2022
Annual INCOSE
international workshop
HYBRID EVENT
Torrance, CA, USA
Jan 29 - Feb 1, 2022

INCOSE Requirements Working Group

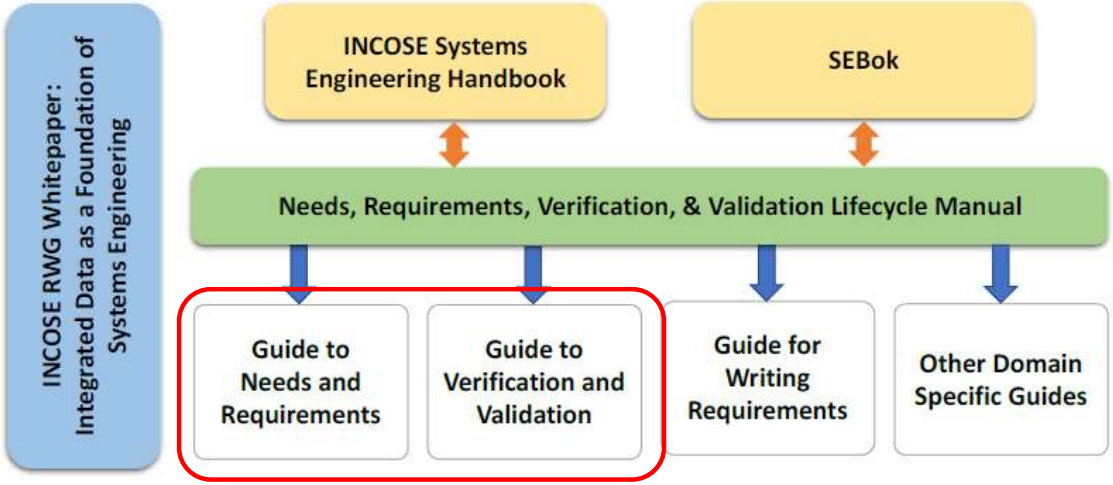
Guide to Needs and Requirements Overview

www.incose.org/IW2022

Upcoming RWG Guides

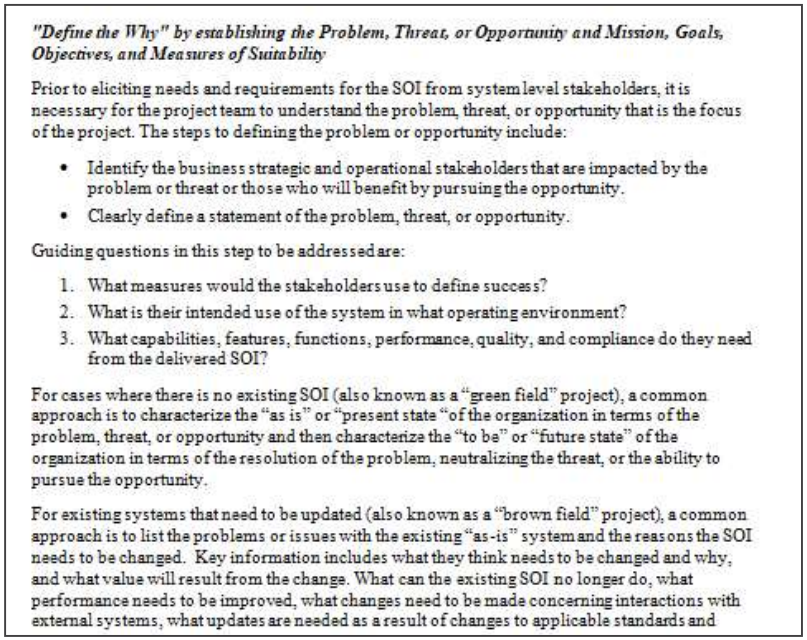
- The RWG has been working on new guidelines in support of application of the Needs, Requirements, Verification and Validation Life Cycle Manual (NRVVLM)
- The NRVVLM addresses the “why”, the guides address the “how”, and provide examples to the user community.

Product	Product Lead/Lead Author
Guide to Needs and Requirements	Tami Katz
Guide to Verification and Validation	Raymond Wolfgang



New Products - Guides

- The guides are condensed content from the NRVVLM that provides practical implementation approaches for systems engineering practitioners
- The Guide for Writing Requirements has been a popular guide by many in the INCOSE community – the new guides will expand on this with developing and managing needs and requirements and verification and validation guidance.



"Define the Why" by establishing the Problem, Threat, or Opportunity and Mission, Goals, Objectives, and Measures of Suitability

Prior to eliciting needs and requirements for the SOI from system level stakeholders, it is necessary for the project team to understand the problem, threat, or opportunity that is the focus of the project. The steps to defining the problem or opportunity include:

- Identify the business strategic and operational stakeholders that are impacted by the problem or threat or those who will benefit by pursuing the opportunity.
- Clearly define a statement of the problem, threat, or opportunity.

