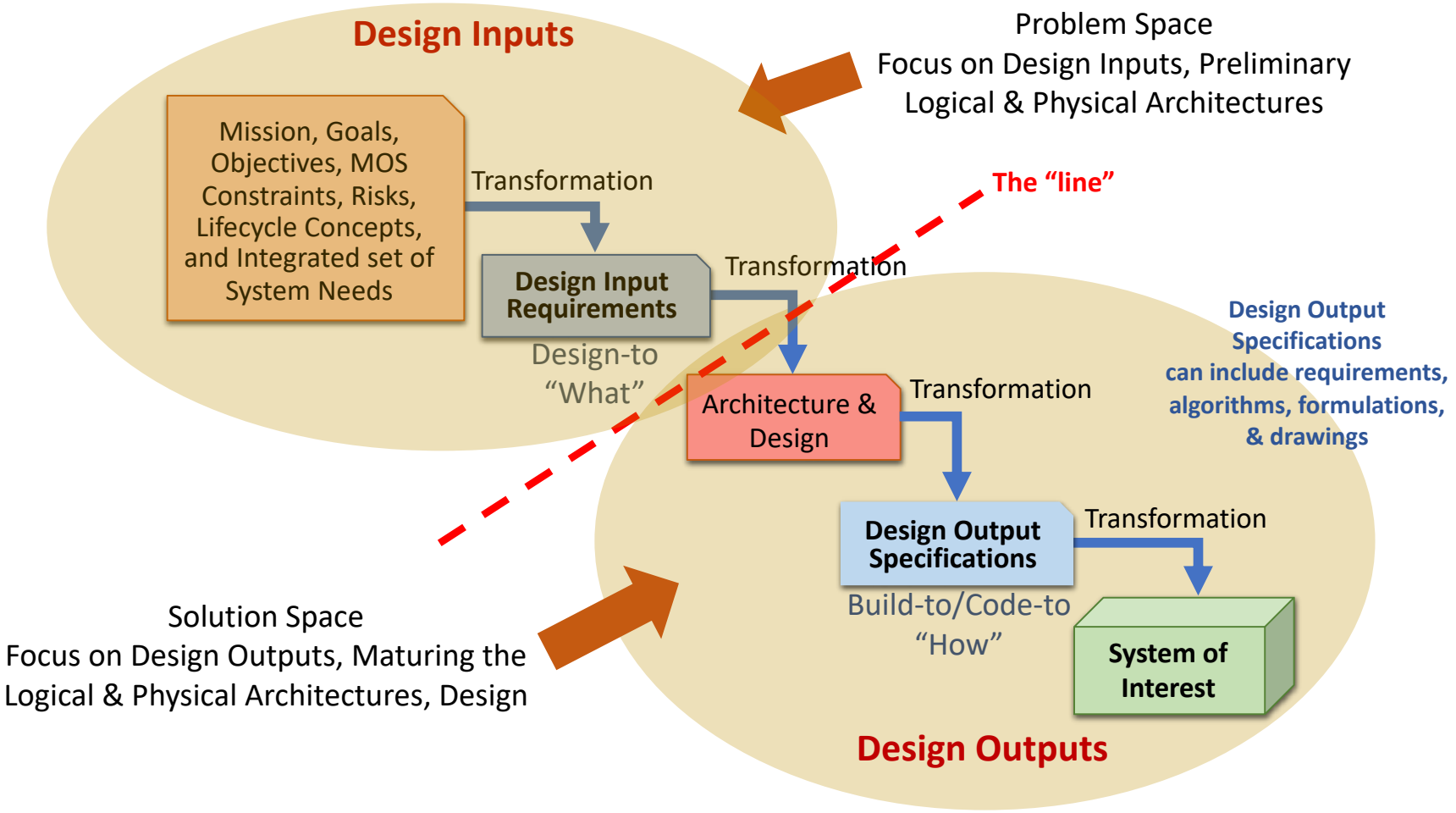
Reducing ambiguity

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

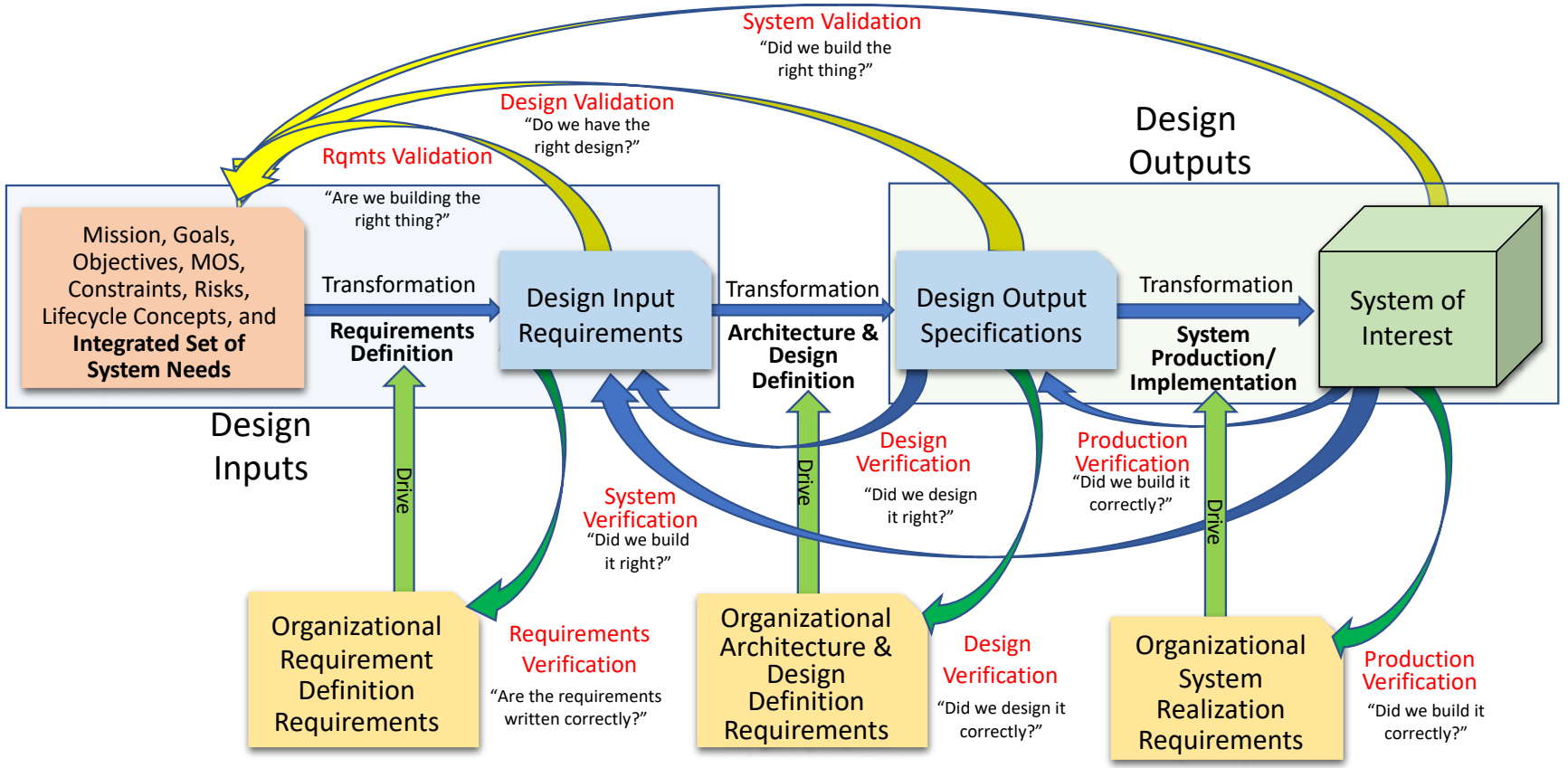
Reducing ambiguity

Design inputs vs design outputs

Requirements vs. specifications



Reducing ambiguity



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

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

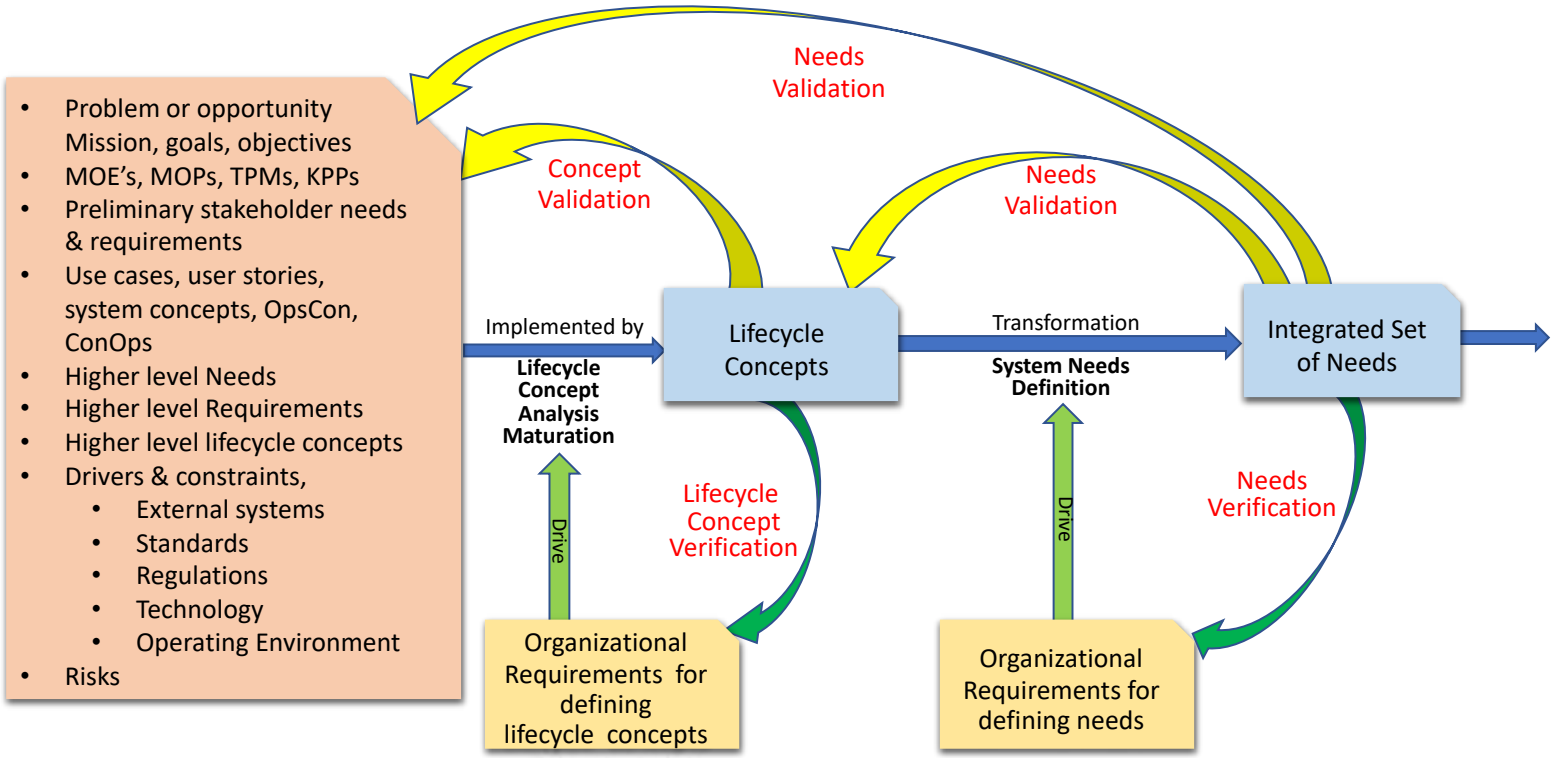
We validate the SOI against the needs, not requirements.

Verification & Validation in Context

Lifecycle Concepts and Needs Definition

Lifecycle Concept V&V

Needs V&V



Do the lifecycle concepts and integrated set of needs represent a system of interest that can accomplish its intended use in the operational environment when operated by its intended users?

