# Lifecycle Concepts and Needs Definition Overview

Needs & Requirements Manual Section 4
Guide to Needs & Requirements Section 2

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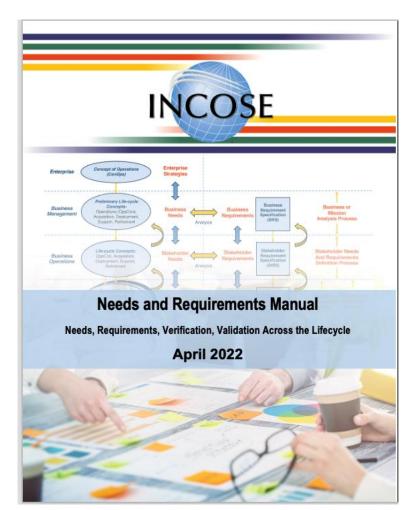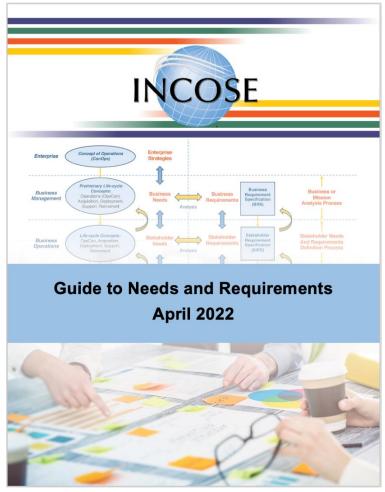# Lifecycle Concepts & Needs Definition

This presentation reflects current best practices as defined in the INCOSE Requirement Working Group (RWG) latest products that are more appropriate for today's increasingly complex, software centric systems.

Focus is on
- lifecycle concept definition, analysis, and maturation
- defining an integrated set of needs

**Covers Sections 4 & 5 of the NRM and Section 2 of the GtNR**

# Introduction

- Supplements and elaborates on the INCOSE SE HB, *Stakeholder Needs and Requirements Definition* & *Systems Requirements Definition* Process activities.
    - Provides more detailed guidance on the what, how, and why concerning lifecycle and needs definition and management across the lifecycle.
    - Addresses ambiguity and inconsistencies in ontology concerning needs and requirements definition and management.
- Focus is on lifecycle concepts and needs definition against which the SOI will be validated against.
- Project success is based on successful system validation - validating that
    - the realized physical, integrated SOI meets its intended purpose/use as defined within the integrated set of needs;
    - identify and assess its behavior and emerging properties in its actual operational environment when operated by its actual intended users;
    - does not enable unintended users to negatively impact the intended use of the system nor allow unintended users to use the system in an unintended way

**It is assumed the organization has moved to a data-centric practice of SE.**
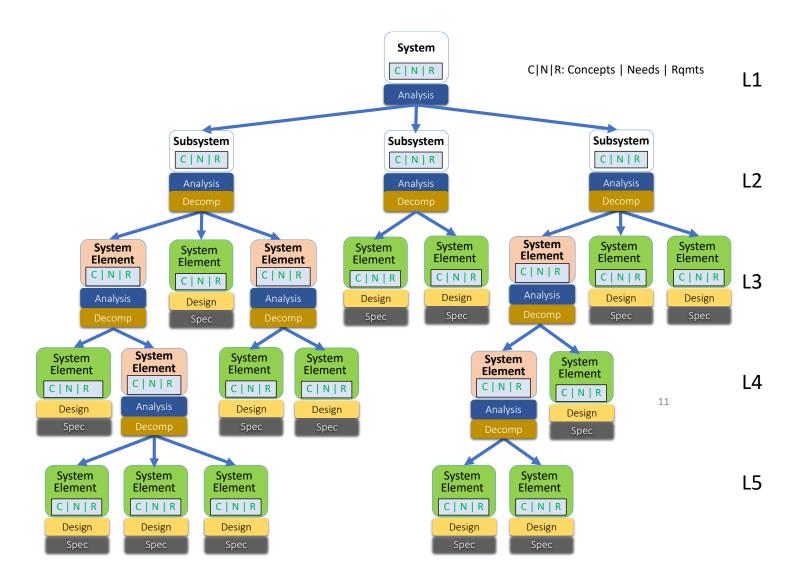
# Needs vs Requirements

- Needs represent the stakeholder, customer/acquirer view of the system of interest (SOI)
  - What do the stakeholders need the system to do that will result in their problem to be solved or opportunity to be realized within defined constraints?
  - Communicates the stakeholder expectations for the end-state once the SOI is delivered – in the end **what will make the customer happy**?
  - The SOI will be <u>validated</u> against its <u>integrated set of needs</u>

- Requirements represent the technical, developer view of the SOI
  - What must the SOI do in order to meet the needs?
  - The SOI will be <u>verified</u> against its <u>design input requirements</u>

*The quality of the requirements is dependent on the quality of the needs from which they are transformed.*