Guiding questions in this step to be addressed are:

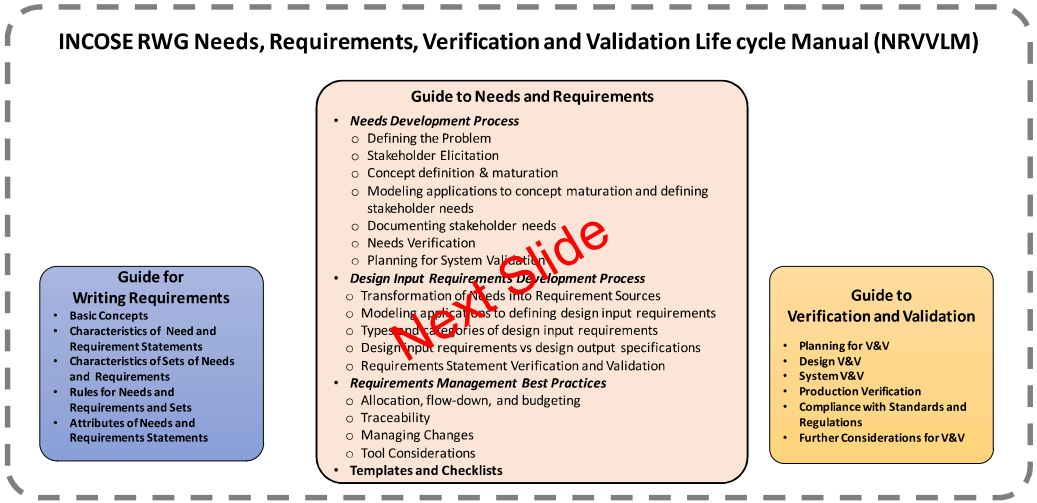
1. What measures would the stakeholders use to define success?
2. What is their intended use of the system in what operating environment?
3. What capabilities, features, functions, performance, quality, and compliance do they need from the delivered SOI?

For cases where there is no existing SOI (also known as a "green field" project), a common approach is to characterize the "as is" or "present state "of the organization in terms of the problem, threat, or opportunity and then characterize the "to be" or "future state" of the organization in terms of the resolution of the problem, neutralizing the threat, or the ability to pursue the opportunity.

For existing systems that need to be updated (also known as a "brown field" project), a common approach is to list the problems or issues with the existing "as-is" system and the reasons the SOI needs to be changed. Key information includes what they think needs to be changed and why, and what value will result from the change. What can the existing SOI no longer do, what performance needs to be improved, what changes need to be made concerning interactions with external systems, what updates are needed as a result of changes to applicable standards and

Relationships Between RWG Guides

- The new RWG Guides align with the NRVVLM to summarize the processes and describe application of approach of the processes.
- Each guide covers a specific area and is intended to be short (<100 pages) to help with user readability.
- This figure shows the summary outline contents of the RWG guides and how the Guide to Needs and Requirements (GtNR) works in conjunction with the other RWG guides.



INCOSE RWG Needs, Requirements, Verification and Validation Life cycle Manual (NRVVLM)

Guide for Writing Requirements

- Basic Concepts
- Characteristics of Need and Requirement Statements
- Characteristics of Sets of Needs and Requirements
- Rules for Needs and Requirements and Sets
- Attributes of Needs and Requirements Statements

Guide to Needs and Requirements

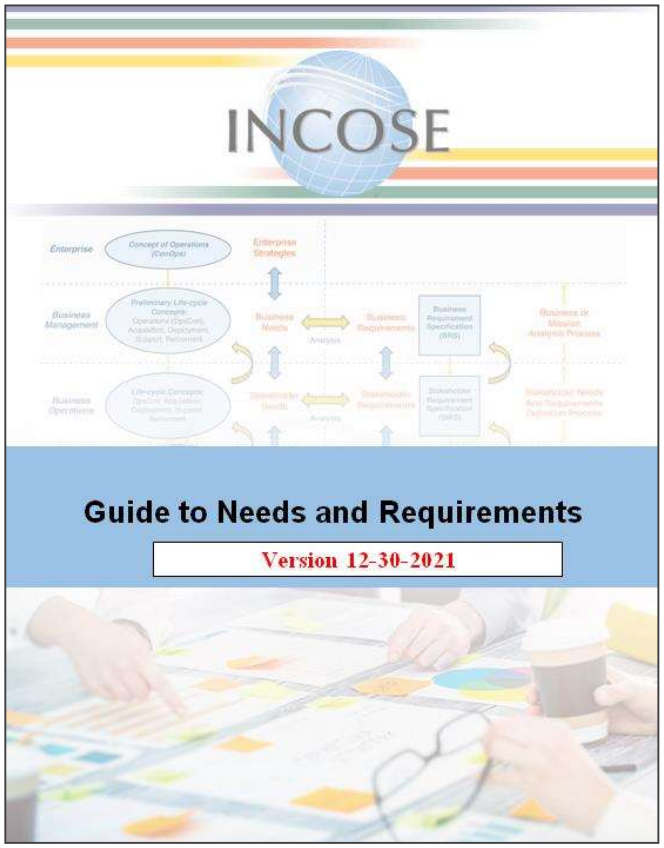
- ***Needs Development Process***
  - Defining the Problem
  - Stakeholder Elicitation
  - Concept definition & maturation
  - Modeling applications to concept maturation and defining stakeholder needs
  - Documenting stakeholder needs
  - Needs Verification
  - Planning for System Validation
- ***Design Input Requirements Development Process***
  - Transformation of Needs into Requirement Sources
  - Modeling applications to defining design input requirements
  - Types and categories of design input requirements
  - Design input requirements vs design output specifications
  - Requirements Statement Verification and Validation
- ***Requirements Management Best Practices***
  - Allocation, flow-down, and budgeting
  - Traceability
  - Managing Changes
  - Tool Considerations
- **Templates and Checklists**

