Guide to Writing Requirements Version 4 Overview

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INCOSE RWG Overview

RWG Charter

1 **Purpose**

Advance:

- Practices, education, and theory of needs and requirements development and management
- Relationship of needs and requirements to other systems engineering activities.

2 **Goal**

Expand and promote the body of knowledge of needs and requirements and their benefits within the systems engineering community.

3 **Scope**

Activities relating to best practices throughout the product lifecycle including:

- Elicitation, Analysis, Allocation, Traceability
- Elaboration, Management, Integration
- Change Assessment and Management
- Expression, Verification, Validation

RWG is About…

- Improving the practice of systems engineering through excellence in needs and requirements definition and management across the lifecycle.
- Learning from experiences and sharing with the SE community.
- Questioning approaches that yield poor outcomes.
- Publishing guidance and continuing research into needs and requirements definition and management, including understanding the role of Needs, Requirements, Verification, and Validation across the lifecycle.

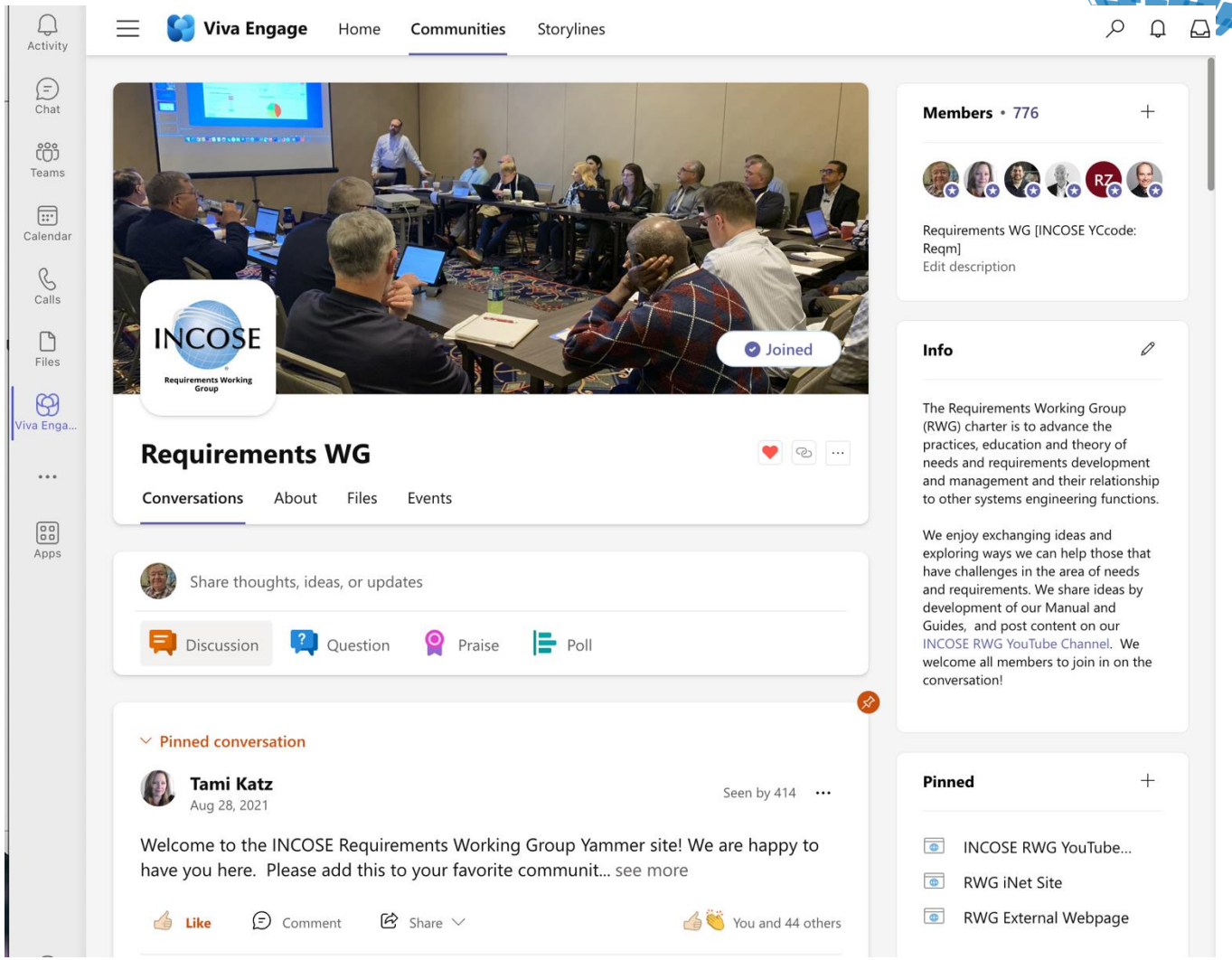
RWG Leadership

- **Chair**: Tami Katz; Ball Aerospace, USA
- **Co-Chair**: Lou Wheatcraft; Wheatland Consulting, LLC, USA
- **Co-Chair**: Mike Ryan; Capability Associates Pty Ltd, AU
- **Co-Chair**: Kevin Orr, Eaton, USA
- **INCOSE Websites:**
  - https://www.incose.org/incose-member-resources/working-groups/process/requirements
  - https://www.incose.org/inet/working-groups/requirements
  - https://www.youtube.com/channel/UCadgYaqKWDckenP2SU8-cPw
- **Number of Members: 466** (997 followers on Viva Engage), one of INCOSE's largest WG

The RWG is comprised of members from industry and academia with a common purpose of improving the practice of systems engineering through improvement of **Needs and Requirements** definition and management across the system lifecycle.