# Hierarchical Architecture View



C|N|R: Concepts | Needs | Rqmts

Classic SE decomposes systems into lower-level subsystems and system elements

Lifecycle concepts, needs, and requirements are defined for each entity within the system architecture
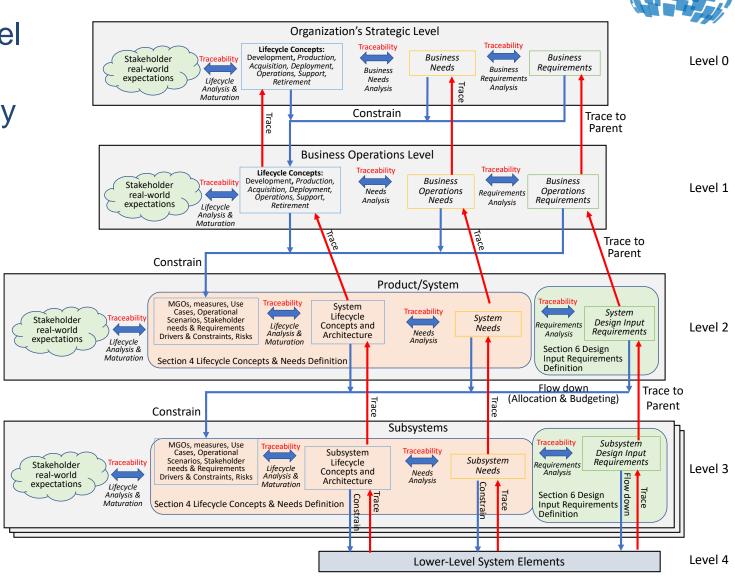
Decomposition stops when no further elaboration is needed for the project to make a build, buy, code, or reuse decision.

# Moving Between Levels

There are stakeholders at each level who have real-world expectations concerning a problem or opportunity and expected outcomes.

Lifecycle Concepts, Needs, and requirements are defined for entities at each level to address those expectations.

Lifecycle concepts, needs, and requirements at one level constrain the lifecycle concepts, needs, and requirements for each entity at the next level of the architecture.

# Project Success
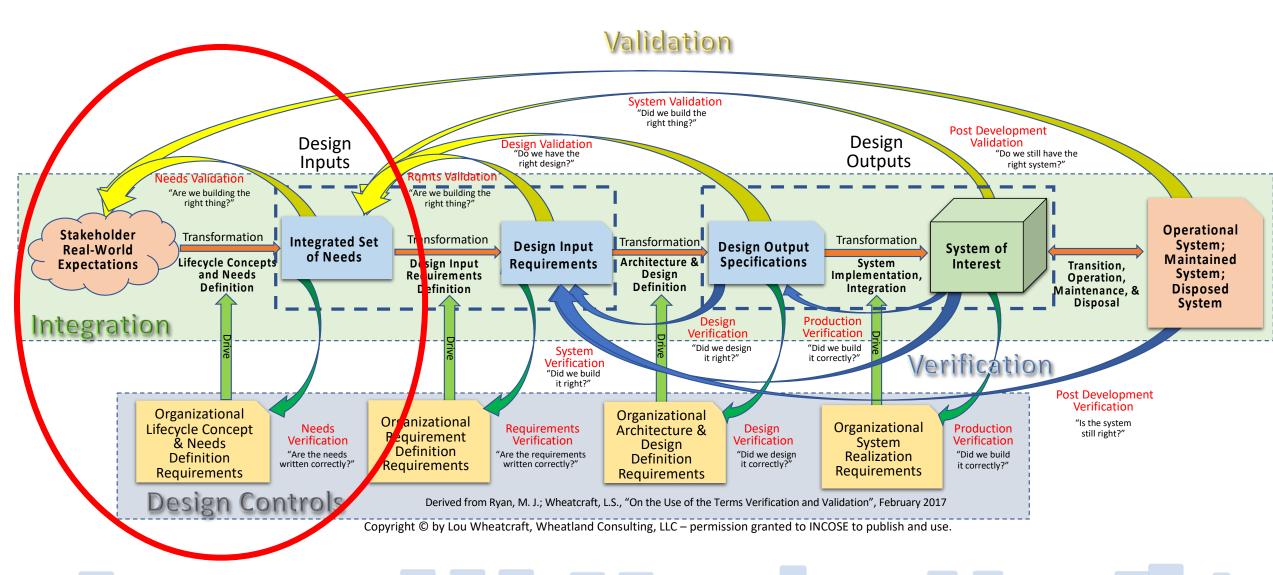
- Depends on the project team understanding:

  - The source of concern, problem/opportunity, higher-level lifecycle concepts, higher-level needs, and higher-level requirements that constitute acceptability or desirability of a solution (what?), measures (how well?), and the conditions in which the SOI must operate (in what operating environment?)

  - This understanding is required no matter the level a SOI exists.

- This knowledge allows lifecycle concepts for the SOI to be defined, analyzed, and matured and a formal integrated set of needs defined, agree-to, and baselined.

- There is a lot of work to be done before developing a set of design input requirements to which the system will be designed and built/coded.