Guide to Verification and Validation

- Planning for V&V
- Design V&V
- System V&V
- Production Verification
- Compliance with Standards and Regulations
- Further Considerations for V&V

Guide to Needs and Requirements Evolution

- This guide was originally called *Guide to Developing and Managing Requirements (GDMR)*
  - Additional focus of **Needs** within the RWG manual was desired in the guide name.
  - The RWG renamed this to *Guide to Needs and Requirements (GtNR)* at IW2021
- Initial guide creation occurred by Kevin Orr, using inputs from contributors (Ron Carson, Celeste Drewien, Lou Wheatcraft, Don McNally, Tami Katz)
- Tami Katz led guide generation efforts starting in 2021
- Guide now at 90% completion, draft sent to RWG prior to IW2022 for comments.
- After IW2022 final comments will be incorporated, guide release expected Spring 2022.



Guide to Needs and Requirements Outline

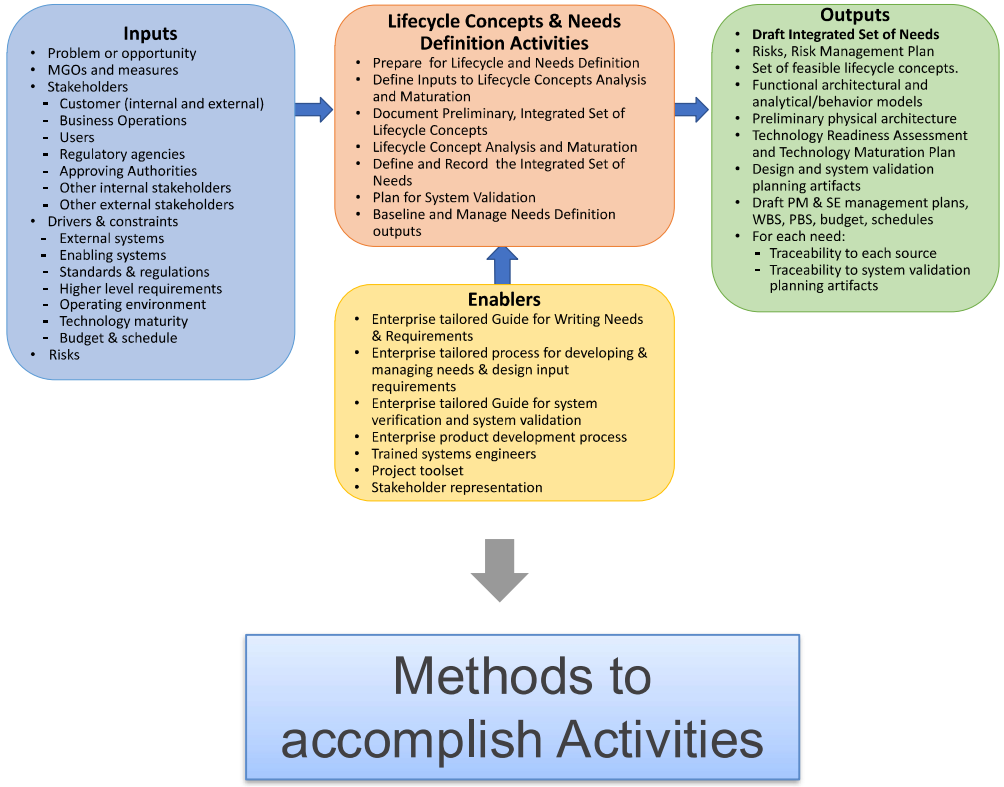
- 1 Introduction
  - 1.1 Purpose and Scope
  - 1.2 Audience
  - 1.3 Approach
  - 1.4 Definitions
  - 1.5 Roles and Responsibilities
  - 1.6 Guide Organization
- 2 Needs Definition, Verification, and Validation
  - 2.1 Needs Definition Activities
    - 2.1.1 Considerations for SOI Developed for Consumers Compared to a Customer
    - 2.1.2 Enabling Processes and Tools
    - 2.1.3 Step 1: Prepare for System Needs Definition
    - 2.1.4 Step 2: Define Inputs to Life cycle Concepts Analysis and Maturation
    - 2.1.5 Step 3: Capture Preliminary, Integrated Set of Life cycle Concepts
    - 2.1.6 Step 4: Analyze and Mature the Life cycle Concepts
    - 2.1.7 Step 5: Define and Record the Integrated Set of Needs
    - 2.1.8 Step 5: Plan for System Validation
    - 2.1.9 Step 6: Baseline and Manage the Needs Definition Outputs
  - 2.2 Needs Verification and Validation
    - 2.2.1 Enabling Processes and Tools
    - 2.2.2 Needs Verification Process
      - 2.2.2.1 Step 1: Plan for Needs Verification
      - 2.2.2.2 Step 2: Perform Needs Verification
      - 2.2.2.3 Step 3: Manage Needs Verification Results
    - 2.2.3 Need Validation Process
      - 2.2.3.1 Step 1: Plan for Needs Validation
      - 2.2.3.2 Step 2: Perform Needs Validation
      - 2.2.3.3 Step 3: Manage Needs Validation Results
- 3 Requirements Definition, Verification and Validation
  - 3.1 Requirements Definition Activities
    - 3.1.1 Enabling Processes and Tools
    - 3.1.2 Step 1: Plan for Requirements Definition