RWG Viva Engage (Yammer) Community

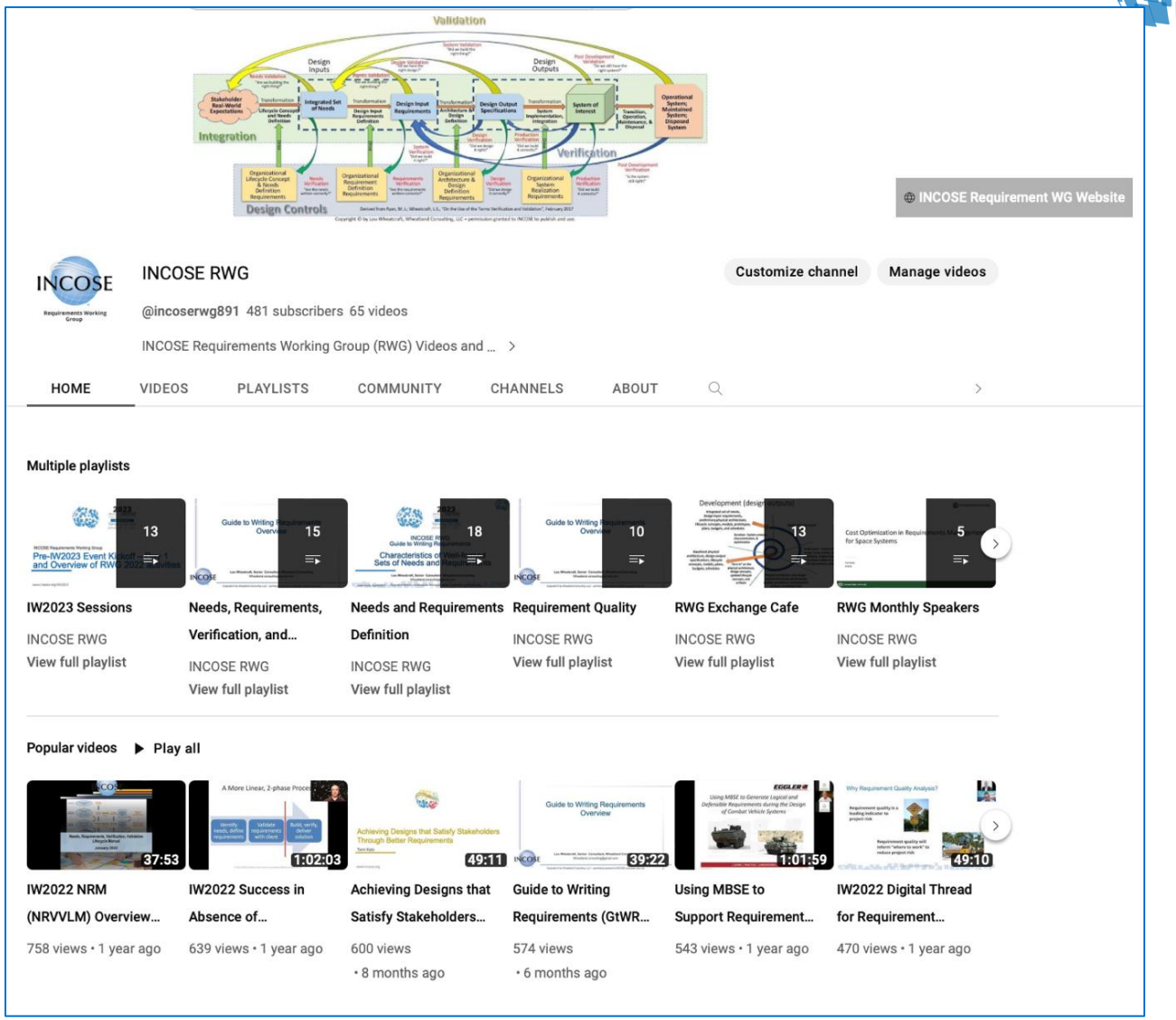
- The INCOSE organization has established Microsoft platforms for INCOSE member engagement.
- Upon obtaining the member login from the INCOSE CIO Barclay Brown, navigate to Viva Engage and join the Requirements WG Community.
- This platform enables more interactive announcements, questions, and discussions throughout the year!



Access to Communities is through the Microsoft Teams App, Viva Engage App (iOS), or the online Microsoft Teams site.