**A primary reason for project failure, is a failure to recognize the need for and doing this upfront work.**
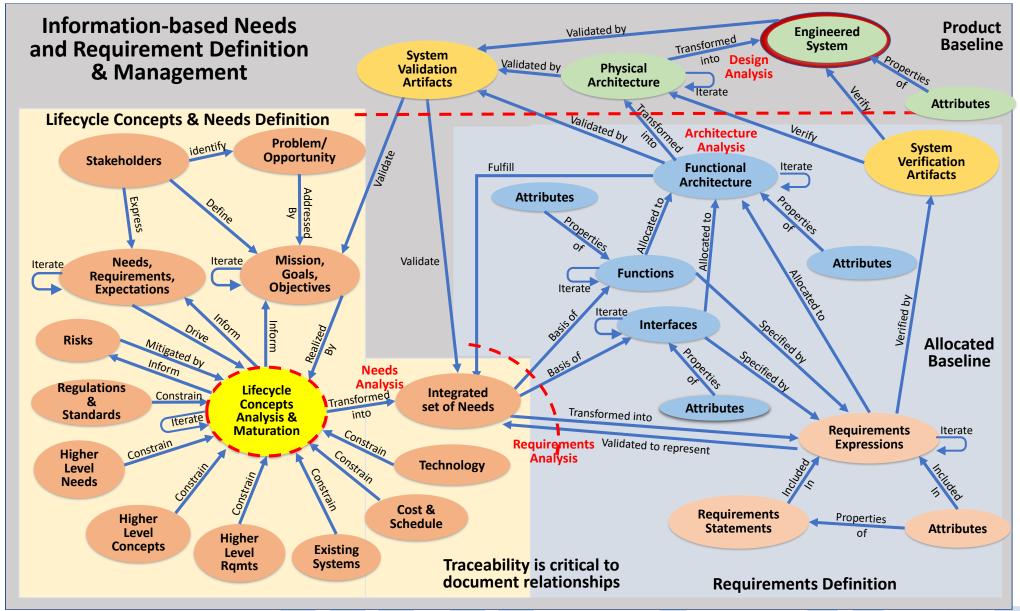
# Verification and Validation in Context



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

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# Data-Centric Practice of Systems Engineering

# IPO Diagram

## Inputs

- Problem or opportunity
- MGOs and measures
- Stakeholders
  - Customer (internal and external)
  - Business Operations
  - Users
  - Regulatory agencies
  - Approving Authorities
  - Other internal stakeholders
  - Other external stakeholders
- Drivers & constraints
  - External systems
  - Enabling systems
  - Standards & regulations
  - Higher level requirements
  - Operating environment
  - Technology maturity
  - Budget & schedule
- Risks

## Lifecycle Concepts & Needs Definition Activities

- Prepare for Lifecycle and Needs Definition
- Define Inputs to Lifecycle Concepts Analysis and Maturation
- Document Preliminary, Integrated Set of Lifecycle Concepts
- Lifecycle Concept Analysis and Maturation
- Define and Record the Integrated Set of Needs
- Plan for System Validation
- Baseline and Manage Needs Definition outputs

## Enablers

- Enterprise tailored Guide for Writing Needs & Requirements
- Enterprise tailored process for developing & managing needs & design input requirements
- Enterprise tailored Guide for system verification and system validation
- Enterprise product development process
- Trained systems engineers
- Project toolset
- Stakeholder representation

## Outputs

- **Draft Integrated Set of Needs**
- Risks, Risk Management Plan
- Set of feasible lifecycle concepts.
- Functional architectural and analytical/behavior models
- Preliminary physical architecture
- Technology Readiness Assessment and Technology Maturation Plan
- Design and system validation planning artifacts
- Draft PM & SE management plans, WBS, PBS, budget, schedules
- For each need:
  - Traceability to each source
  - Traceability to system validation planning artifacts

# Activities Involved



Traceability and Feedback

**Define Inputs to System Lifecycle Concept Analysis & Maturation**
**Section 4.3**

# Activities Involved – part 2



Traceability and Feedback

**System Lifecycle Concept Definition**
- Capture Preliminary Integrated Set of Lifecycle Concepts — Section 4.4
- Lifecycle Concepts Analysis & Maturation — Section 4.5

**Needs Definition Section 4.6**
- People Needs — Section 4.6.1
- Processes (Procedures) Needs — Section 4.6.1
- People Requirements Project Plans SOWs * 
- Process Requirements Procedures, Work instructions*
- Define and Record the Integrated Set of Needs — Section 4.6.2

* Not included in this manual

Alternate non I-NRDM Path

- Plan for System Validation — Section 4.7
- Verify & Validate the Integrated Set of Needs — Section 5.0
- Baseline and Manage Lifecycle Concepts & Needs Definition Outputs — Section 4.8 / Section 14.0

- Design Input Requirements Definition — Section 6.0
- Needs, Requirements, Verification, and Validation Management — Section 14.0

# 4.3.1  Define the Problem, Threat, or Opportunity

- Enables the project team to understand why the project is worth doing, the system is needed, and the capabilities, functions, performance, and features that are important to the customers, users, and operators of the system.

- The steps to defining the problem or opportunity include:

  1. Identify the organization's strategic and business operations level stakeholders that are impacted by the problem or threat or those who will benefit by pursuing the opportunity.