    - 3.1.3 Step 2: Perform Requirements Definition
      - 3.1.3.1 Transforming Needs into Design Input Requirements
      - 3.1.3.2 Traceability Process
    - 3.1.4 Step 3: Manage the Requirements
  - 3.2 Requirement (Expression) Verification Activities
    - 3.2.1 Enabling Processes and Tools
    - 3.2.2 Step 1: Prepare for Requirements Verification
    - 3.2.3 Step 2: Perform Requirement Verification
    - 3.2.4 Step 3: Manage Requirements Verification Results
  - 3.3 Requirement Validation Activities
    - 3.3.1 Enabling Processes and Tools
    - 3.3.2 Step 1: Prepare for Requirements Validation
    - 3.3.3 Step 2: Perform Requirements Validation
    - 3.3.4 Step 3: Manage Requirements Validation Results
- 4 Needs and Requirements Management
  - 4.1 Needs and Requirements Management Processes
    - 4.1.1 Manage Traceability
    - 4.1.2 Managing the Unknowns and Unresolved (TBX)
    - 4.1.3 Generating a Needs and Requirements Management Plan
    - 4.1.4 Needs and Requirements Configuration Management
      - 4.1.4.1 Needs and Requirements Baseline Process
      - 4.1.4.2 Needs and Requirements Monitoring and Change Identification
      - 4.1.4.3 Change Impact Analysis
      - 4.1.4.4 Assessing Impacts of Change Across Life Cycle Stages
      - 4.1.4.5 Assessing Needs and Requirements Scope Creep
      - 4.1.4.6 Managing Needs and Requirements Change
      - 4.1.4.7 Document and Communicate Results
  - 4.2 Needs and Requirements Management Methodology and Examples
    - 4.2.1 Management and Trace Using a System Model
    - 4.2.2 Management and Trace in a Requirements Management Tool
  - 4.3 Needs and Requirements Management Best Practices
    - 4.3.1 Attributes for Requirements Management
    - 4.3.2 Managing Needs and Requirements for a Product Line
    - 4.3.3 Managing Needs and Requirements for Internal Teams
    - 4.3.4 Managing Requirements for Heritage or Off-The-Shelf Products
    - 4.3.5 Connection of Needs and Requirements Data to System Verification and System Validation Activities
    - 4.3.6 Considerations on Tools and Data Exchange

- Appendix A: Acronyms and Abbreviations
- Appendix B: Needs and Requirements Management Plan Content
- Appendix C: Stakeholder Needs Elicitation Questions
- Appendix D: Checklists
  - D1. Sample Need Verification Checklist
  - D2. Sample Need Validation Checklist
  - D3. Sample Requirement Verification Checklist
  - D4. Sample Requirement Validation Checklist
- Appendix E: Comment Form