INCOSE RWG YouTube Channel

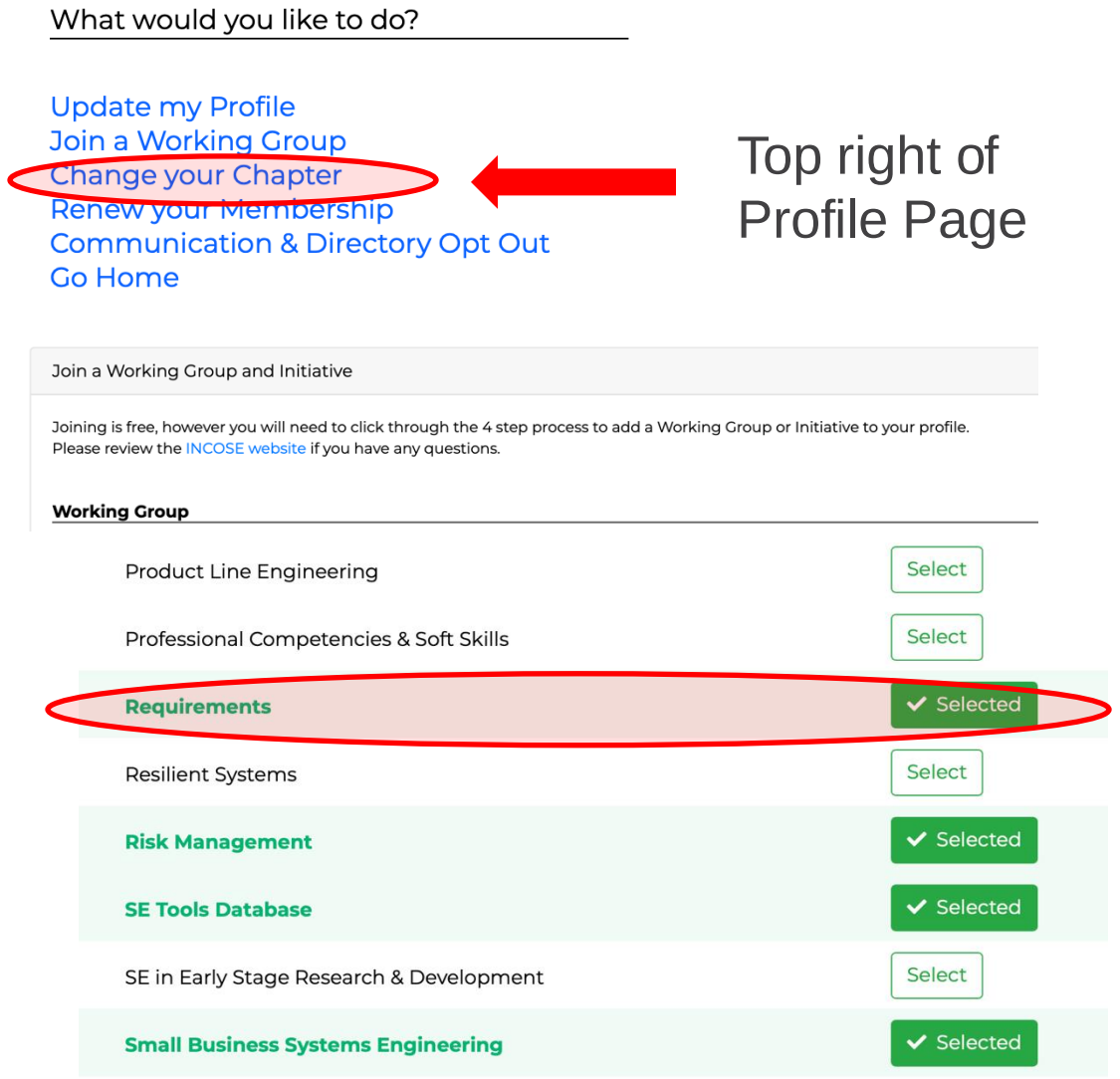
- INCOSE RWG YouTube channel has recordings of meetings and presentations to the broader community.
- Available to everyone to catch up on events and learn more about the RWG activities and products.
- Also exists to attract interest in joining INCOSE and the RWG and share experiences, lessons learned, best practices, wisdom, and ideas with all that engage in needs, requirements, verification, and validation activities.