  2. Work with of these stakeholders to understand how they are impacted by the problem or threat or those that will benefit by pursuing the opportunity.

  3. Clearly define a statement of the problem, threat, or opportunity.

  4. Get stakeholder agreement for the problem, threat, or opportunity statement.

# 4.3.2 Define Mission, Goals, Objectives, & Measures

- The **mission statement** defines the "why" - why does the project exist? What does the organization's strategic and business operations level stakeholders or the customer need to be accomplished? "What is the expected outcome?"

- **Goals** are elaborated from the mission statement communicating those things that need to be achieved that will result in achieving the mission.

- **Objectives** are elaborated from the goals providing more details concerning what must be done to meet the goals that will result in the mission to be achieved.

- **Measures** are used to both validate the objectives against as well as to manage system development across the lifecycle.

**Achievement of the MGOs and measures should result from the achievement of the integrated set of needs defined for the SOI.**

# 4.3.3   Identify External and Internal Stakeholders

- Stakeholders are the primary source of needs and requirements

- The choice of a relevant set of stakeholders is critical for being able to determine the completeness and correctness of the integrated set of needs and resulting design input requirements.

- Stakeholders are any individual or organization with a personal stake in the SOI, who may be affected by the SOI, who will participate in the development of the SOI, are able to influence the definition and development of the SOI, or with whom the project team will interact across the SOI lifecycle.

- A key part of stakeholder identification is to determine who the **Approving Authorities** are within the group of stakeholders.

- There can be many stakeholders for a SOI over its lifecycle; therefore, considering the lifecycle concepts across the lifecycle provides a thorough source for stakeholder identification.

**It is important to go beyond just users and the customer – rather that voice of the customer (VOC), think VOX**

# 4.3.4 Elicit Stakeholder Needs & Stakeholder-owned Requirements

- Engage the stakeholders to understand their needs and technical requirements for the SOI not only just during operations but for all lifecycle stages.

- The elicitation activities allow the project team to discover and understand what is needed, what processes exist, how stakeholders interact with SOI, what happens over the SOI's lifecycle - good and bad, what states and transitions the SOI might undergo or experience during use, nominal, alternate-nominal, and off-nominal operations, and other considerations.

- Each stakeholder has a unique perspective in terms of concerns, problems, challenges, issues, risk, opportunities, experience, failures, and successes.

- During elicitation, the project team should collaborate with the stakeholders to understand the source and context (rationale) of their stated needs and requirements.

- Techniques and methods used during elicitation include brainstorming, workshops, focus groups, interviews, document analysis, interface analysis, prototype analysis, observations of like products, questionnaires, site visits, models, and diagrams.

**Successful elicitation results from proper planning on the methods and identification of the types of information to be obtained and specific questions to ask that will result in that information.**

# 4.3.5 Document Elicitation Outcomes

- It is critical that all the information obtained from the elicitation activities be recorded *in the SOI's integrated dataset*.
- The form will vary depending on the type of product, product development approaches, and tools used to record the information.
- There will be many issues with the information obtained during elicitation:
  - Uncertainty as to the expected results,
  - Ambiguity as to what is really being communicated
  - Incomplete, inconsistent, conflicting information
  - How (implementation) vs What (design input)
  - Implicit vs explicit needs and requirements
  - Questionable feasibility as to what the stated needs and requirements say.

**The project team will have to address these challenges and issues.**

# 4.3.6 Identify Drivers and Constraints

- Design constraints (parts, materials, organizational design best practices, etc.).
- Design standards (industry, domain, business management, business operations).
- Production constraints (existing technology, facilities, equipment, cost, throughput, etc.).
- Human factors (human/machine interface - HMI).
- Regulations (law).
- Operating environment (natural, induced).
- Operating environment (social, cultural).
- Existing systems: (interactions, interfaces, dependencies).
- Technology Maturity.
- Cost.
- Schedule.
- Mission drivers - examples for space missions include launch date, launch vehicle performance, orbit, destination, duration, logistics, crewed/un-crewed, orbital Mechanics, etc.
- Higher-level requirements allocated to the SOI. At the system level, these will be business operations level stakeholder needs and stakeholder-owned system requirements. At lower levels of the architecture, these will be requirements allocated to the SOI from the level above.

**Drivers and Constraints is a major source of requirements**

# 4.3.7   Identify, Assess, and Handle Risk

- As part of the elicitation activities, issues and risk must be identified and assessed.
- Stakeholders should be asked specifically about any issues and risk they think could prevent the SOI to be developed and delivered within budget, schedule, or risk during operations.
- Failing to address risk will result in an incomplete set of needs and resulting design input requirements resulting in a SOI that will fail system validation.
- Classes of risk to be assessed and handled:
    – Management risk
    – Development risk
    – Production risk
    – System Integration, System Verification, and System Validation risk
    – Compliance risk
    – Operational risk
- Risks to be mitigated via the SOI will be a source of needs and requirements

**Traceability across the lifecycle of risks being mitigated by the SOI is critical to final system acceptance for its intended use.**