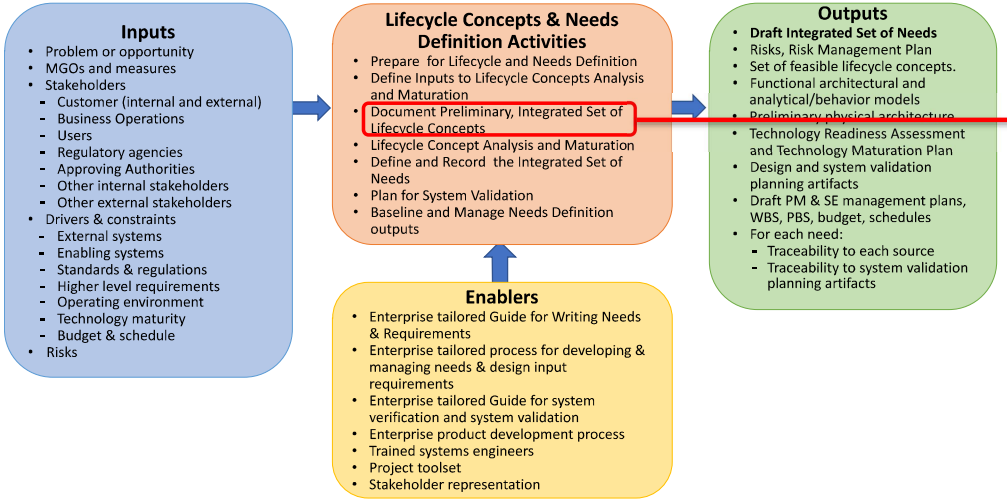
The GtNR Outline: Four sections and multiple appendices containing numerous examples and methods of approach.

GtNR Approach

- This guide expands upon the input/process/output (IPO) diagrams from the NRVVLM and provides procedural steps towards implementation
- In addition to procedural steps, situational considerations and example applications are provided.
- The next slides will cover some of the material to demonstrate this approach.



Example GtNR Approach



"Capture the Needs" by Recording the Elicitation Outcomes

Stakeholders often state their needs and expectations in natural language and may combine several needs into one statement, or stakeholders may express needs as bullets or phrases. Various stakeholders can have similar needs that are stated in different ways yet have common meanings; for example, user-friendly and easy to use have some common underlying objectives. An example of needs for a coffee maker is shown below:

Key stakeholder needs: safe, affordable, cost-effective manufacturing, user-friendly

Consumer needs: affordable, high quality, good coffee, options for other hot beverages, easy to use

It is critical that all the information obtained from the elicitation activities be recorded *in the project's integrated dataset*. There are various forms and media that can be used to record the information gained from the elicitation activities. In some cases, e.g., use cases and models, there is a predefined format defined within some toolsets. In other cases, the information is captured as text. Below are common forms used.

- Operational Scenarios
- User Stories
- Use cases
- Diagrams/drawings
- Models
- Lists
- Tables
- Text

Table 3 identifies some examples of scenario/use case topics for a coffee maker as provided by the Stakeholders.

More GtNR Examples (Needs Definition)

Each stakeholder has a unique perspective, the sum of which results in an integrated set of scenarios/use cases to help frame the needs/requirements to the life cycle stage activities for the SOI and provide context for the integrated set of needs. The objective of this activity is to integrate the use cases and operational scenarios recorded as a result of the integrated scenario elicitation activities. Figure 5 shows an example of assessing life cycle concepts using scenario/use cases for a coffee maker in a system model of the SOI as part of a model-based systems engineering (MBSE) approach.

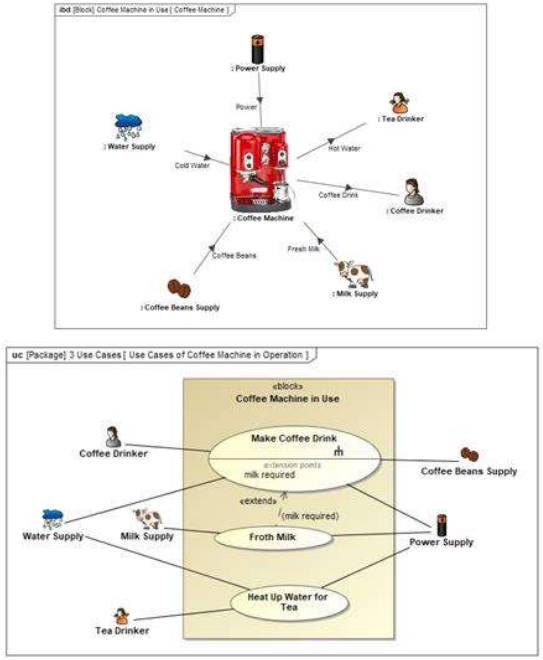


Figure 5. Coffee Maker Use Case Model Examples.

The use cases and operational scenarios for each life cycle that were captured during elicitation are used to develop or build upon a system model of the SOI. The focus of this model is the SOI to be developed in the context of all life cycle stages. This model will be matured, a preliminary architecture defined, and the integrated set of needs will be derived during the development efforts of the SOI; an example model for the coffee maker operational scenario is shown in Figure 6.