https://www.youtube.com/channel/UCadgYaqKWDckenP2SU8-cPw/playlists

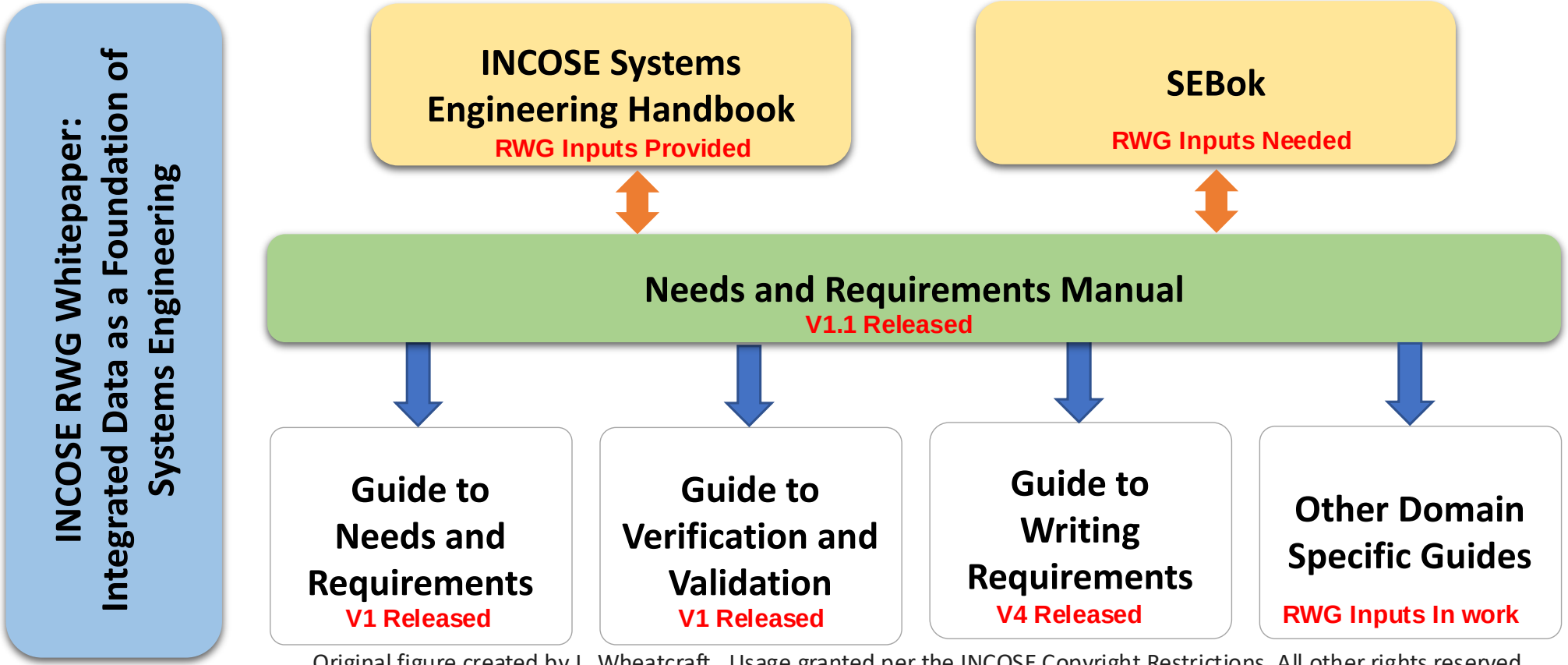
How to Become Involved in RWG

- As a large working group, the RWG has been very active in virtual events as well as smaller product team efforts.
- Joining the RWG enables the members to learn about the products, provide an opportunity to contribute to product development, and participate in the RWG virtual events with other practitioners.
- Members can be very involved (product support), involved in our monthly meetings, or minimally involved (view Viva Engage conversations or watch meeting recordings) - the intention is to enable all levels of participation and interaction.



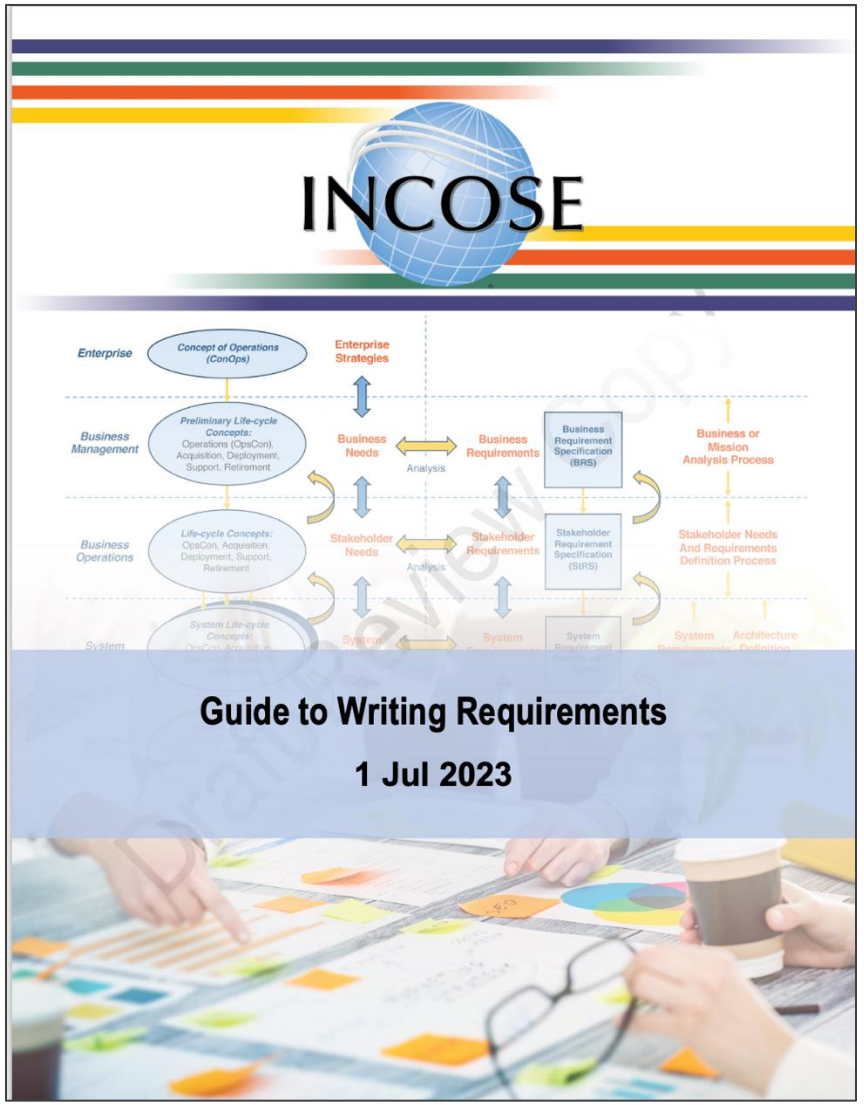
RWG Product Tree

The RWG has developed a family of products and supported development of other INCOSE publications.