# 4.4    Capture Preliminary Integrated Set of Lifecycle Concepts

- The results of the proceeding activities are integrated into a set of preliminary set of lifecycle concepts and supporting data.
- The set of lifecycle concepts can include concepts for acquisition, development, design, verification, validation, operations, deployment, support, and retirement concepts.
- These preliminary set of lifecycle concepts and supporting data and information are inputs into the lifecycle concept analysis and maturation activities.
- ConOps/OpsCon
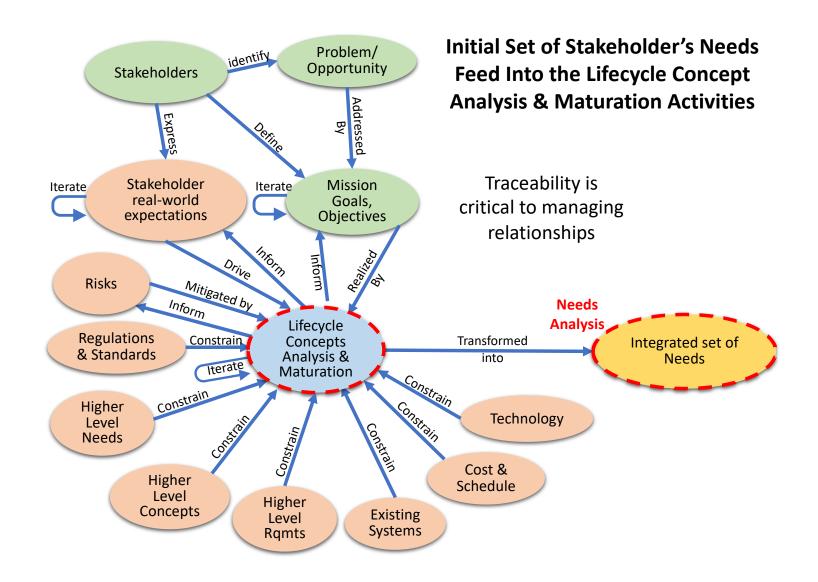
| Stakeholder (S)/ Lifecycle (L) | L1 | L2 | L3 | L4 | L5 |
|---|---|---|---|---|---|
| S1 | X | | X | | X |
| S2 | | X | X | | |
| S3 | X | | X | | X |
| S4 | | X | | X | X |
| S5 | | | X | X | X |
| Combined | XXX | XXX | XXX | XXX | XXX |

Table 4-4: Preliminary Integrated Set of Lifecycle Concepts.
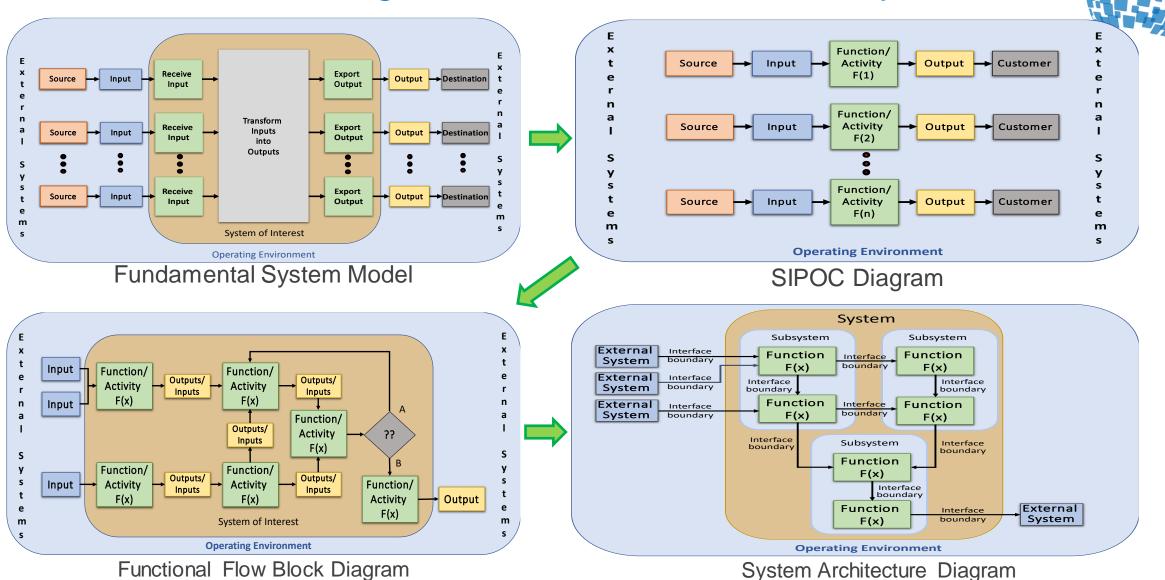
- These are preliminary in the sense the detailed analysis concerning feasibility, completeness, consistency, and correctness has not yet been completed.
- The specific lifecycle concepts used depend on the organization, its product lines, processes, and culture.