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?
- **V&V requirements** that communicate what must be included within the V&V 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

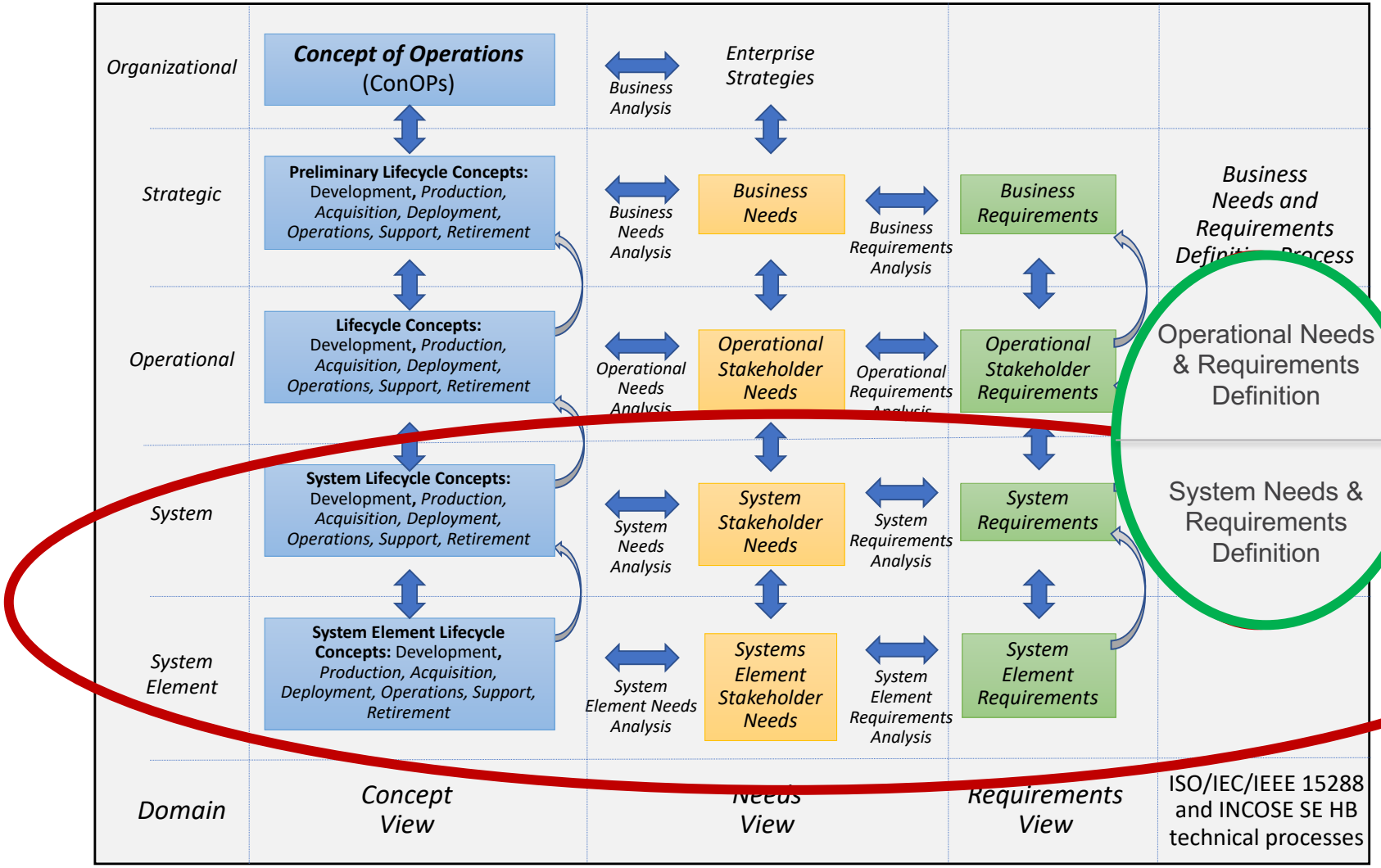
Needs and Requirements Working Group ??????

Needs and Requirements Engineer??

Reducing ambiguity

- 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

Reducing ambiguity



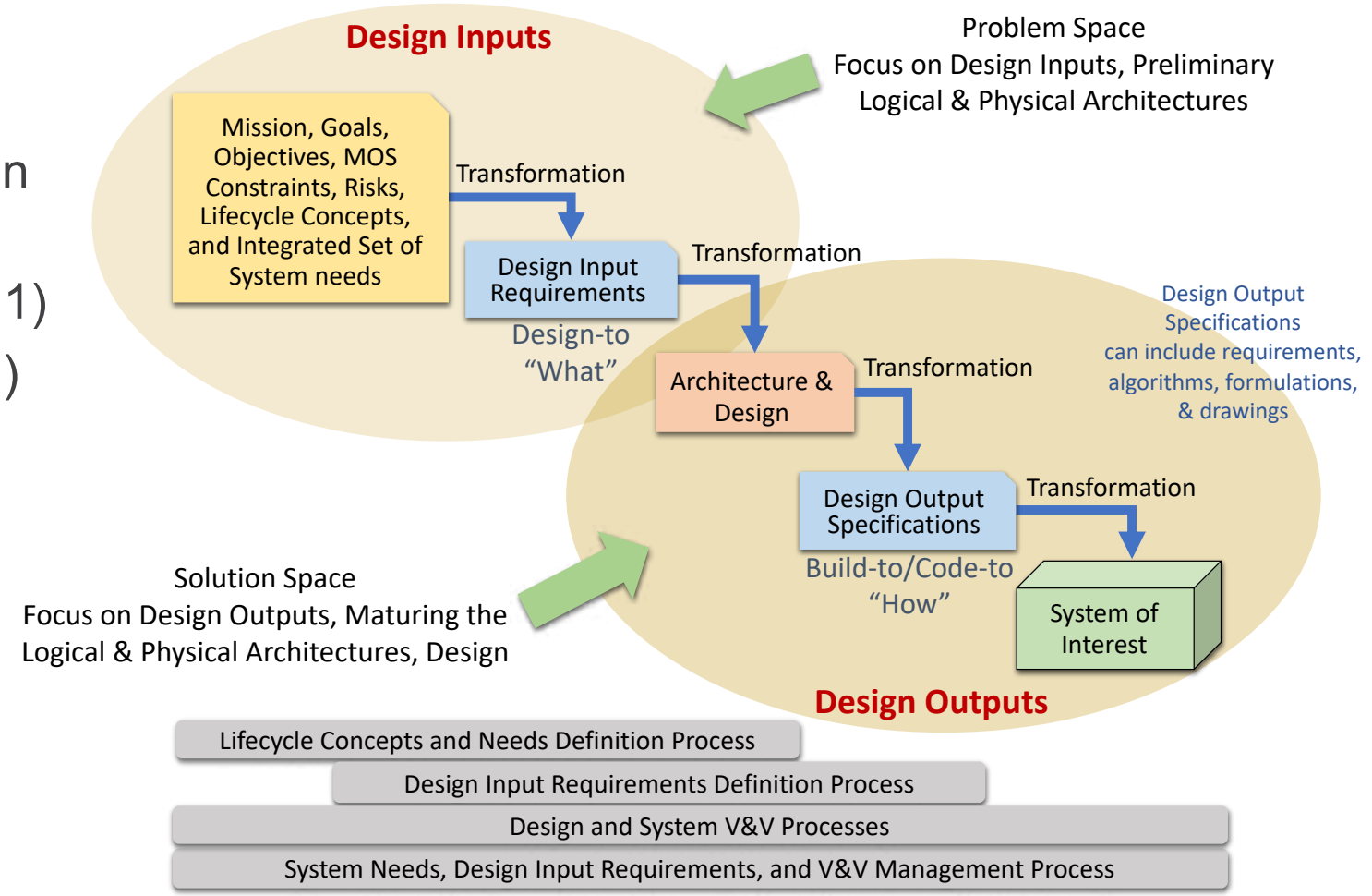
Stakeholders Exist at all levels

Focus in this Manual

Triad of lifecycle concepts, needs, and requirements

Process Areas discussed in this Manual

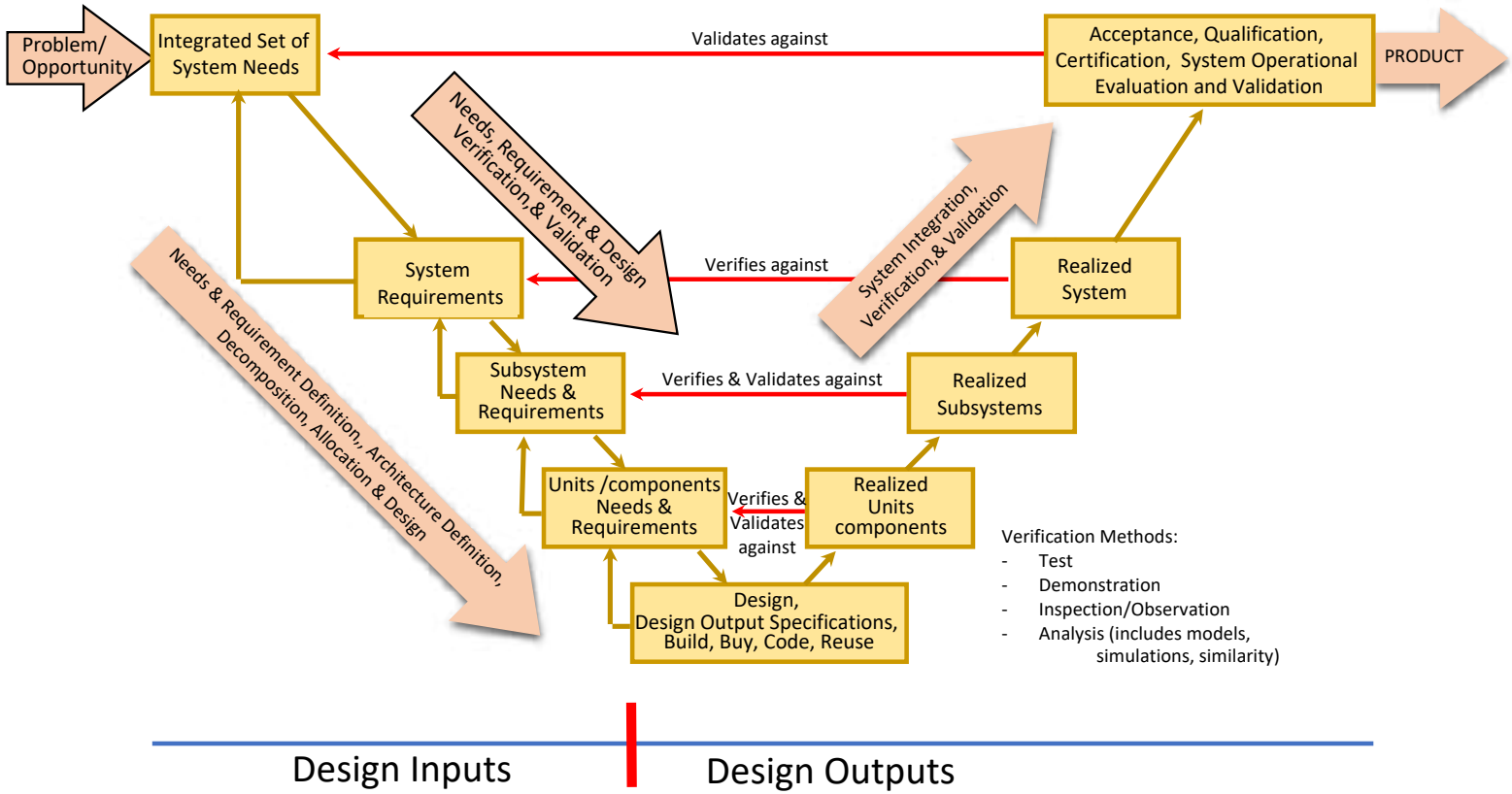
- Lifecycle Concepts and Needs Definition (Section 4)
- Design Input Requirements Definition (Section 6)
- System Verification (Sections 10 & 11)
- System Validation (Sections 10 & 11)
- Needs, Design Input Requirements, and System V&V Management (Section 14)