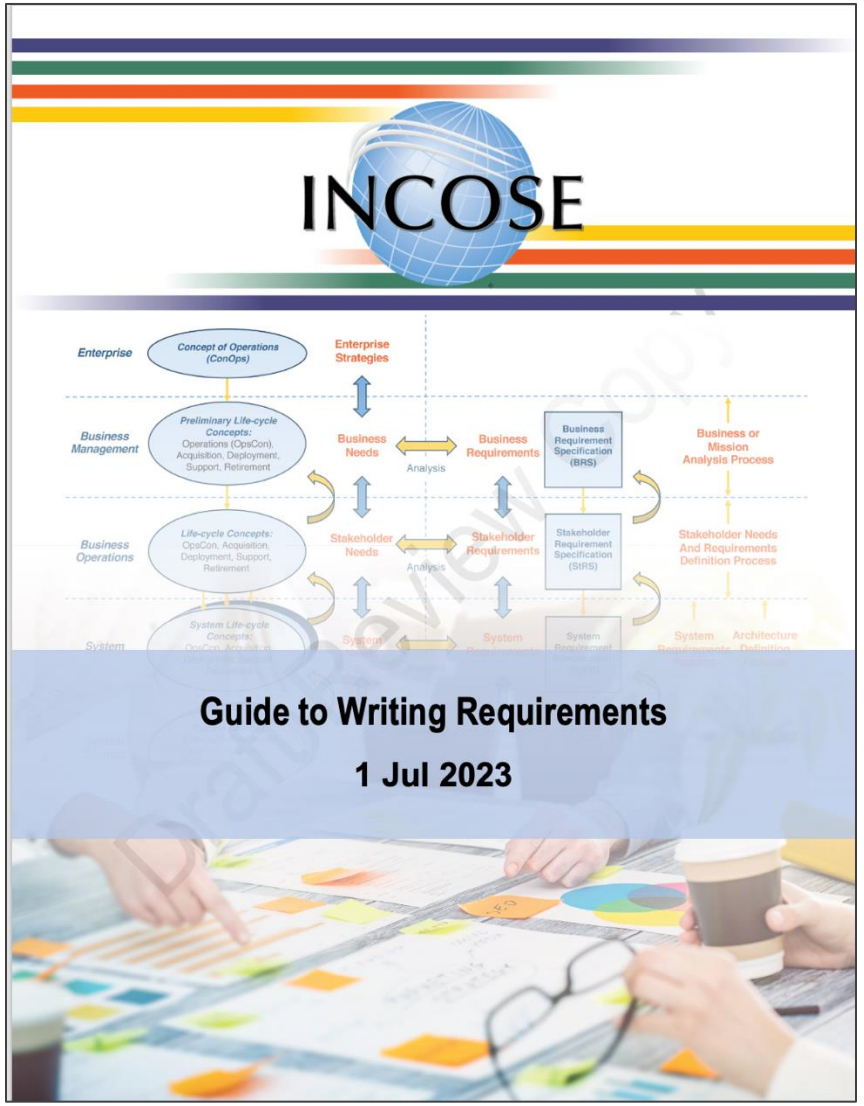
Guide to Writing Requirements Updates

Guide to Writing Requirements



- The Guide to Writing Requirements (GtWR) has been a popular product from the RWG for many years.
- The **Gold Standard** for writing quality need and requirement statements.
- The RWG released V3.1 in May 2022 update to align the GtWR with the NRM, GtNR, & GtVV.
- **V4 was released in June 2023.**

GtWR Presentations on YouTube



At IW2023, several presentations were given on the GtWR:

- Section 1 - Introduction and Basic Concepts
- Section 2 - Characteristics of well-formed needs and requirements
- Section 3 - Characteristics of well-formed sets of needs and requirements.

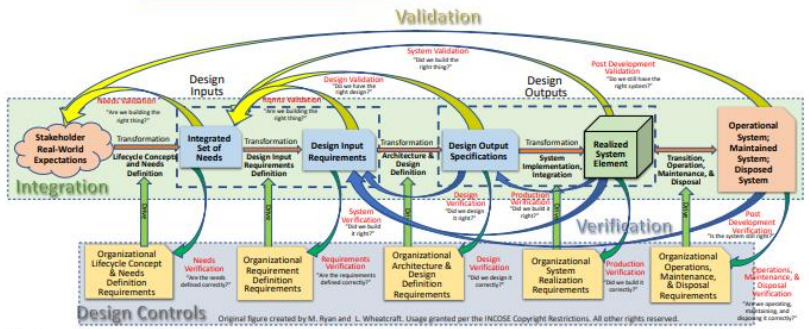
In May, presentation to the ChicagoLand Chapter on Section 4: Rules for Individual Need and Requirement Statements and Sets of Needs and Requirements.

In addition, presentations have been developed applying the rules to requirements developed for a case study.

Recordings of these presentations are available on the [INCOSE RWG YouTube Channel]

GtWR
7-page Summary Sheet

INCOSE Guide to Writing Requirements V4 – Summary Sheet



Needs and Requirements are the common threads that tie all lifecycle activities and artifacts together. Once the needs are verified and validated, all subsequent artifacts are validated against the needs and once the resulting design input requirements are verified and validated, all subsequent artifacts are verified against those design input requirements.

Definitions

An ***entity*** is a single item to which a concept, need, or requirement applies: an organization, business unit, project, supplier, service, procedure, SOI (system, subsystem, system element), product, process, or stakeholder class (user, operator, tester, maintainer, etc.).