**Must get agreement from the stakeholders before proceeding.**

# 4.5   Lifecycle Concepts Analysis and Maturation



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

Traceability is critical to managing relationships
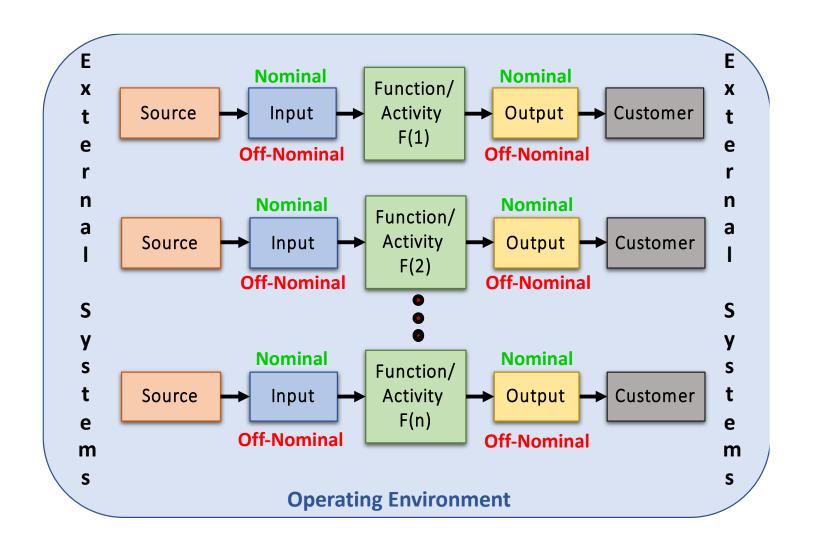
# Use of Diagrams and Models for Analysis



Fundamental System Model

SIPOC Diagram

Functional Flow Block Diagram

System Architecture Diagram
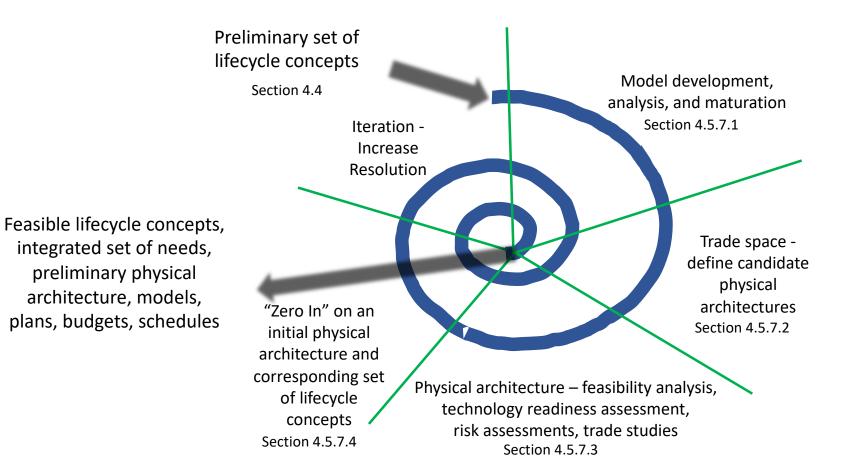
# Risk Assessment

# Iteration to Mature Lifecycle Concepts

Preliminary set of
lifecycle concepts

Section 4.4

Iteration -
Increase
Resolution

Model development,
analysis, and maturation
Section 4.5.7.1

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

Trade space -
define candidate
physical
architectures
Section 4.5.7.2

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

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

## Doctrine of Successive Refinement – Zeroing in on a set of Feasible Concepts

# 4.6 Define and Record the Integrated Set of Needs



Needs are not requirements

Needs can be communicated at a higher-level of abstraction than requirements

Can organize by function, fit, form, quality, and compliance

Serves as an outline for the design input requirements transformed from the needs

Using a data-centric practice of SE, the needs will be traced to their source and to the resulting design input requirements transformed from the needs.

# Needs vs Requirements
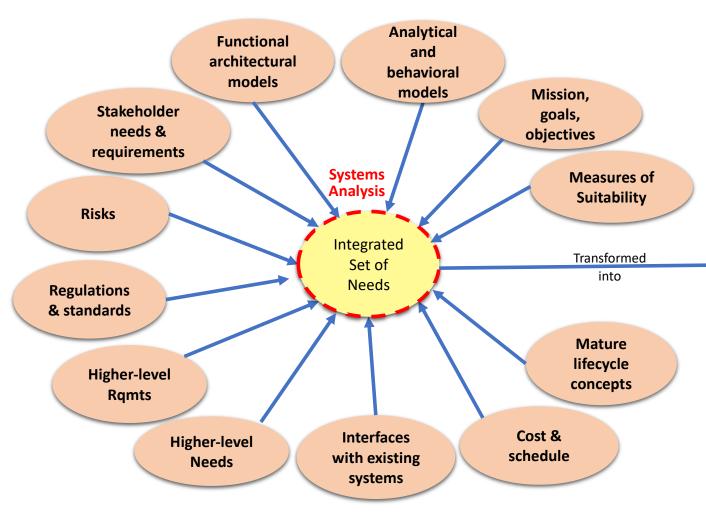
- Need statements do **not** include the word "shall"

- Examples:
  - "The stakeholders <span style="color:red">need</span> the system to ……….." or
  - "The stakeholders <span style="color:red">would like</span> the system to ……." for a goal
  - Rather than "The users <span style="color:red">shall</span> be able to ……" say
    "The users <span style="color:red">need</span> to be able to ……" or
    "The stakeholders <span style="color:red">need</span> the system to allow users to ……….."
  - Rather than ""The system <span style="color:red">shall</span> meet applicable government safety standards and regulations."  say
    "The stakeholders <span style="color:red">need</span> the system to meet applicable government safety standards and regulations."