The SE Vee – Left-side vs Right-side

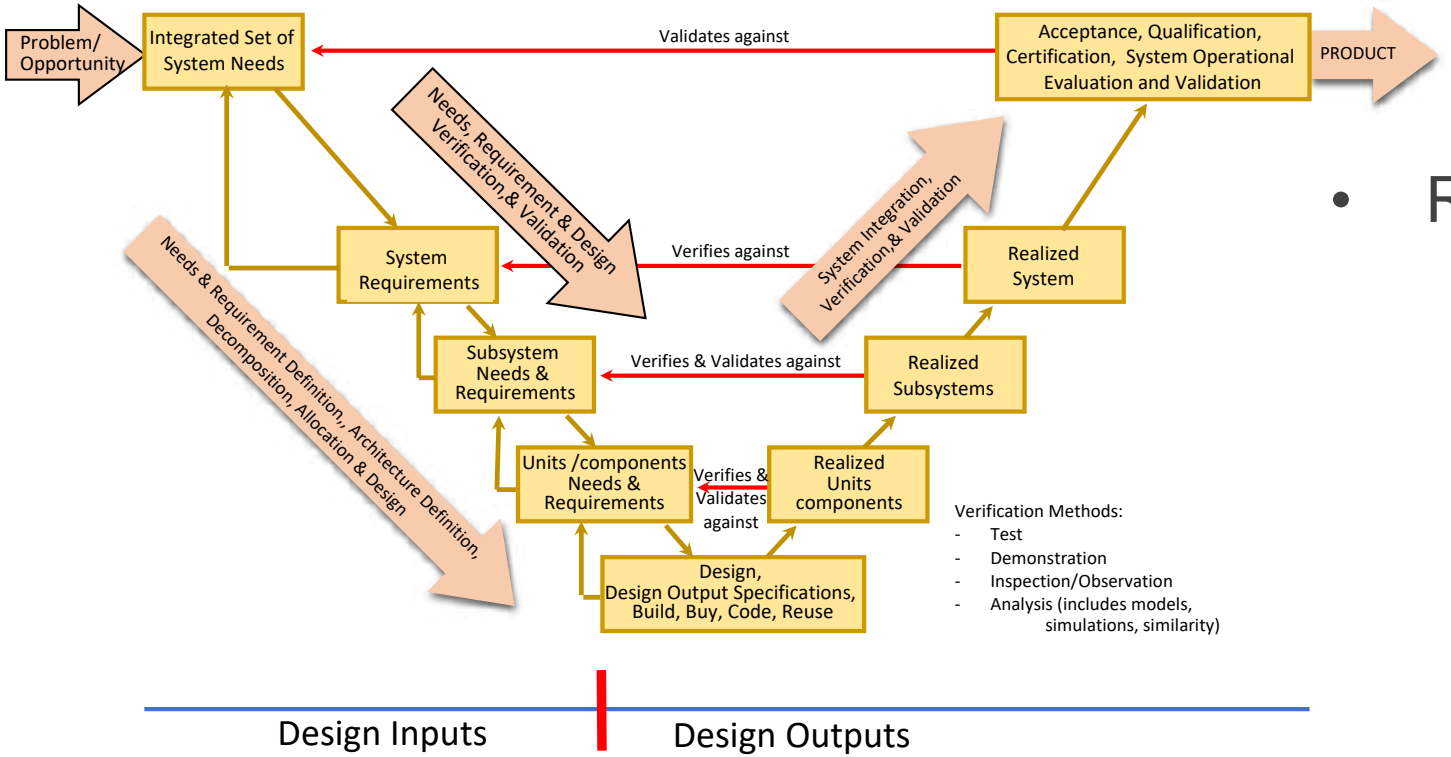
The SE Vee – Left-side vs Right-side

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



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



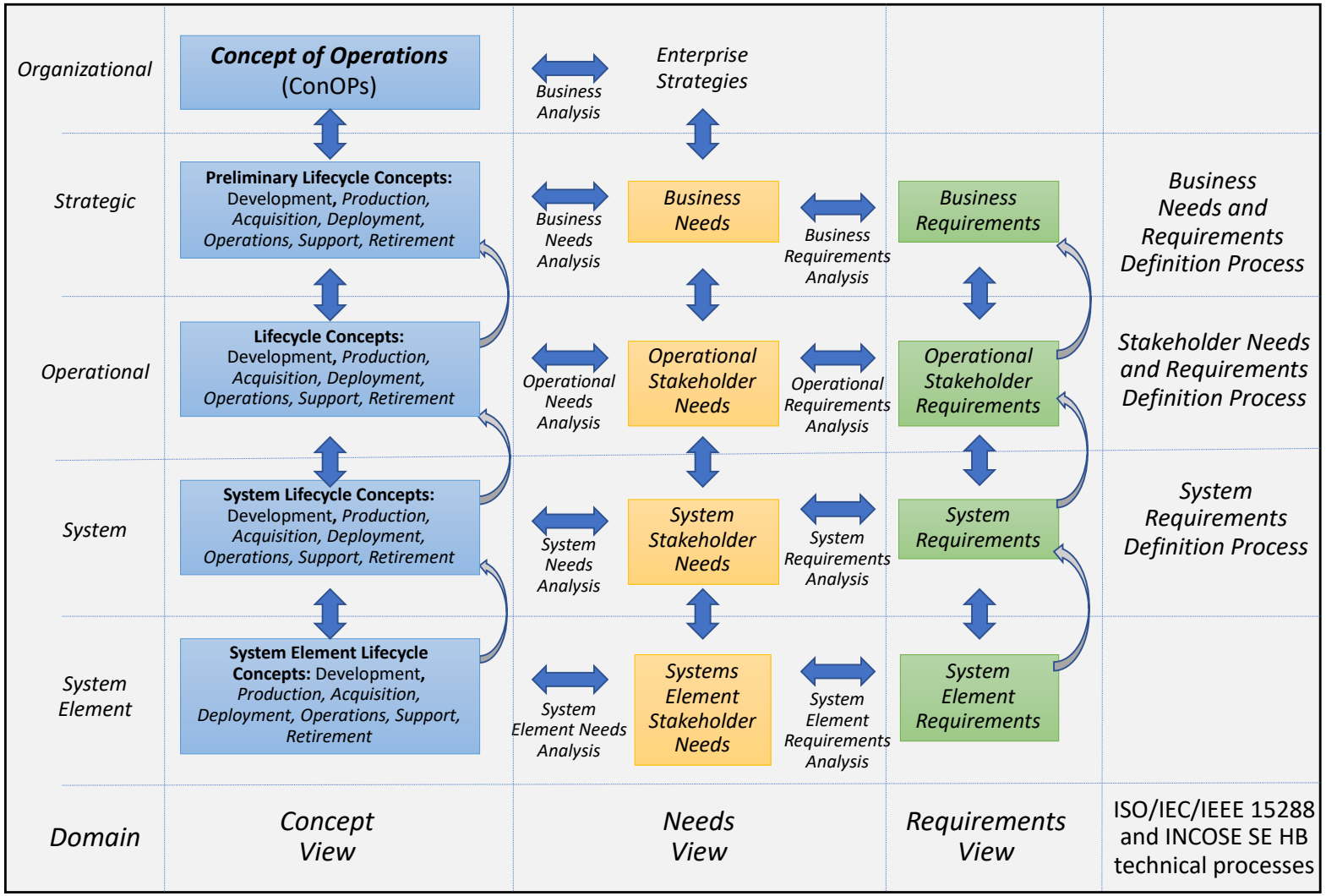
Adapted from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017 and INCOSE SE HB, Version 4, Figures 4.15 & 4.19

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

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

Organizational levels vs architectural levels

Organizational Levels vs Architectural Levels



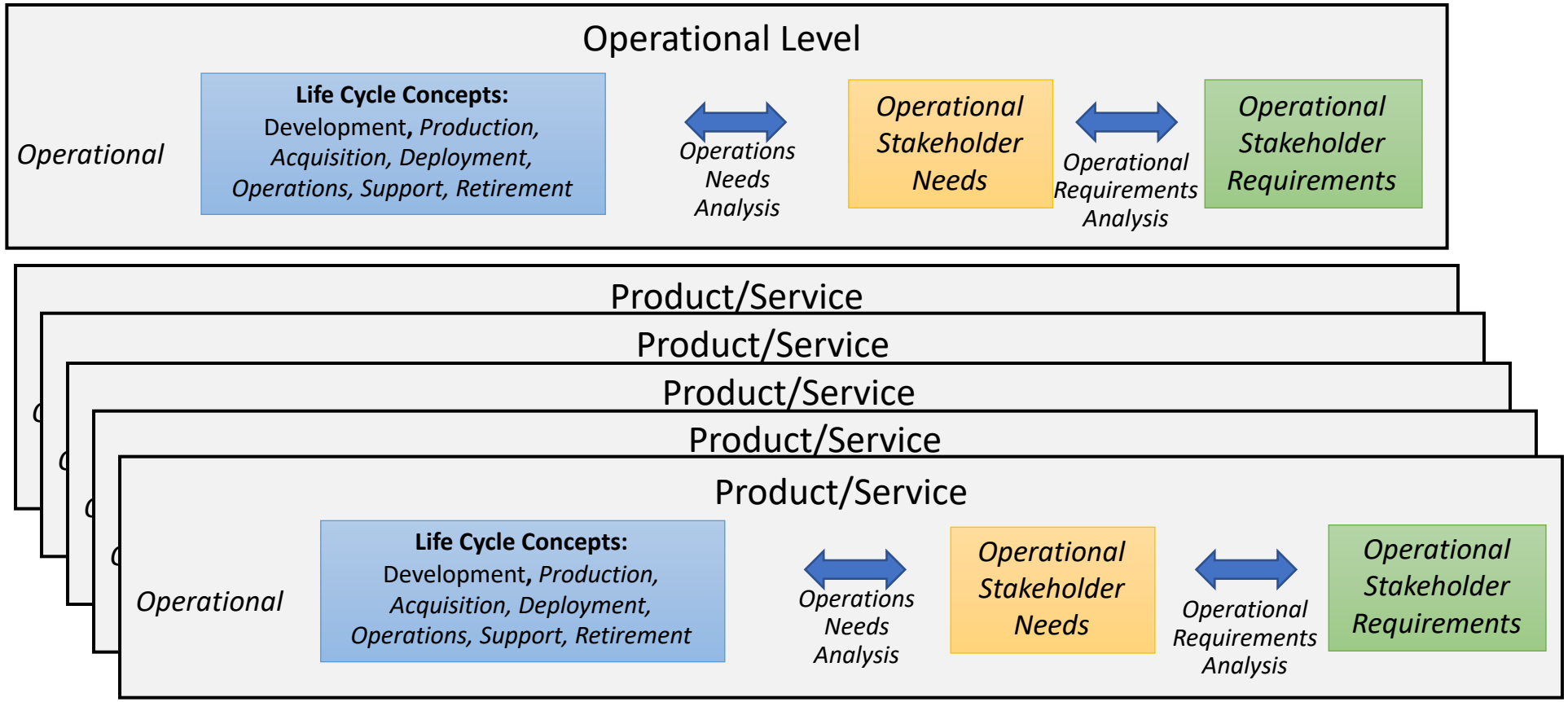
Limited discussion in 15288 and SE HB

More detailed elaboration in the Guide for Writing Requirements

The Manual provides an even more detailed elaboration

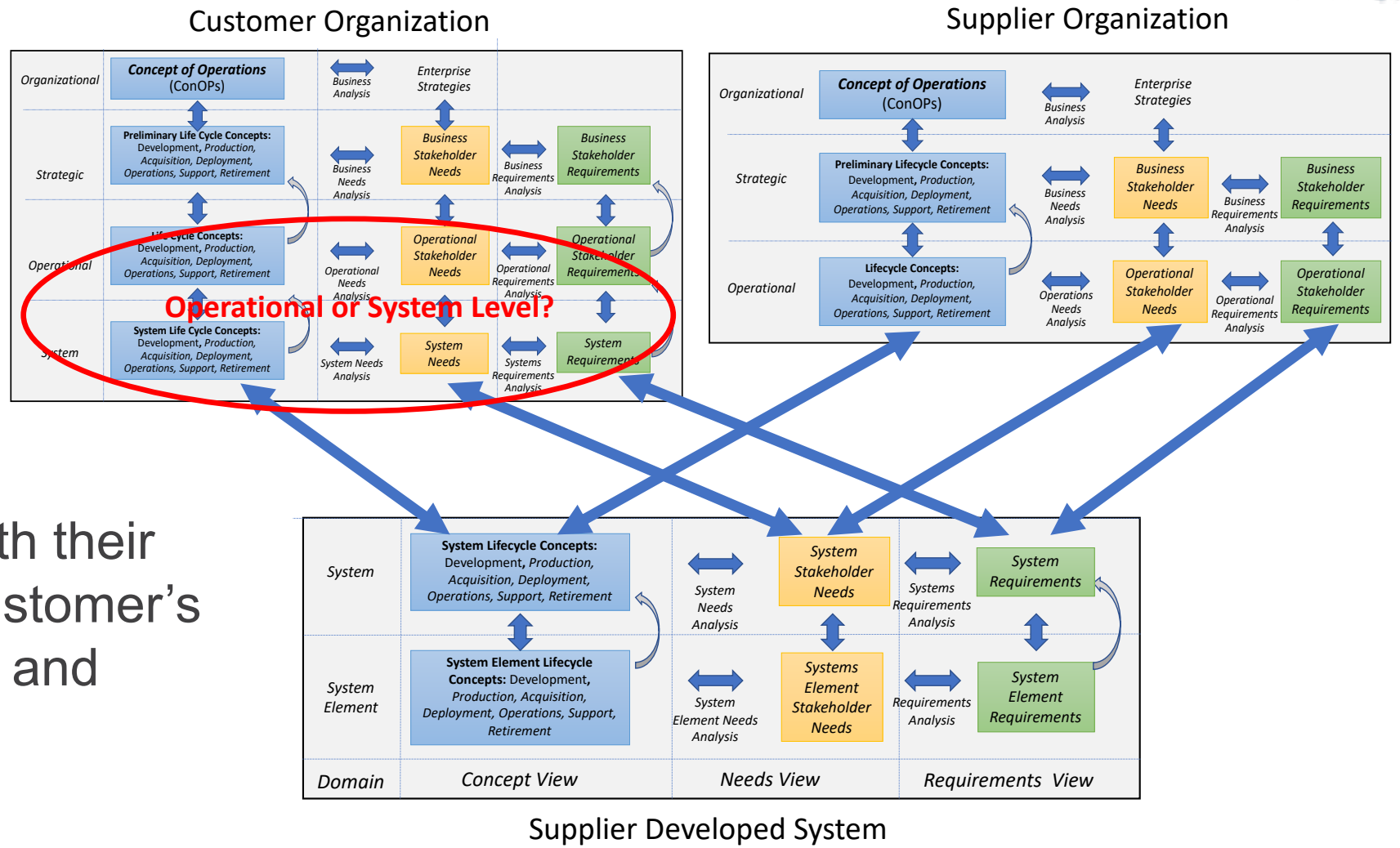
Triad of lifecycle concepts, needs, and requirements at each level