*A **concept** is a textual or graphic representation that concisely expresses how an entity can fulfill the problem, threat, or opportunity it was defined to address within specified constraints with acceptable risk that provides a business in terms of people, process, and products.*

*A set of **lifecycle concepts** includes multiple concepts across the lifecycle for how the organization (and stakeholders within an organization) expects to manage, acquire, define, develop, build/code, integrate, verify, validate, transition, install, operate, support, maintain, and retire an entity.*

*A **need statement** is the result of a formal transformation of one or more sources or lifecycle concepts into an agreed-to expectation for an entity to perform some function or possess some quality within specified constraints with acceptable risk.*

A ***requirement statement*** is the result of a formal transformation of one or more sources, needs, or higher-level requirements into an agreed-to obligation for an entity to perform some function or possess some quality within specified constraints with acceptable risk.

Characteristics

When defining needs and requirements, it is important that they have the characteristics of well-formed needs and requirements. These characteristics are a result of following the rules defined in the Guide to Writing Requirements (GtWR) as well as performing the activities associated with the definition of the needs and requirements as discussed in the Needs and Requirements Manual (NRM) and Guide to Needs and Requirements (GtNR). The underlying analysis from which a need or requirement was derived is as important as how well the need or requirement statement is formed.

Formal Transformation. Given the need and requirement is a result of a formal transformation, the following characteristics of a well-formed need or requirement have been derived:

C1 - Necessary: The need requirement statement defines capability, characteristic, constraint, or quality factor *needed or required* to satisfy a lifecycle concept, need, source, or higher-level requirement.

C2 - Appropriate: The specific intent and amount of detail of the need or requirement statement is appropriate to the level (the level of abstraction, organization, or system architecture) of the entity to which it refers.

C5 - Singular: The need or requirement statement should state a single capability, characteristic, constraint, or quality factor.

C8 - Correct: The need statement must be an accurate representation of the lifecycle concept or source from which it was transformed. The requirement statement must be an accurate representation of the need, source, or higher-level requirement from which it was transformed.

C9 - Conforming: Statements and expressions of individual needs and requirements should conform to an approved standard pattern and style guide or standard for writing and managing needs and requirements.

Agreed-to Obligation. Since the need and requirement is to be a part of a fair agreement to meet an obligation, the following characteristics of a need or requirement have been derived:

C3 - Unambiguous: Need and requirement statements must be stated such that their intent is clear and can be interpreted in only one way by all intended audiences.

C4 - Complete: *The need statement sufficiently describes the necessary capability, characteristic, constraint, conditions, or quality factor to meet the lifecycle concept or source from which it was transformed.* The requirement statement sufficiently describes the necessary capability, characteristic, constraint, conditions, or quality factor to meet the need, source, or higher-level requirement from which it was transformed.

C6 - Feasible: The need or requirement can be realized within entity constraints (for example: cost, schedule, technical, legal, ethical, safety) with acceptable risk.

C7 - Verifiable: The need statement is structured and worded such that its realization can be validated to the approving authority's satisfaction. The requirement statement is structured and worded such that its realization can be verified to the approving authority's satisfaction.

Characteristics of well-formed needs and requirements.

Rules for Need and Requirement Statements and Sets of Needs and Requirements

Accuracy

R1 - Structured Statements: Need and requirement statements must conform to one of the agreed patterns, thus resulting in a well-structured complete statement.

R2 – Active Voice: Use the active voice in the need or requirement statement with the responsible entity clearly identified as the subject of the sentence.

R3 - Appropriate Subject-Verb: Ensure the subject and verb of the need or requirement statement are appropriate to the entity to which the statement refers.

R4 - Defined Terms: Define all terms used within the need statement and requirement statement within an associated glossary and/or data dictionary.

R5 - Definite Articles: Use the definite article "the" rather than the indefinite article "a".

R6 - Common Units of Measure: When stating quantities, all numbers should have appropriate and consistent units of measure explicitly stated using a common measurement system in terms of the thing the number refers.

R7 - Vague Terms: Avoid the use of vague terms that provide vague quantification, such as "some", "any", "allowable", "several", "many", "a lot of", "a few", "almost always", "very nearly", "nearly", "about", "close to", "almost", and "approximate". Avoid vague adjectives such as "ancillary", "relevant", "routine", "common", "generic", "significant", "flexible", "expandable", "typical", "sufficient", "adequate", "appropriate", "efficient", "effective", "proficient", "reasonable" and "customary."

R8 - Escape Clauses: Avoid the inclusion of escape clauses that state vague conditions or possibilities, such as "so far as is possible", "as little as possible", "where possible", "as much as possible", "if it should prove necessary", "if necessary", "to the extent necessary", "as appropriate", "as required", "to the extent practical", and "if practicable".

R9- Open-Ended Clauses: Avoid open-ended, non-specific clauses such as "including but not limited to", "etc." and "and so on".

Concision

R10 - Superfluous Infinitives: Avoid the use of superfluous infinitives such as "to be designed to", "to be able to", "to be capable of", "to enable", "to allow".

R11 - Separate Clauses: Use a separate clause for each condition or qualification.

Non-ambiguity

R12 - Correct Grammar, 13 - Correct Spelling, 14 - Correct Punctuation - Use correct grammar, spelling, punctuation.

R15 - Logical Expressions: Use a defined convention to express logical expressions such as "[X AND Y]", "[X OR Y]", [X XOR Y]", "NOT [X OR Y]".