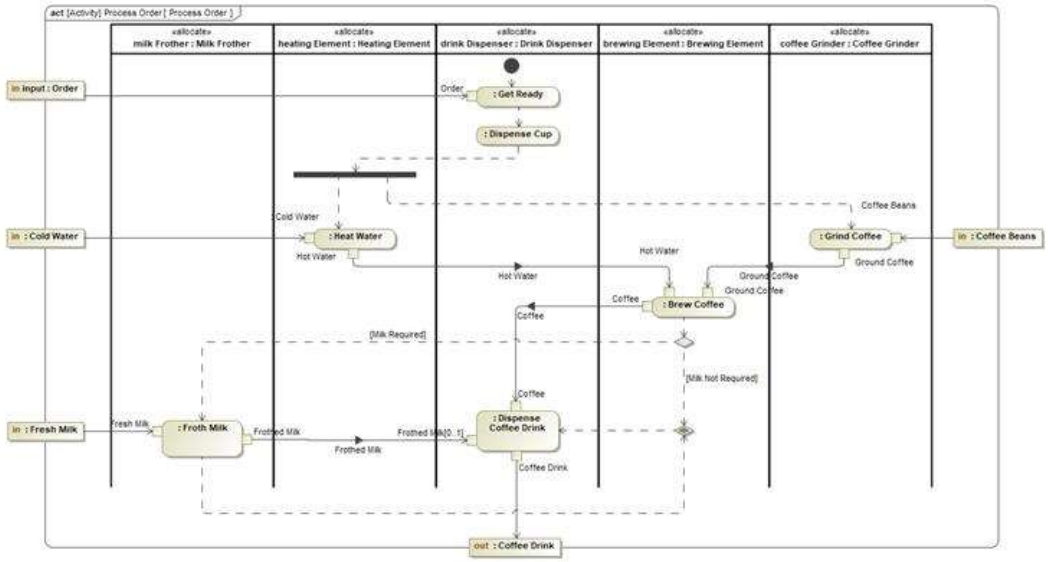


Figure 6. Operational Scenario Model Example.

More GtNR Examples (Needs Capture)

Developing and agreeing on a set of feasible life cycle concepts for the SOI results in an integrated set of needs based on those concepts. Per the definition of a "need", the project team derives an integrated set of needs that reflect the set of feasible system life cycle concepts selected, the MGOs, MOS, business operations level and system level stakeholder needs and requirements, drivers and constraints, and risk mitigation. It is this integrated set of needs that will be transformed into the set of requirements for the SOI and that is the subject of requirement, design, and system validation as discussed later in this manual. The sources of the integrated set of needs are shown in Figure 7.

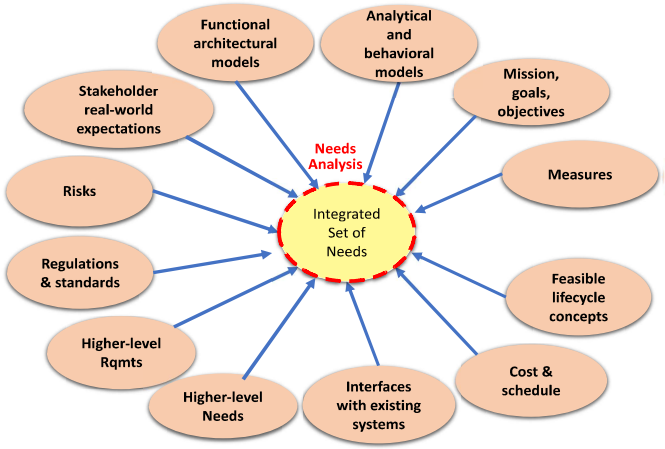


Figure 7: Sources of the Integrated Set of Needs from NRVVLM.

When managing the needs it is best to associate them with **attributes,** or additional information, that aid understanding or management of the need; and example of this is with an attribute called "Rationale". In the above example, the need statement about affordability might have an attribute designating it as "price-related" to collect and manage price-related needs. If this need is important, the need statement may have an attribute designating "high" for priority.

A **need expression** includes a need statement plus a set of associated attributes, including validation attributes. Examples of need expressions are shown in Table 5.

Table 5. Example of Two Need Expressions

ID	Name	Need Statement	Rationale	Safety Related	Priority	Price-Related		
COF-MN-1	Safe	The stakeholders and consumers need the coffee system to be safe.	Key stakeholder: ensure reputation of product; meet regulations Consumer: not get hurt making coffee	Yes	High	No	2	1
COF-MN-2	Affordable	The stakeholders and consumers want the coffee system to be affordable.	Key stakeholder: maximize profits Consumer: minimize cost	No	High	Yes	1	0

More GtNR Examples (Requirements Transformation)

Recommended steps for transformation of needs to requirements include:

1. Review each need and evaluate how the SOI would respond to that need.
2. Draft a design input requirement that corresponds to the need.
3. Assess the design input requirement against the characteristics of the GfWR (is it singular, verifiable, feasible, etc.?).
4. Group the design input requirements into logical categories and assess for any overlaps and gaps against the needs.
5. Review the design input requirements with stakeholders to ensure needs are addressed and requirement set is complete.