**Using these distinct formats helps make a clear distinction between needs and design input requirements.**

# Needs Before Requirements



Stakeholder needs & requirements

Functional architectural models

Analytical and behavioral models

Mission, goals, objectives

Measures of Suitability

Risks

Regulations & standards

Higher-level Rqmts

Higher-level Needs

Interfaces with existing systems

Cost & schedule

Mature lifecycle concepts

Systems Analysis

Integrated Set of Needs

Transformed into

Design Input Requirements

Systems Analysis

Must understand the stakeholder's needs for the SOI before defining what the SOI must do to meet those needs.
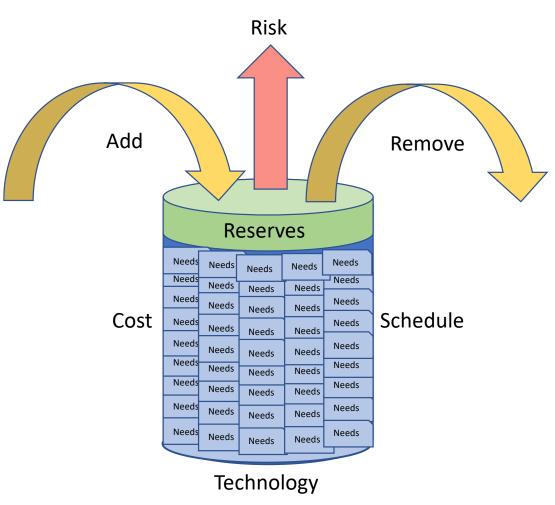
Rather than just having a set of requirements, we also have the underlying analysis and integrated set of needs from which they were transformed.

# The "Needs Bucket'

- Used to control the number of needs

- Needs are assessed for feasibility and risk **before** putting them in the bucket

- Useful to help control change

# 4.7    Plan for System Validation

- Best practice to plan for system validation when the needs are defined and the set baselined.

- Define the success criteria, method, and strategy

- Determine who is responsible and what each organizations responsibility

- Planning is necessary to endure budget, schedule, and resources are available.

- Enabling system may be needed to do system validation activities.

- Validation attributes:
  - A6 - System Validation Success Criteria.
  - A7 - System Validation Strategy.
  - A8 - System Validation Method.
  - A9 - System Validation Responsible Organization.

# 4.8 Baseline and Manage Lifecycle Concepts and Needs Definition Outputs

**Lifecycle Concepts & Needs Definition Activities**
- Prepare for Lifecycle and Needs Definition
- Define Inputs to Lifecycle Concepts Analysis and Maturation
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**Enablers**
- Enterprise tailored Guide for Writing Needs & Requirements
- Enterprise tailored process for developing & managing needs & design input requirements
- Enterprise tailored Guide for system verification and system validation
- Enterprise product development process
- Trained systems engineers
- Project toolset
- Stakeholder representation

**Outputs**
- **Draft Integrated Set of Needs**
- Risks, Risk Management Plan
- Set of feasible lifecycle concepts.
- Functional architectural and analytical/behavior models
- Preliminary physical architecture
- Technology Readiness Assessment and Technology Maturation Plan
- Design and system validation planning artifacts
- Draft PM & SE management plans, WBS, PBS, budget, schedules
- For each need:
  - Traceability to each source
  - Traceability to system validation planning artifacts

There are many outputs of the lifecycle concepts and needs definition activities.

The integrated set of needs will be verified and validated (next slide) and then be baselined.