R16 - Use of "Not": Avoid the use of "not."

R17 - Use of Oblique Symbol: Avoid the use of the oblique ("/") symbol except in units, i.e., Km/hr, or fractions.

Singularity

R18 - Single Thought Sentence: Write a single sentence that contains a single thought conditioned and qualified by relevant sub-clauses.

R19 – Combinators: Avoid words that join or combine clauses, such as "and", "or", "then", "unless", "but", "as well as" "but also", "however", "whether", "meanwhile", "whereas", "on the other hand", or "otherwise".

R20 - Purpose Phrases: Avoid phrases that indicate the "purpose of ", "intent of", or "reason for" the need statement or requirement statement.

R21 – Parentheses: Avoid parentheses and brackets containing subordinate text.

R22 – Enumeration: Enumerate sets explicitly instead of using a group noun to name the set.

R23 - Supporting Diagram, Model, or ICD: When a need or requirement is related to complex behavior, refer to a supporting diagram, model, or ICD.

Completeness

R24 – Pronouns; Avoid the use of personal and indefinite pronouns.

R25 – Headings: Avoid relying on headings to support explanation or understanding of the need or requirement.

Realism

R26 – Absolutes: Avoid using unachievable absolutes such as 100% reliability, 100% availability, all, every, always, never, etc.

Conditions

R27 - Explicit Conditions: State conditions' applicability explicitly instead of leaving applicability to be inferred from the context.

R28 - Multiple Conditions: Express the propositional nature of a condition explicitly for a single action instead of giving lists of actions for a specific condition.

Uniqueness

R29 – Classification: Classify needs and requirements according to the aspects of the problem or system it addresses.

R30 - Unique Expression: Express each need and requirement once and only once.

Abstraction

R31 – Solution Free: Avoid stating implementation in a need statement or requirement statement unless there is rationale for constraining the design.

Quantifiers

R32 - Universal Qualification: Use "each" instead of "all", "any", or "both" when universal quantification is intended.

Tolerance

R33 - Range of Values: Define each quantity with a range of values appropriate to the entity to which the quantity applies and against which the entity will be verified or validated.

Quantification

R34 - Measurable Performance: Provide specific measurable performance targets appropriate to the entity to which the need or requirement is stated and against which the entity will be verified to meet.

R35 - Temporal Dependencies: Define temporal dependencies explicitly instead of using indefinite temporal keywords such as "eventually", "until", "before", "after", "as", "once", "earliest", "latest", "instantaneous", "simultaneous", and "at last".

Uniformity of Language

R36 - Consistent Terms and Units: Ensure each term and unit of measure used throughout need and requirement sets as well as associated models and other SE artefacts developed across the lifecycle are consistent with the project's defined ontology.

R37 – Acronyms: If acronyms are used, they must be consistent throughout need and requirement sets as well as associated models and other SE artefacts developed across the lifecycle.

R38 – Abbreviations: Avoid the use of abbreviations in needs and requirement statements as well as associated models and other SE lifecycle artefacts.

R39 - Style Guide: Use a project-wide style guide for individual need statements and requirement statements.

R40 - Decimal Format: Use a consistent format and number of signification digits for the specification of decimal numbers.

Modularity

R41 - Related Needs and Requirements: Group related needs and requirements together.

R42 – Structured Sets; Conform to a defined structure or template for organizing sets of needs and requirements.

Attributes of Need and Requirement Statements (defined in the NRM)

A minimum set of attributes that should be defined for each requirement are annotated with an asterisk ("*")

Attributes to Help Define Needs & Requirement and Their Intent

A1 - Rationale*
A2 - Trace to Parent*
A3 - Trace to Source*
A4 - States and Modes
A5 - Allocation/Budgeting*

Attributes Associated with System Verification & System Validation

A6 - System Verification or System Validation Success Criteria*
A7 - System Verification or System Validation Strategy*
A8 - System Verification or System Validation Method*
A9 - System Verification or System Validation Responsible Organization*
A10 - System Verification or System Validation Level
A11 - System Verification or System Validation Phase
A12 - Condition of Use
A13 -System Verification or System Validation Results
A14 -System Verification or System Validation Status

Attributes to Help Maintain the Requirements

A15 - Unique Identifier*
A16- Unique Name
A17 - Originator/Author*
A18 - Date Requirement Entered
A19- Owner*
A20 – Stakeholders
A21 - Change Board
A22 - Change Proposed
A23 - Version Number
A24 - Approval Date
A25 - Date of Last Change
A26 - Stability/Volatility
A27 - Responsible Person
A28 - Need or Requirement Verification Status*
A29 - Need or Requirement Validation Status*
A30 - Status of the Need or Requirement
A31 - Status (of Implementation)
A32 - Trace to Interface Definition
A33 - Trace to Dependent Peer Requirements
A34 - Priority*
A35 - Criticality or Essentiality*
A36 - Risk (of Implementation) *
A37 - Risk (Mitigation)
A38 - Key Driving Need or Requirement (KDN/KDR)
A39 - Additional Comments
A40 - Type/Category