Table 7. Example Coffee Maker Need to Requirements Transformation.

Column A Needs	Column B Design input requirements	Column C External Interface
Functional/Performance (Function)		
The stakeholders need the coffee maker to have three temperature settings (warm, normal, extra hot) for the water temperature and control the temperature to within 2 C.	The coffee maker shall have a temperature selector with three settings for coffee temperature: Warm: 71°C, Hot: 80°C, Extra Hot: 85°C. Rationale: Values are resulting from analysis associated with consumer research surveys and safety regulations. The coffee maker shall provide coffee at the selected temperature within 2°C. The coffee maker shall heat water from an initial temperature of 13°C +15°C/- 10°C. Rationale: Values are consistent with tap water temperature ranges. NOTE: This represents only a subset of requirements, there would be additional requirements related to final coffee temperature, quality of water, definition of local environments, etc.	Water Source Coffee Grounds

More GtNR Examples (Best Practices)

4.3.3 Managing Needs and Requirements for Internal Teams

When defining needs and requirements for external organizations, the needs and requirements are communicated formally in the contract via the statement of work and a needs or requirements document. The contract then clearly communicates what is necessary for acceptance, enabling proof of contractual compliance for the established service or product.

However, when establishing needs and requirements for SOI systems and system elements being developed within the same company or organization, some efficiencies may be gained by looking for a less formal, data driven approach towards the formality of needs and requirement definition and management and associated compliance, verification, and validation activities.

A recommendation is for the organization to establish a method of needs and requirements management, change control, and communications that enables all project members to ensure they are working to the correct needs and requirements, the communication to stakeholders is established, and discussions on any change or compliance impacts are able to be held and assessed against related needs and requirements. For some organizations this could be achieved entirely within a project toolset, as shown in the earlier section, where others may need a more formal method between organizations to establish provider/customer deliverables.

4.3.4 Managing Requirements for Heritage or Off-The-Shelf Products

One area to consider is whether a formal set of requirements is required for specific products within the organization that have already been developed using a capabilities-based approach (heritage products), or already exist and are being purchased as an Off-the-shelf (OTS) product.

Section 12 of the NRVVLM provides a comprehensive approach to ensure existing products can be reconciled against a set of integrated needs and requirements for an SOI. When determining the needs and requirements for the OTS, the project team uses an external view the OTS with a focus on form, fit, function, quality, and compliance and address the following questions:

- What functionality and level of performance is needed when the SOI is operating within the SOI's operational environment?
- What are the allowable induced environments for the OTS?
- What are the interface boundaries, how are they defined, and what are the characteristics of each interaction across those boundaries?
- What is the allowable envelope, mass, power requirements, and other physical attributes requirements for the OTS?
- What quality (-ilities) requirements need to be met by the OTS?

4.3.6 Considerations on Tools and Data Exchange

Over the years multiple software applications have been developed to address management of needs and requirements; a requirements management tool (RMT) can enable a project's success with its execution, verification and validation of the end product. As the number of software applications has been growing over the past few years, the INCOSE organization has partnered with Project Performance International (PPI) to develop an online, searchable systems engineering tools database, https://www.incose.org/setdbtest/system-engineering-tools-database.

Desired capabilities and features of needs and requirements management tools include definition, collaboration, change control, and trace to other project data. It is recommended that tools are more effective if they are setup with project configuration and templates beforehand, ensuring the definition team spends their time on management of the requirements and not infrastructure development of the management tool. While projects may vary in their needs and ability to afford different solutions, a recommendation is to determine the overall complexity and scale of the requirement data, the anticipated number of changes and change reviewers that should be interfacing with a tool, and the need to connect requirement data with other project data, such as system model or test procedures. Considerations to use in tool selection include:

- Requirements specification and prioritization - ability to add, edit, delete and prioritize requirements easily.
- Traceability and dependencies - ability to create relationships between requirements and change the data model to reflect the traceability needed in the organization.
- Stakeholder management, review and collaboration - ability to give feedback on requirements or initiate workflows to approve requirements.
- Change control - ability to baseline requirements, track changes after a baseline, or revert requirements set back to a baseline.
- Visual Modeling - ability to create and edit models in the tool or link requirements to visual models.
- Import/export and reporting - ability to import to / export from MS Word, Excel, Visio or other sources and report he requirements, models or subset of either group.
- Requirements process support - ability to set up own templates and object types to support a methodology with things like checklists, issues, risks or constraints.
- Task / Iteration management - ability to track definition tasks on requirements, set release or iteration dates, or create burndown charts.
- Licensing, support and tool administration - flexible licensing for the tool, adequate support materials and ease of maintenance.