Operational Level Expanded



Portfolio of products and services

Supplier Developed Systems



Supplier Developed System

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

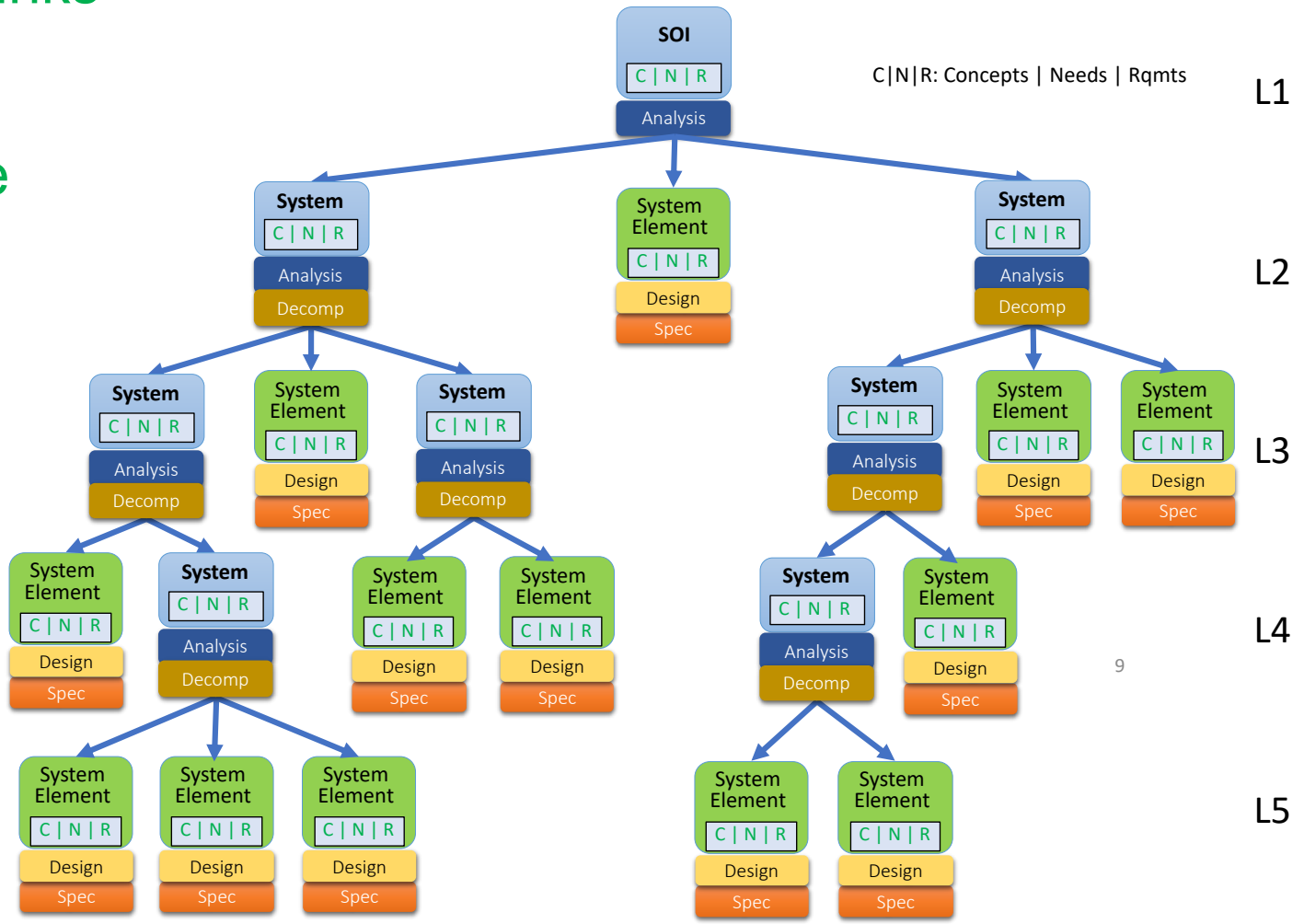
Levels of a System – Hierarchical View

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

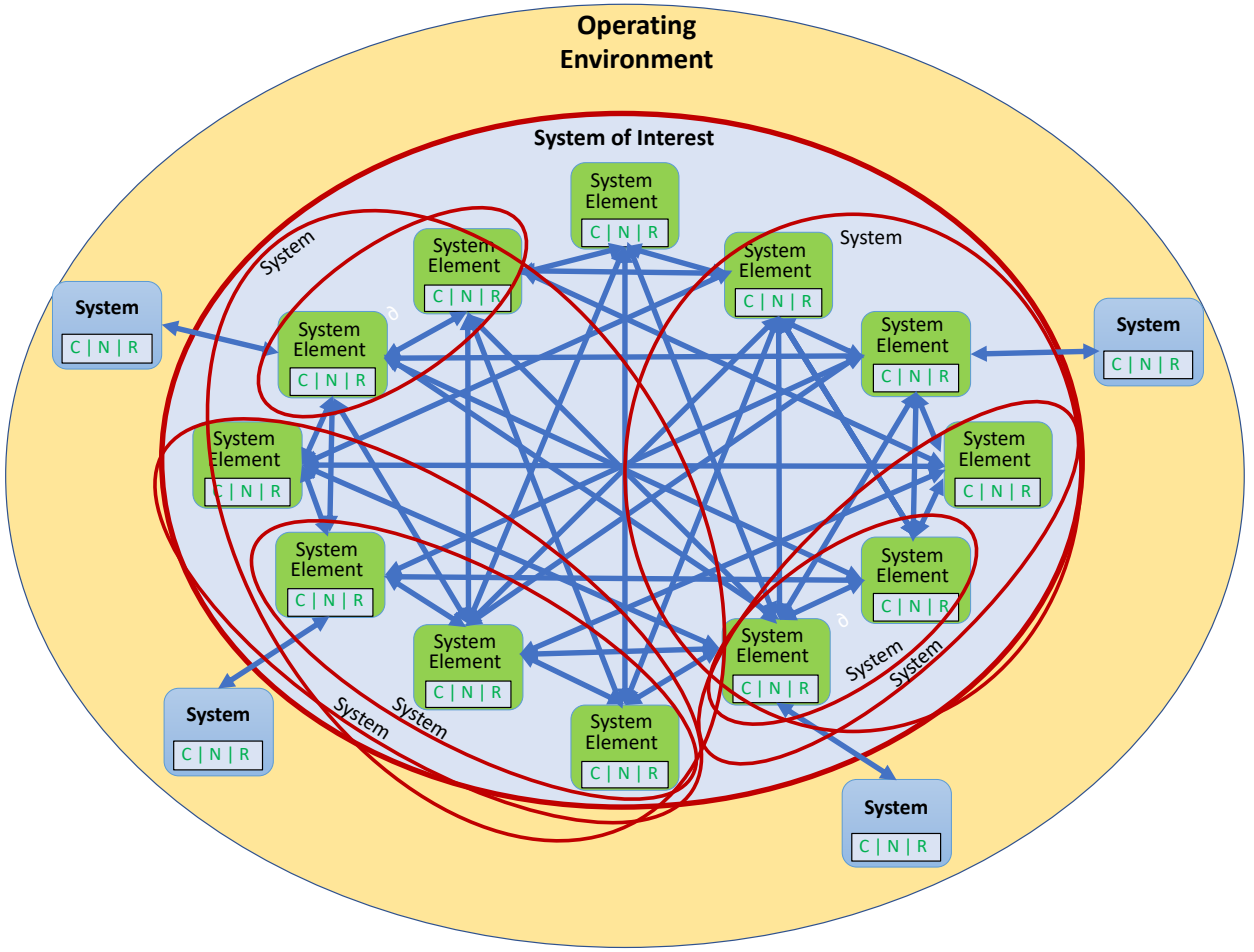
Interactions (Interfaces) not shown in this view

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



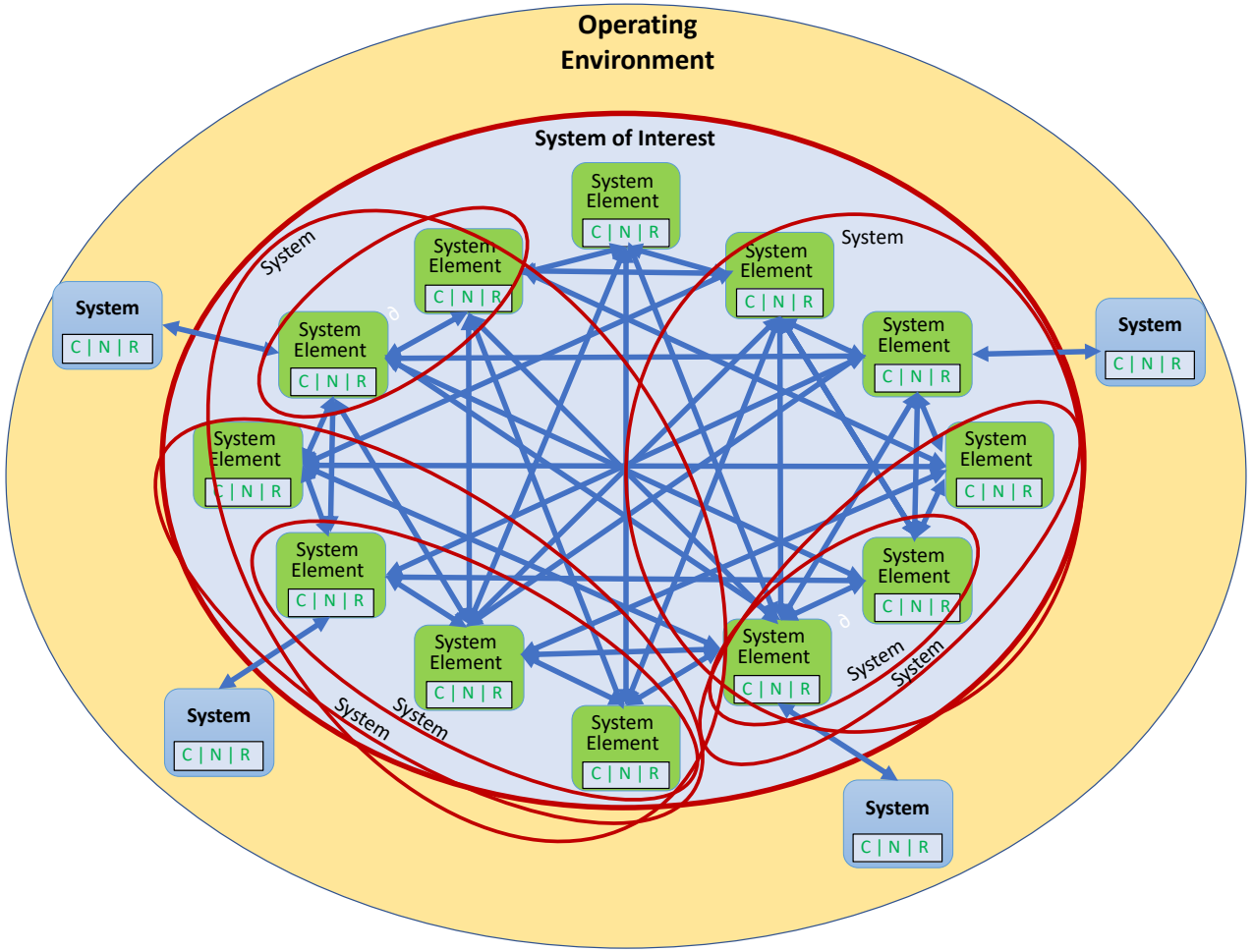
Focus on behavior and emerging properties of the integrated SOI based on interactions between the systems and system elements that make up the SOI, as well as interactions with external systems and the operational environment.

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.

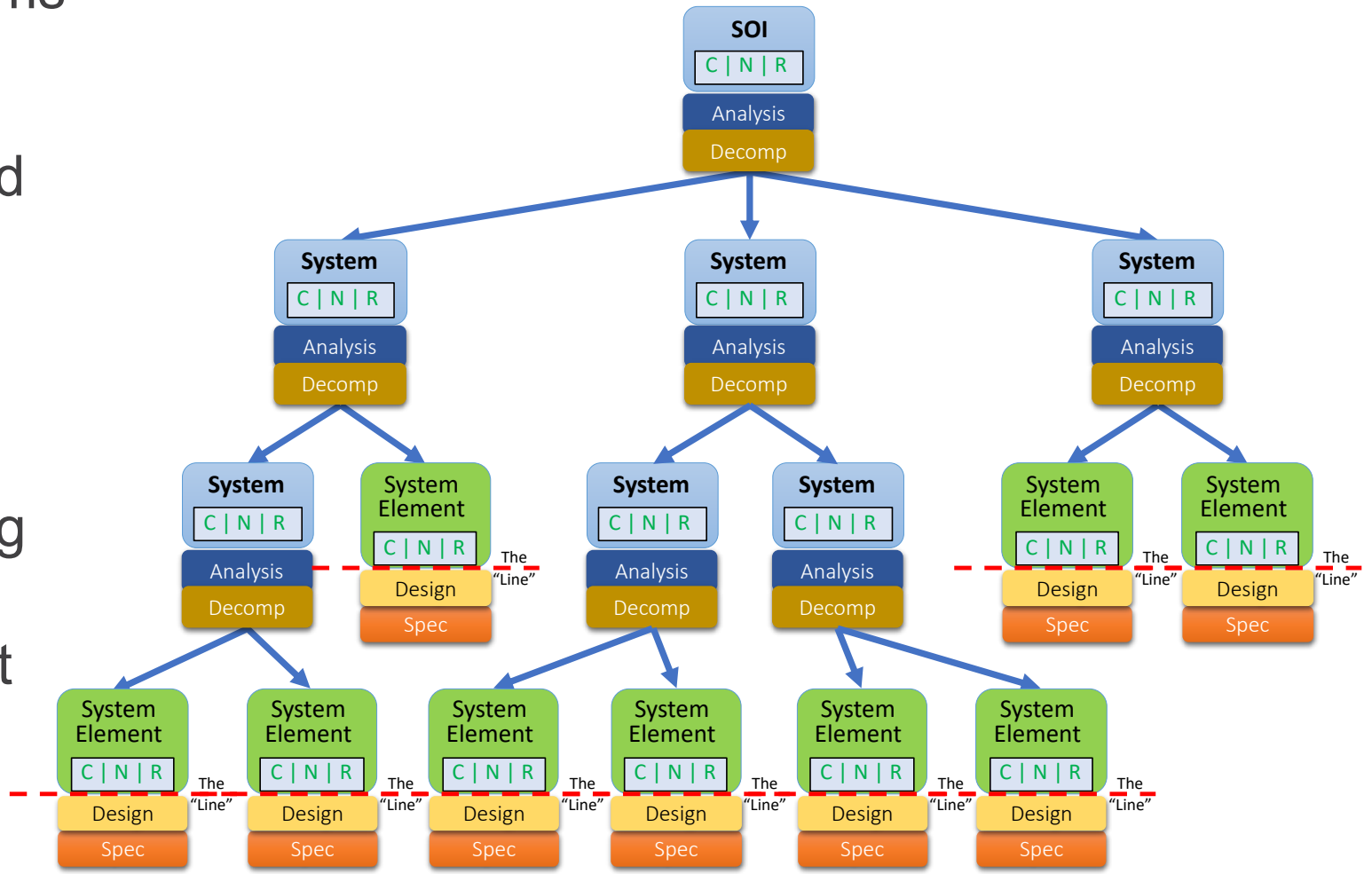


The Concept of “The Line”