Once baselined, they will be put under configuration control and managed across the lifecycle.
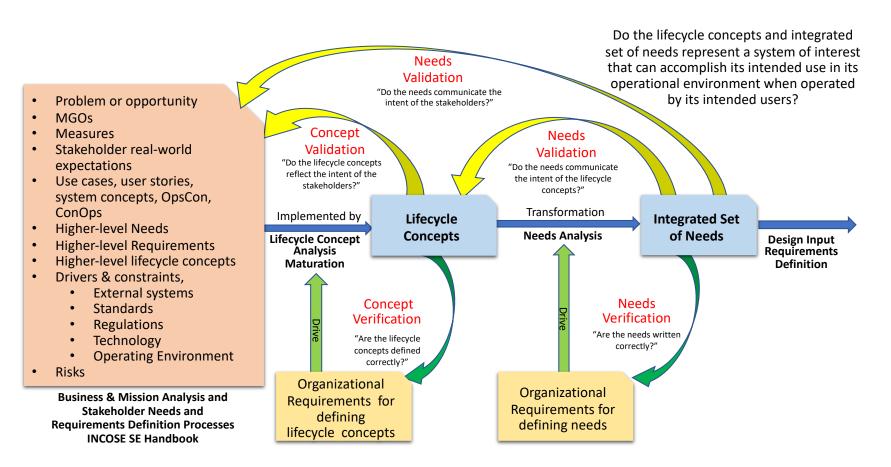
During requirements, architecture, and design activities issues will be discovered that may result in a change to the lifecycle concepts and needs.
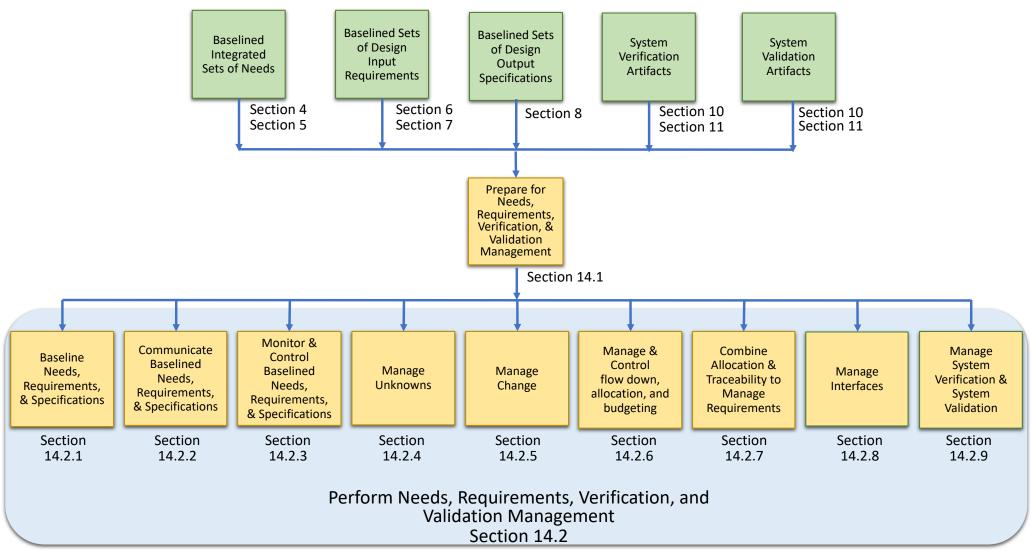
# 5.0 Needs Verification and Needs Validation

Prior to baselining the lifecycle concepts and needs, they need to be verified and validated.

Once verified and validated, they will be baselined, along with other PM and SE work products and artifacts at a gate review such as a Scope Review (SR), System or Mission Concept Review (SCR or MCR).

**Business & Mission Analysis and Stakeholder Needs and Requirements Definition Processes INCOSE SE Handbook**

Bullet list in orange box:
- 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

**Needs Validation** "Do the needs communicate the intent of the stakeholders?"

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?

**Concept Validation** "Do the lifecycle concepts reflect the intent of the stakeholders?"

**Needs Validation** "Do the needs communicate the intent of the lifecycle concepts?"

Implemented by
**Lifecycle Concept Analysis Maturation**

**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

# SECTION 14: NEEDS, REQUIREMENTS, VERIFICATION, AND VALIDATION MANAGEMENT

# Questions and Discussion

INCOSE Requirements Working Group

# Lou Wheatcraft



- **Lou Wheatcraft** is a senior consultant and managing member of Wheatland Consulting, LLC.  Lou is an expert in systems engineering with a focus on needs and requirements development, management, verification, & validation.  Lou provides consulting and mentoring services to clients on the importance of well-formed needs & requirements helping them implement needs & requirement development and management processes, reviewing and providing comments on their needs and requirements, and helping clients write well-formed needs & requirements.

- Specialties include: Understanding and documenting the problem; defining project & product scope; defining and maturing system concepts; assessing, mitigating, & managing risk; documenting stakeholder needs; transforming needs into well formed design input requirements; allocation, budgeting, and traceability; interface management, requirement management; & verification and validation.

- Lou's goal is to help clients practice better systems engineering from a needs & requirements perspective across all life cycle stages of system/product development. Getting the needs & requirements right upfront is key to a successful project. Poor needs & requirements can triple the chances of project failure.

- Lou has over 50 years' experience in systems engineering, including 22 years in the United States Air Force. Lou has taught over 200 requirement seminars over the last 21 years. Lou supports clients from all industries involved in developing and managing systems and products including aerospace, defense, medical devices, consumer goods, transportation, and energy.

- Lou has spoken at Project Management Institute (PMI) chapter meetings and INCOSE conferences and chapter meetings. Lou has published and presented many papers concerning needs and requirement for NASA's *PM Challenge*, INCOSE, INCOSE *INSIGHT Magazine*, and *Crosstalk Magazine*. Lou is a member of INCOSE, past Chair and current Co-Chair of the INCOSE Requirements Working Group (RWG), a member of the Project Management Institute (PMI), the Software Engineering Institute (SEI), the World Futures Society, and the National Honor Society of Pi Alpha Alpha.

- Lou has a BS degree in Electrical Engineering from Oklahoma State University; an MA degree in Computer Information Systems; an MS degree in Environmental Management; and has completed the course work for an MS degree in Studies of the Future from the University of Houston – Clear Lake.