More GtNR Examples (Appendix - Checklists)

APPENDIX D: CHECKLISTS

D1. Sample Need Verification Checklist

1. *Establish the need expressions are well-formed:* Verify individual needs expressions and the sets of needs have the characteristics per the rules defined in the INCOSE GfWR or similar guide; this can be done manually, through use of a natural language processor (NLP), or through use of another autonomous tool.
2. *Verify the need expression contains a complete set of attributes*: Are the attributes agreed to by the project team defined? The project toolset should be able to produce a report concerning completeness and data defined for each attribute. For example, does the text in the rationale statement include the information expected to be in the rationale? Does the rationale state why the need statement is necessary? Is the source of any numbers explained?
3. *Establish the needs expressions are well formed such that the system will be able to be validated to meet the needs as written:* Verify individual needs expressions have the set of system validation attributes defined and have values agreed to by the project team. For example, does the text in the validation attribute that defines the validation success criteria include the information expected?
4. *Establish the integrated set of system needs is complete:* Use the project toolset to generate trace matrices to confirm traceability of each need to one or more input artifacts (sources) and confirm each need trace to at least one source from which it was derived. Use the project toolset to generate trace matrices to confirm each source has at least one derived system need that addresses that source. (*Bidirectional traceability – if the tool allows a trace from a need to its source, it should also include the capability to trace each source to its implementing life cycle concept and associated need statement(s)*).

D3. Sample Requirement Verification Checklist

Below is a set of basic checks that can be used as a starting point for creating a tailored requirement verification checklist. It is assumed that requirements are organized in Sets that applies to the SOI or any of its system elements (within brackets are the characteristics in the GfWR that contributes to compliance):

1. Does the statement follow the organizations agreed-to template for writing requirements? Consider the requirement type if the boilerplate is tailored to different types of requirements (functional performance, interface, non-functional/constraints etc.) (C9)
2. Does the statement contain the basic elements of: entity, what, how well and under what conditions? A requirement should have one 'how well' statement to be singular, there are however many ways to express how well, can be a number or a list of things. (C3, C4, C5, C10)
3. Are entity names and function names consistent with the system architecture model? (C3, C8)
4. Is the requirement constructed so that compliance can be determined by observing the behavior at the boundary of the entity it applies to? Essentially the 'how well' part of the requirements should refer to something observable on the boundary of the entity, not on other entities. (C2)
5. Are required traceability in place? Basic traceability to needs, parent requirements, architecture model elements, system analysis records, and design/system verification methods (C1, C4, C6, C8, C7)
6. Have the required agreements been completed, articulated by life cycle state attributes. Verify to established business rules. (C4, C6)
7. Are a sufficient set of attributes defined for the requirement considering the life cycle state of the project? Verify to established business rules. (C4)
8. Are entity names, function names, terms and units used consistently throughout the Set? (C11)

More GtNR Examples (Appendix – NRM Plan Template)

APPENDIX B: NEEDS AND REQUIREMENTS MANAGEMENT PLAN CONTENT

This section supplies recommended content for a Needs and Requirements Management Plan. The Template should follow the organization's approach and format for generation of a plan. Key provisions of the NRMP can include, but are not limited to following:

- Provide details needed to implement the needs and requirements definition and management processes consistent with the project requirements defined in the PMP and SEMP concerning how the needs and requirements definition and management activities of the project will be conducted.
- Define the oversight (control) and insight (monitoring) of the project's needs and requirements definition and management processes.
- Identify the relevant stakeholders who will be involved in the needs and requirements definition processes.
- Assign roles and responsibility, authority, and resources needed to define needs and requirements, perform the needs and requirements management activities, and develop the needs and requirements management work products.
- Define the artifacts and work products that need to be developed as part of needs and requirements definition and management.
- Identify and manage the relationships between the integrated set of needs, requirements, and design output specifications and other project and system engineering artifacts and work products throughout the system development life cycles.
- Provide a schedule for performing the needs and requirements definition and management activities and delivery of needs and requirements definition and management artifacts and work products.

Call for GtNR Feedback

- The draft for *Guide to Needs and Requirements* has been posted on the RWG Connect site.
- RWG community is welcome to review and provide inputs up to 2/28/22.
- In March the guide will be finished and submitted to INCOSE for release.
- Future updates are planned, so feedback after release is still able to be obtained using the comment form process.

2022
Annual INCOSE
international workshop
HYBRID EVENT
Torrance, CA, USA
Jan 29 - Feb 1, 2022

www.incose.org/IW2022