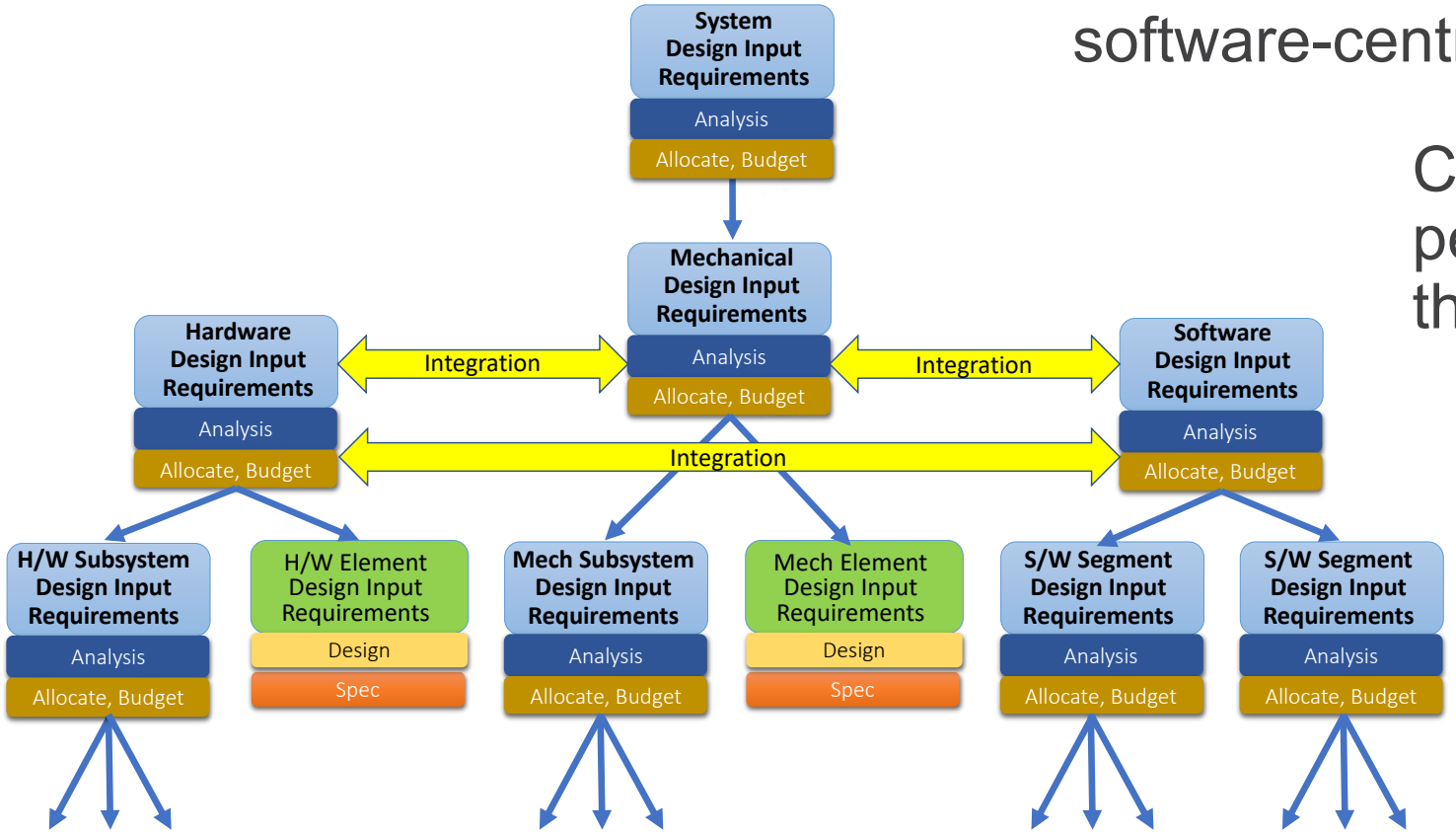
A SOI is decomposed into systems and system elements.

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

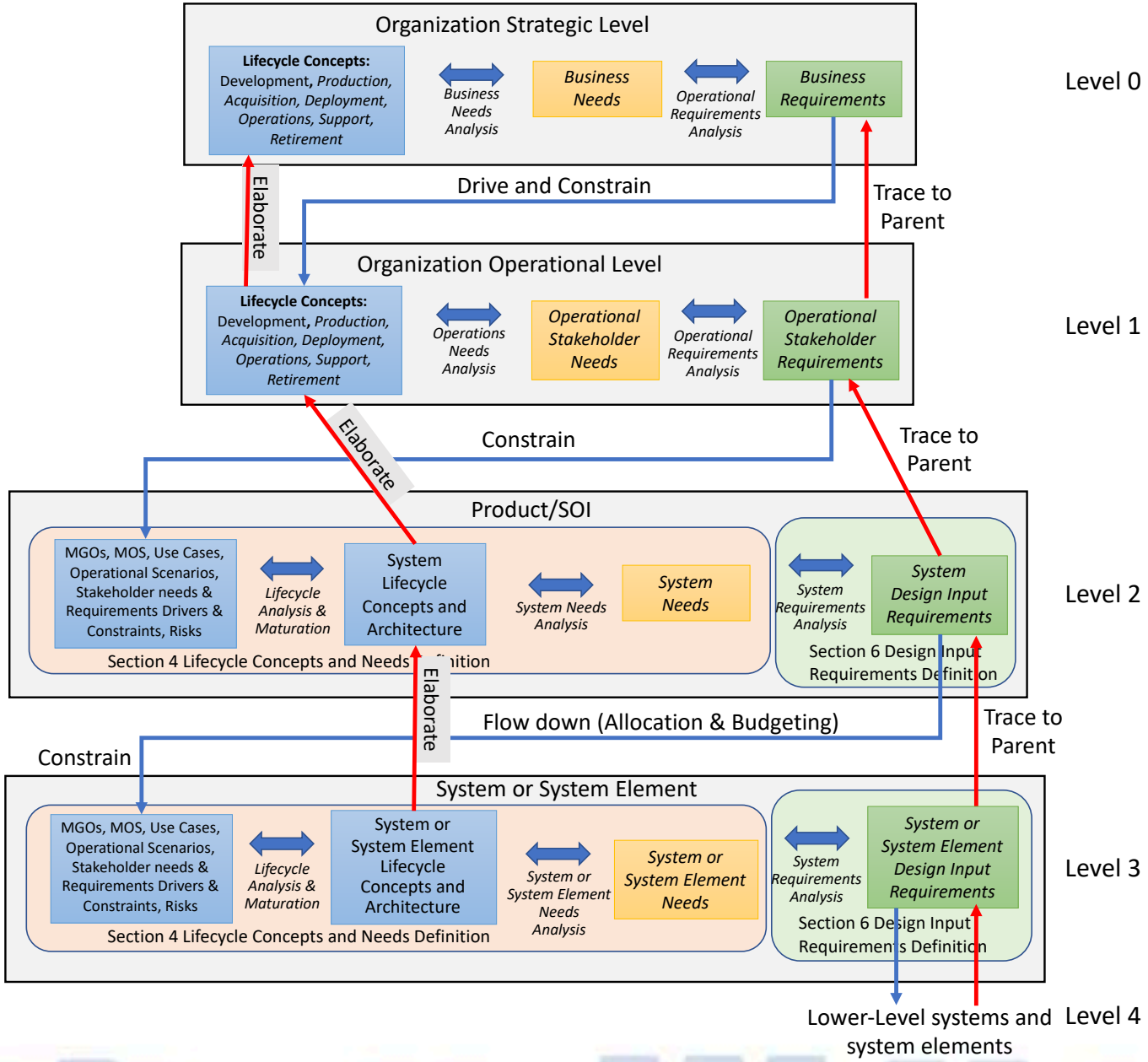


Classical decomposition and architecture for hardware-centric systems not well suited for software-centric systems.

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.

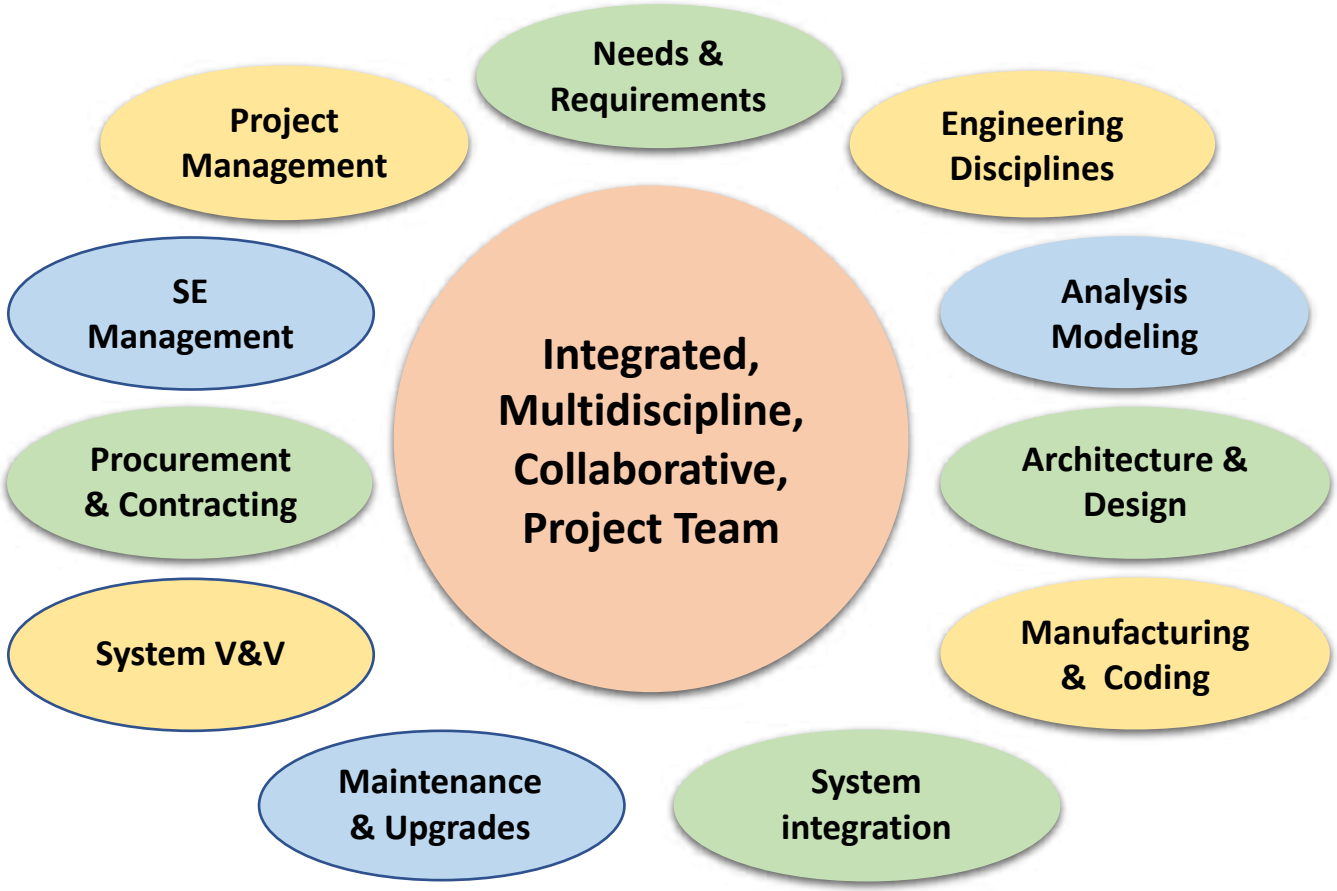


Moving Between Levels

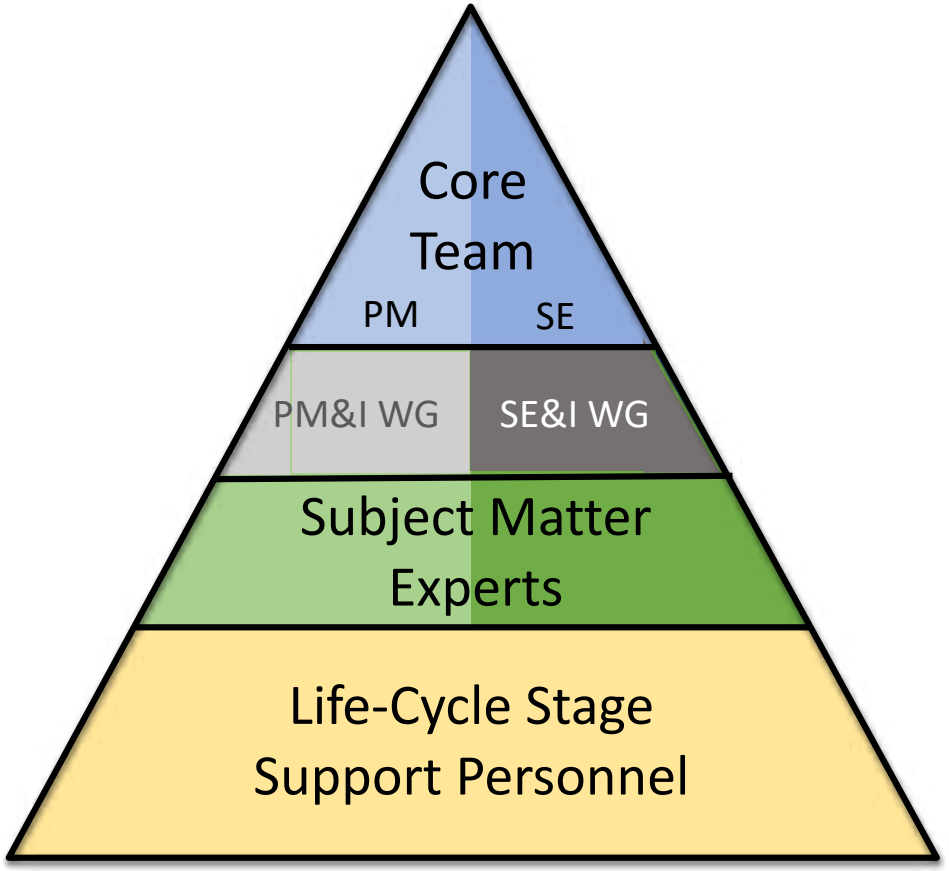
Integrated, collaborative, multidisciplined project team – no silos!

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

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

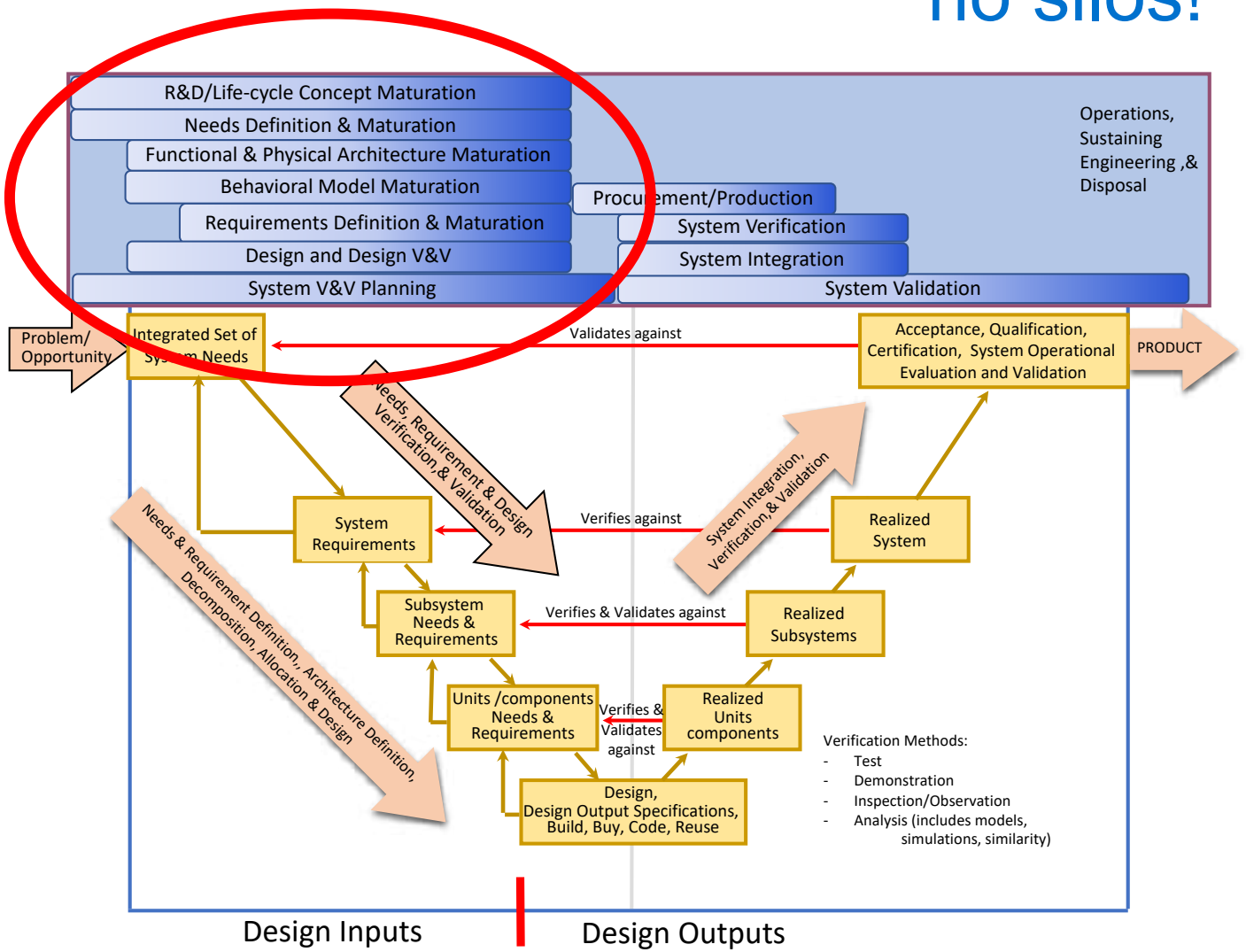


Integrated, collaborative, multidisciplined project team – no silos!



Project Team Organization

Integrated, collaborative, multidisciplined project team – no silos!



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

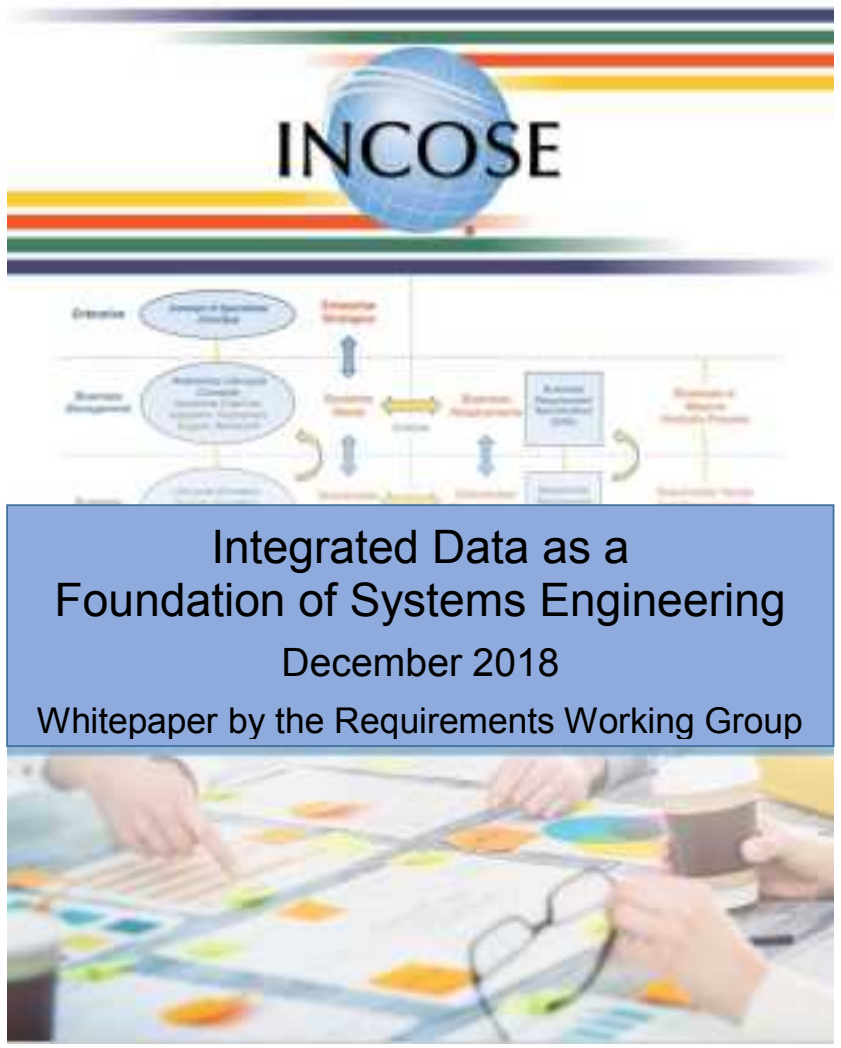
Concurrent Analysis, Maturation, Definition

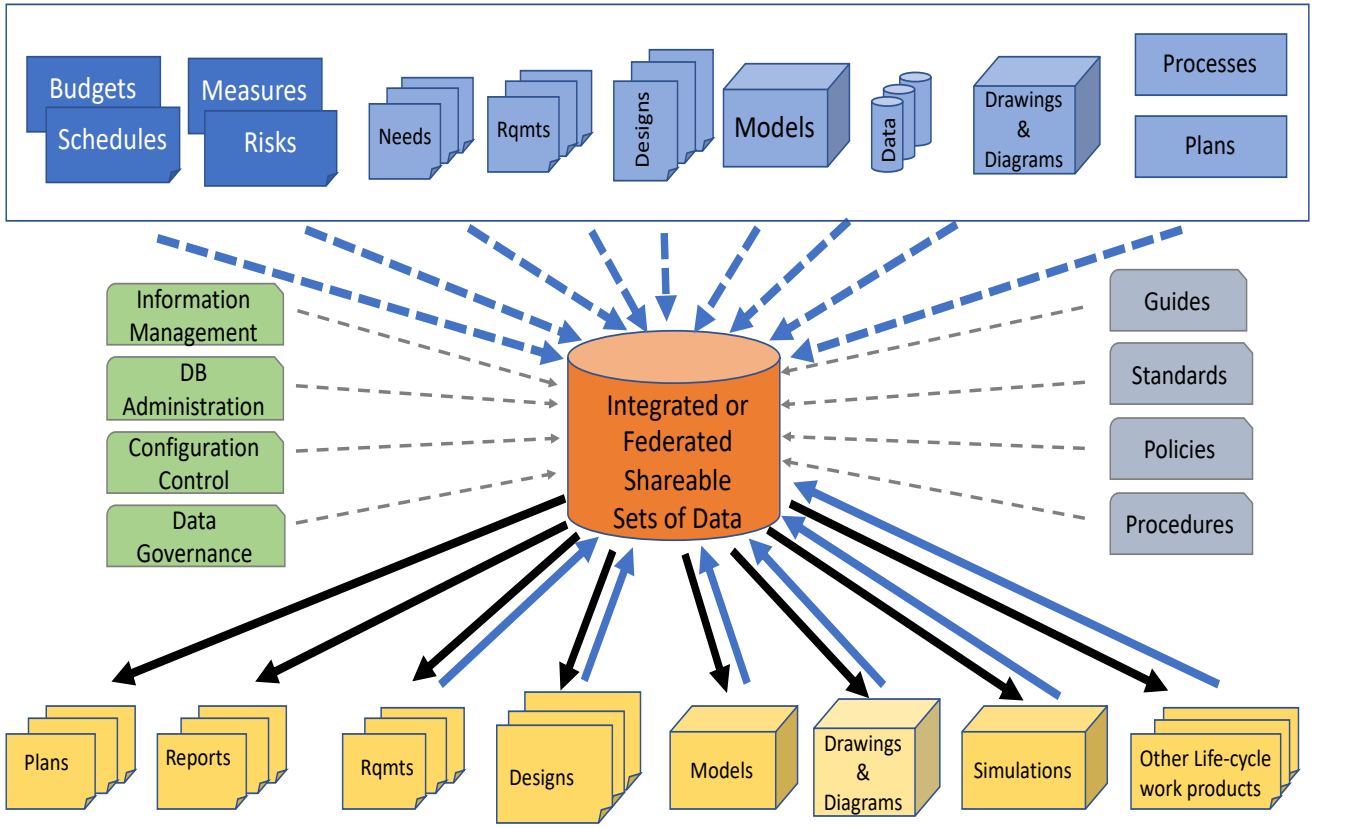
Faster and cheaper than classical waterfall/serial process, with silos

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

Data-Centric practice of Systems Engineering

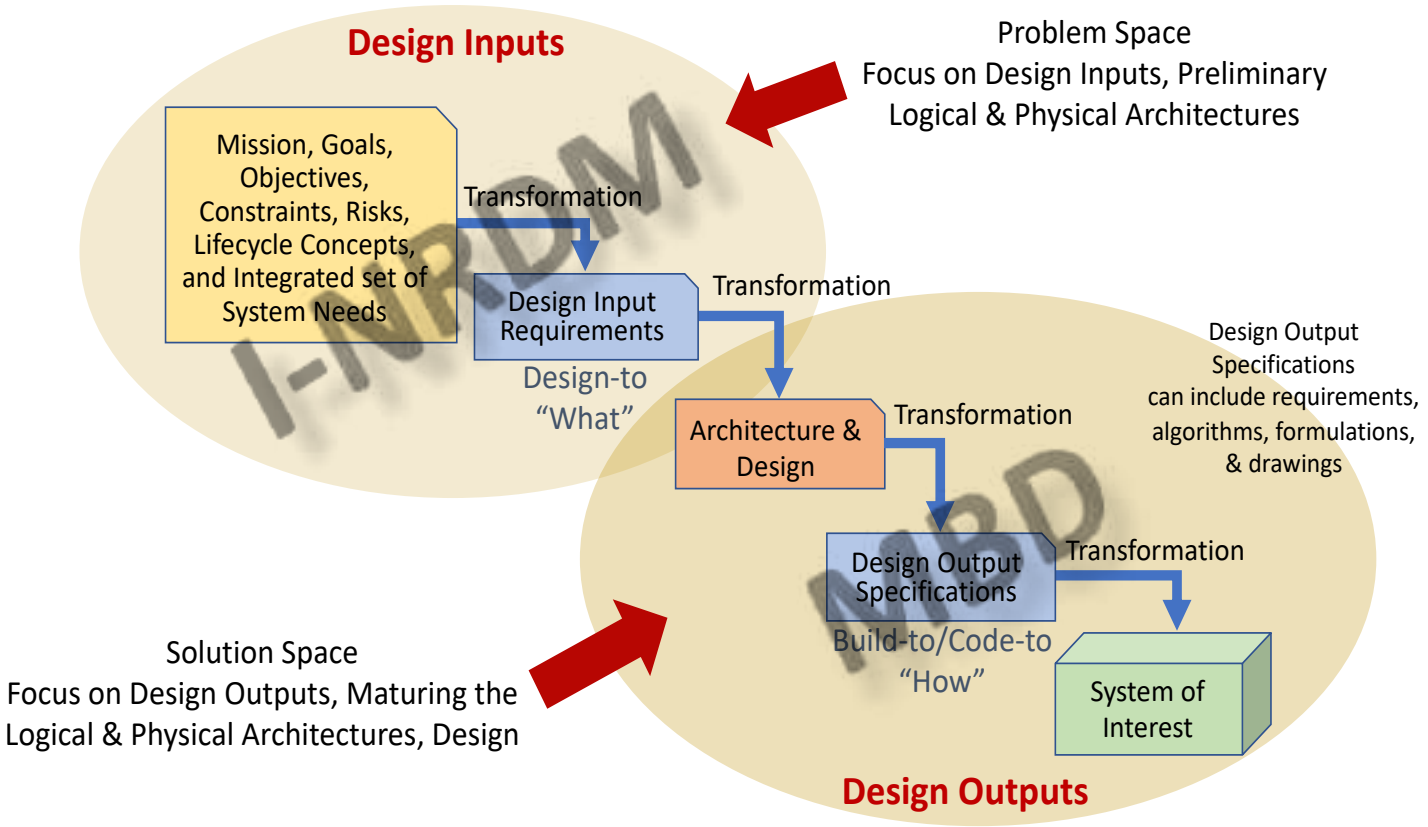
Data-Centric practice of Systems Engineering





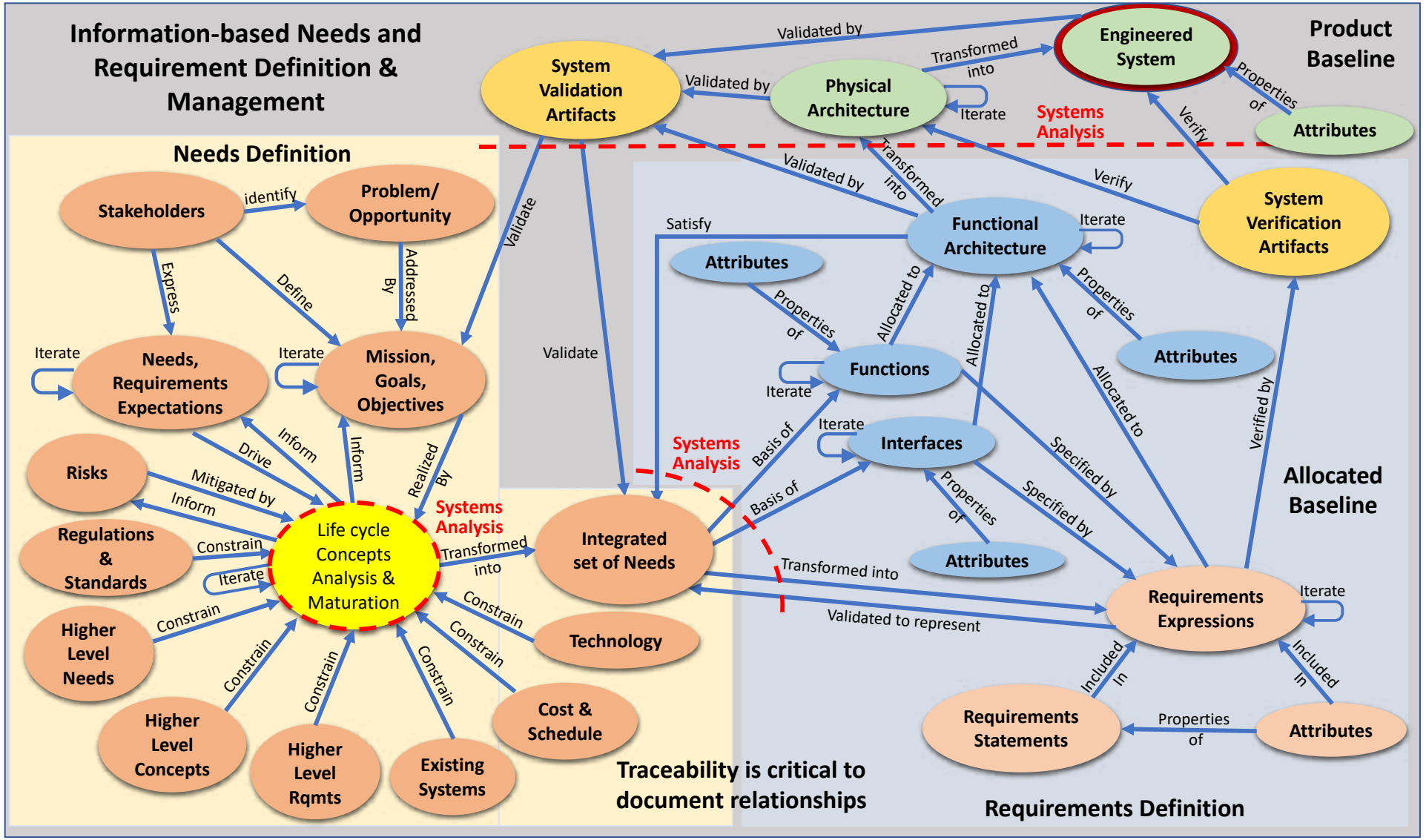
Original Developed by INCOSE RWG at IW 2017

Data-Centric practice of Systems Engineering



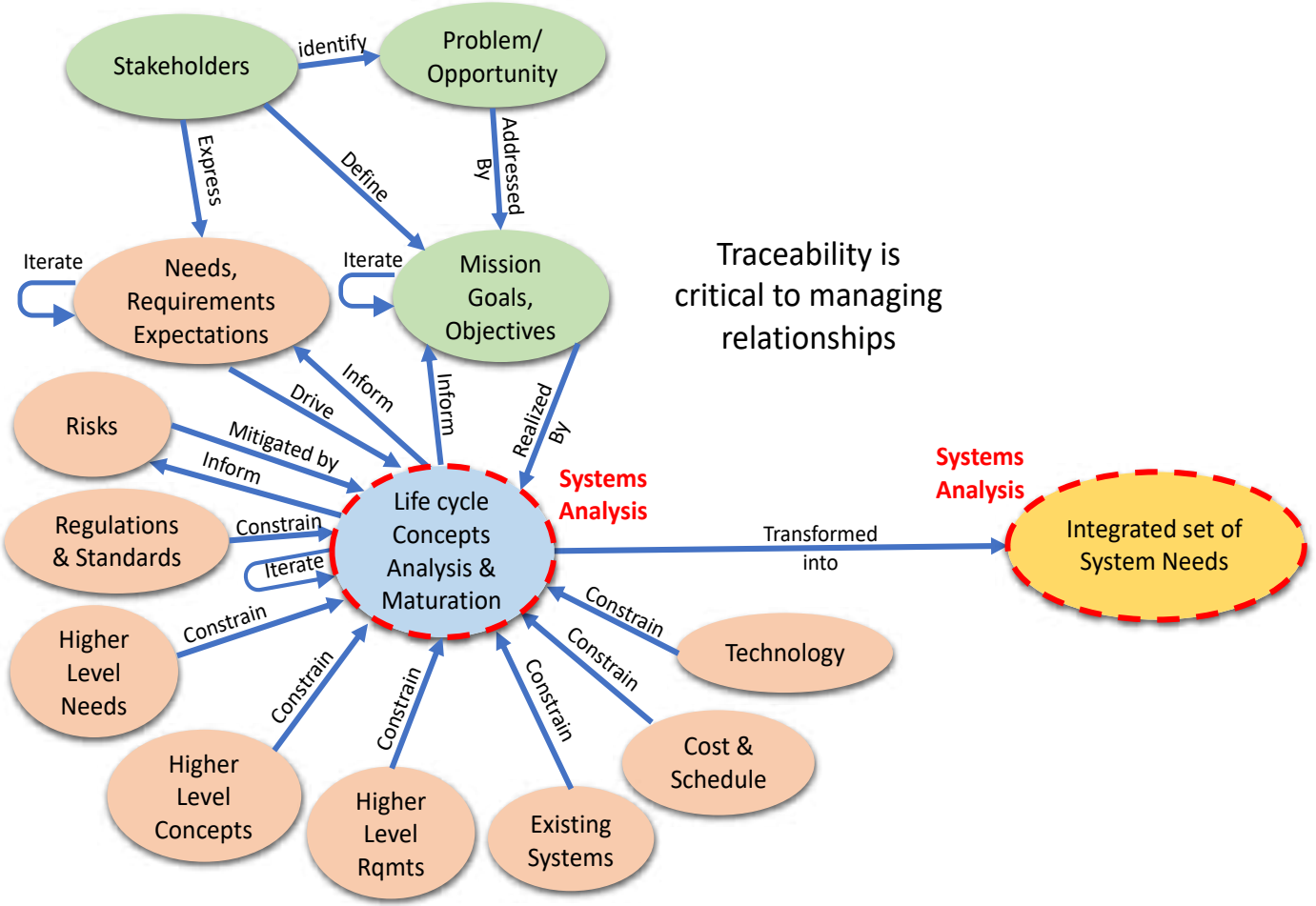
I-NRDM + MBD = MBSE

Data-Centric practice of Systems Engineering



Needs before Requirements

Needs before Requirements



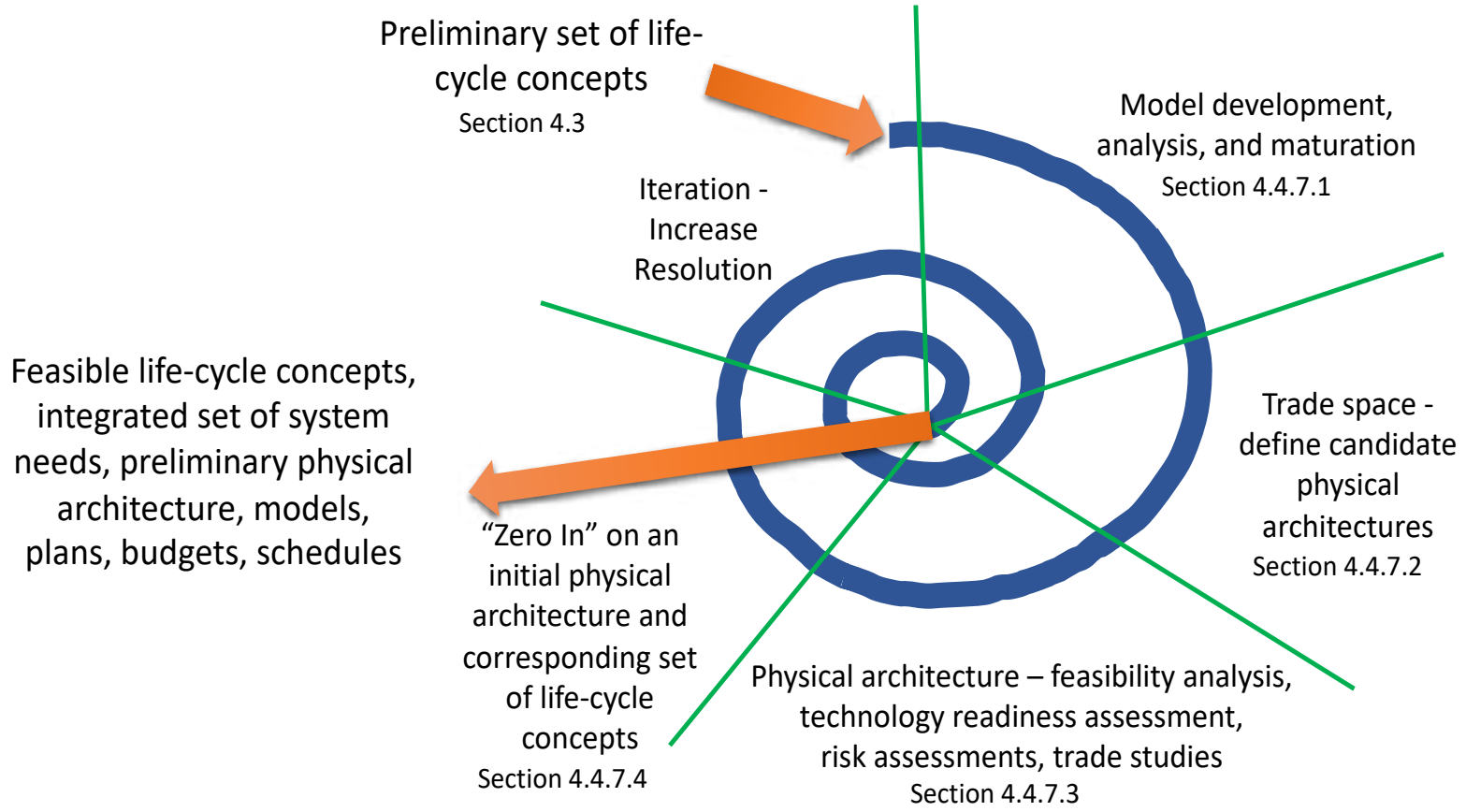
Traceability is critical to managing relationships

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

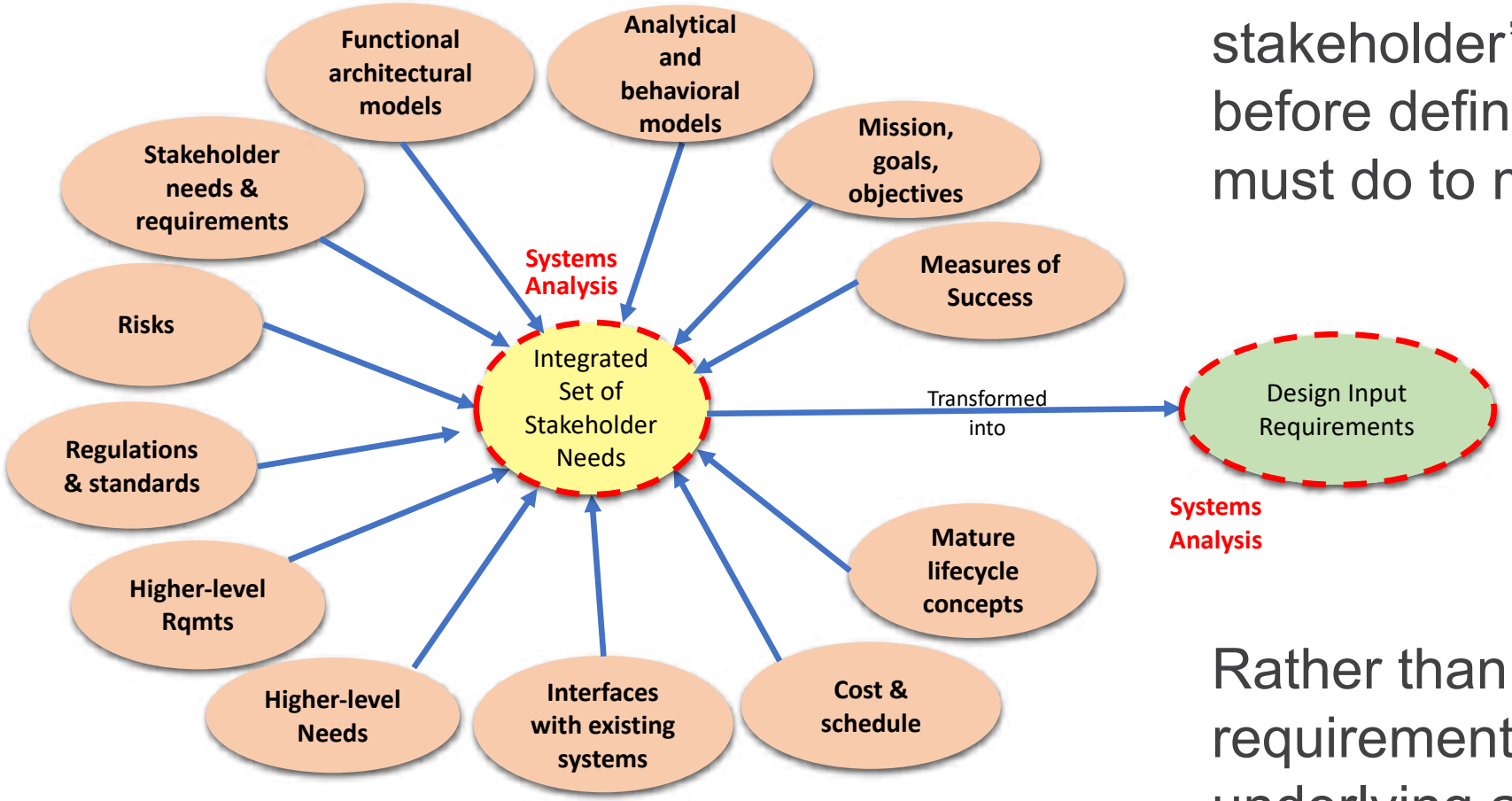
Needs before Requirements

Lifecycle Analysis and Maturation

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



Needs before Requirements



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……

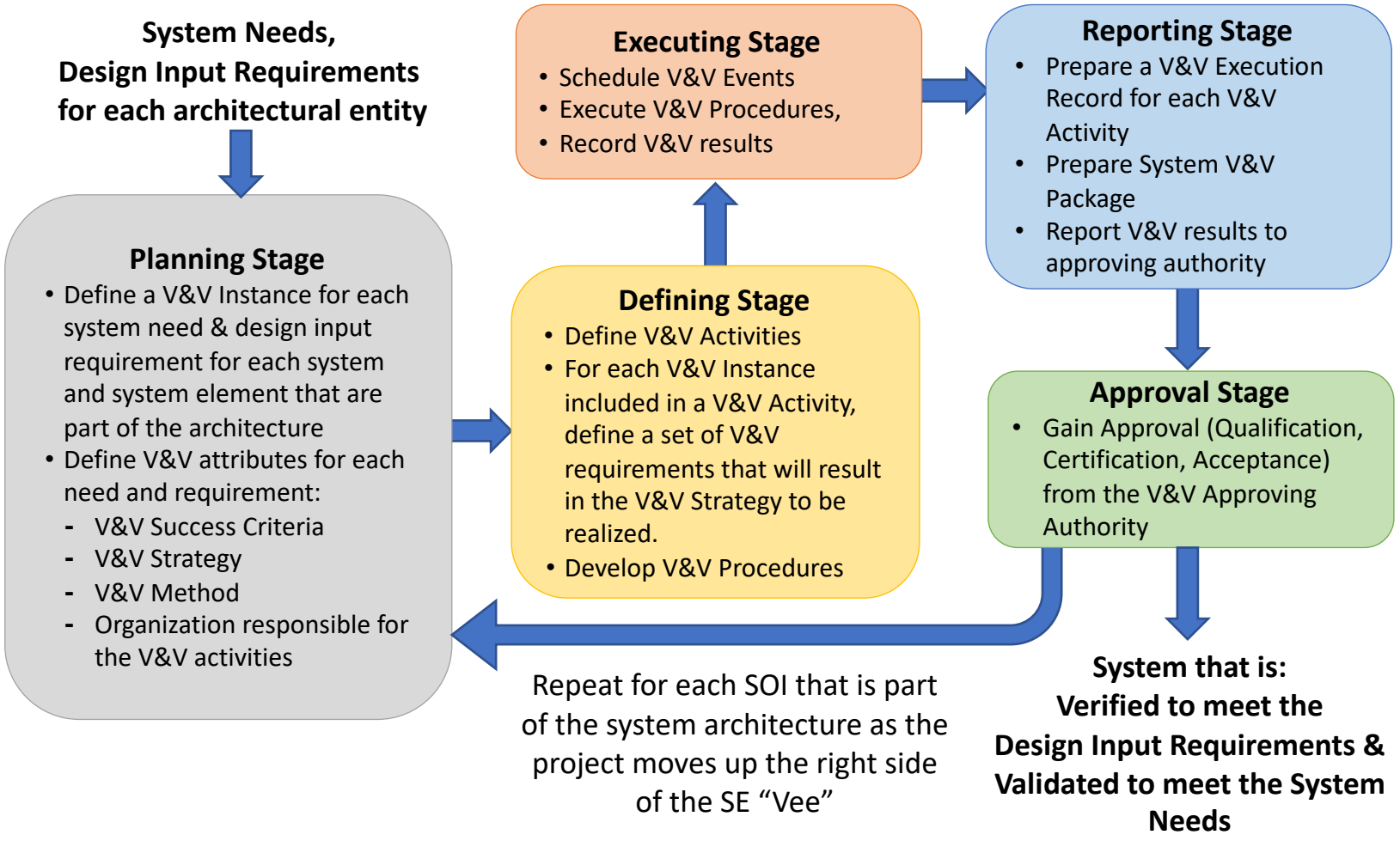
A more rigorous process for verification and validation

- **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 V&V 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 V&V Success Criteria that determines what is ***necessary for acceptance***.

A more rigorous process for verification and validation

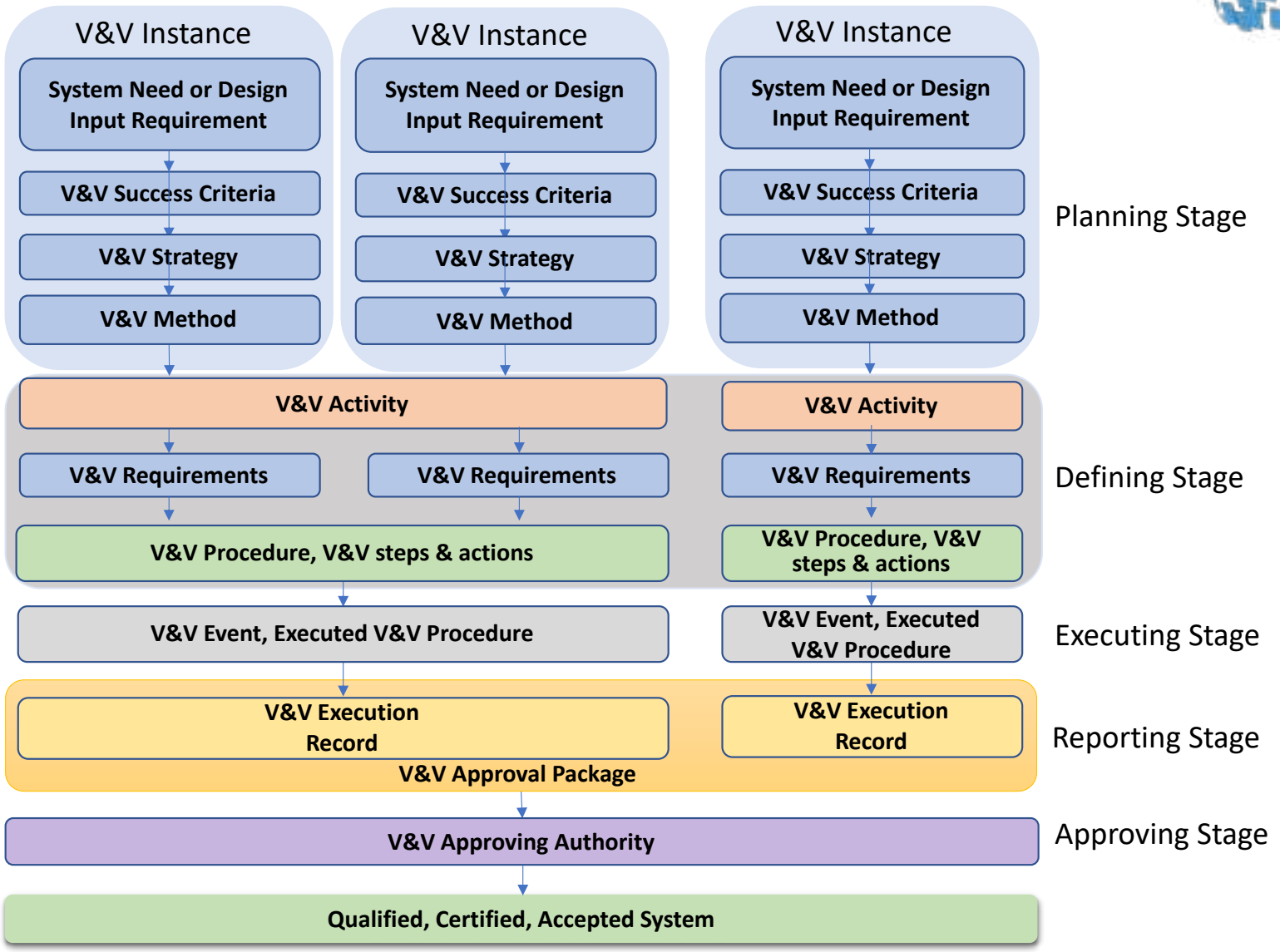
- Attributes that address system validation that should be defined as each need statement is written just as system verification must be addressed as each design input requirement statement is written
  - A6 – System V&V Success Criteria
  - A7 – System V&V Strategy
  - A8 – System V&V Method
  - A9 – System V&V Responsible organization.
  - A10 – System V&V Level
  - A11 – System V&V Phase
  - A12 – Condition of Use
  - A13 – System V&V Results
  - A14 – System V&V Status

A more rigorous process for verification and validation



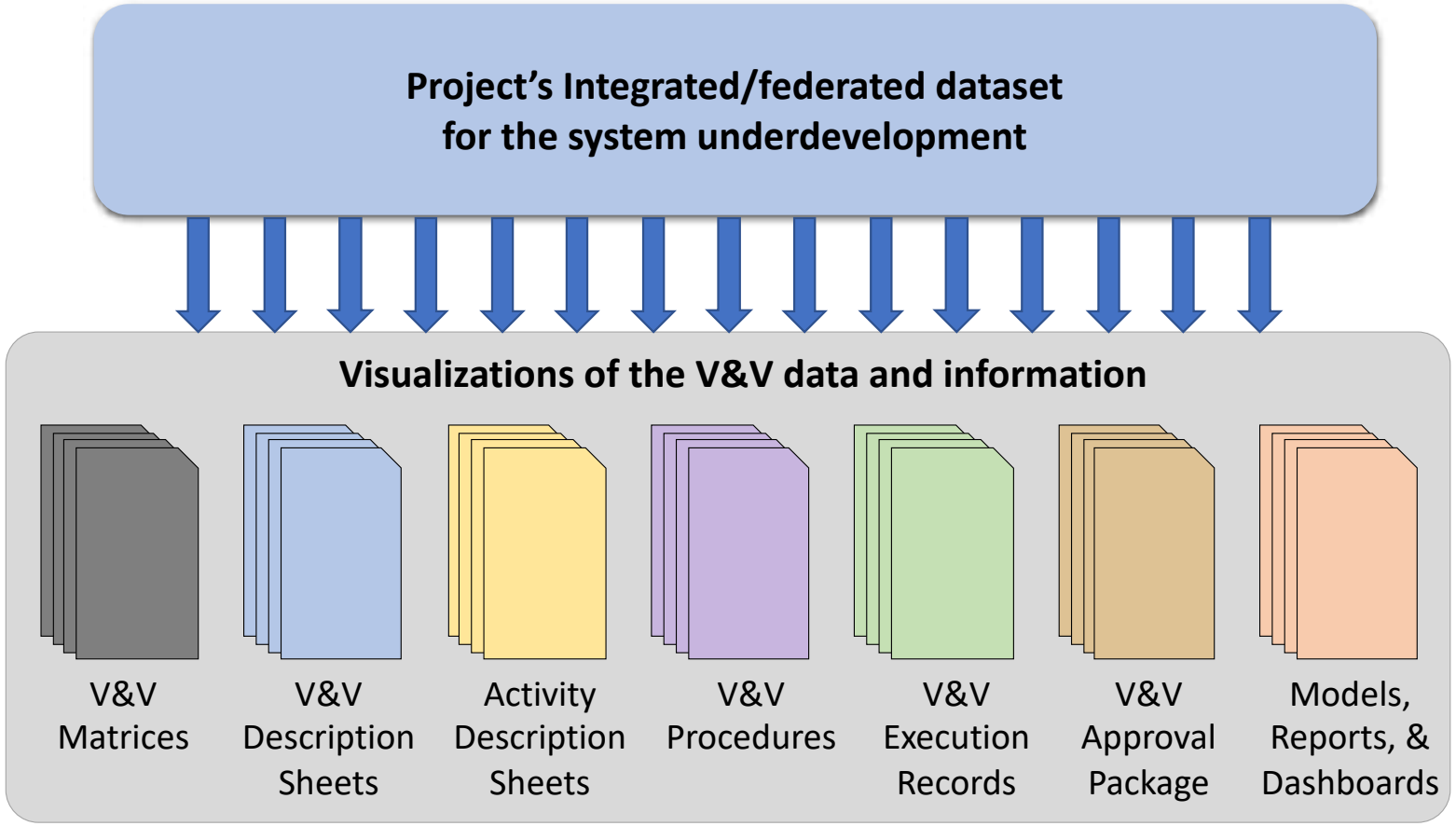
A more rigorous process for verification and validation

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



A more rigorous process for verification and validation

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



Questions and Discussion

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

www.incose.org/IW2021