Attributes to Show Applicability and Allow Reuse

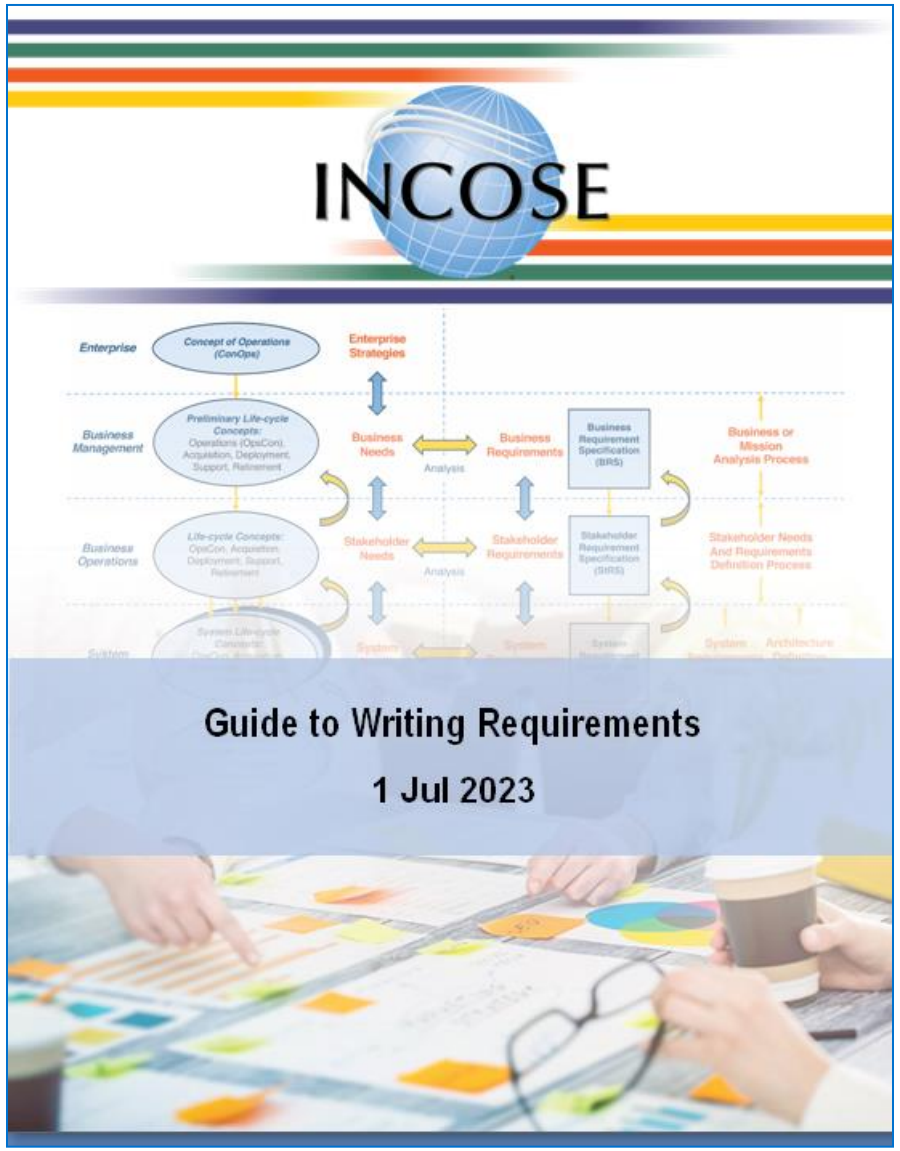
A41- Applicability
A42 - Region
A43 - Country
A44 - State/Province
A45 - Market Segment
A46 - Business Unit

Attributes to Aid in Product Line Management

A47 – Product Line
A48 - Product Line Common Needs and Requirements
A49 - Product Line Variant Needs and Requirements

			Characteristics for Individual needs and requirements									Characteristics for Sets of needs requirements				
			Necessary	Appropriate	Unambiguous	Complete	Singular	Feasible	Verifiable	Correct	Conforming	Complete	Consistent	Feasible	Comprehendible	Able to be validated	Correct
Quality Focus	Rule	Subject	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Accuracy	R1	Structured Statements			X	X			X	X	X						
	R2	Active Voice		X	X	X			X								
	R3	Appropriate Subject-Verb		X	X				X			X				X	
	R4	Defined Terms			X				X				X		X	X	X
	R5	Definite Articles			X				X								
	R6	Common Units of Measure			X	X			X	X							
	R7	Vague Terms			X	X			X								
	R8	Escape Clauses			X				X								
	R9	Open-ended Clauses			X	X	X		X								
Concision	R10	Superfluous infinitives			X				X								
	R11	Separate Clauses			X	X			X	X							
Non-ambiguity	R12	Correct Grammar			X				X	X	X						
	R13	Correct Spelling			X				X								
	R14	Correct Condition			X					X							
	R15	Logical Expressions			X				X								
	R16	Use of "Not"			X				X	X							
	R17	Use of Oblique Symbol			X				X								
Singularity	R18	Single-thought Sentence			X		X		X		X				X		
	R19	Combinators			X		X										
	R20	Purpose Phrases	X				X										
	R21	Parentheses					X										

(includes the matrices)



144 pages

1: Introduction
2: Characteristics of Need & Requirement Statements
3: Characteristics of Sets of Needs & Requirements
4: Rules for Need and Requirement Statements &Sets Of Needs & Requirements
Appendix A: References
Appendix B: Acronyms and Abbreviations
Appendix C: Patterns
Appendix D: Rule Applicability Matrix
Appendix E: Cross Reference Matrices
Appendix F: Comment Form

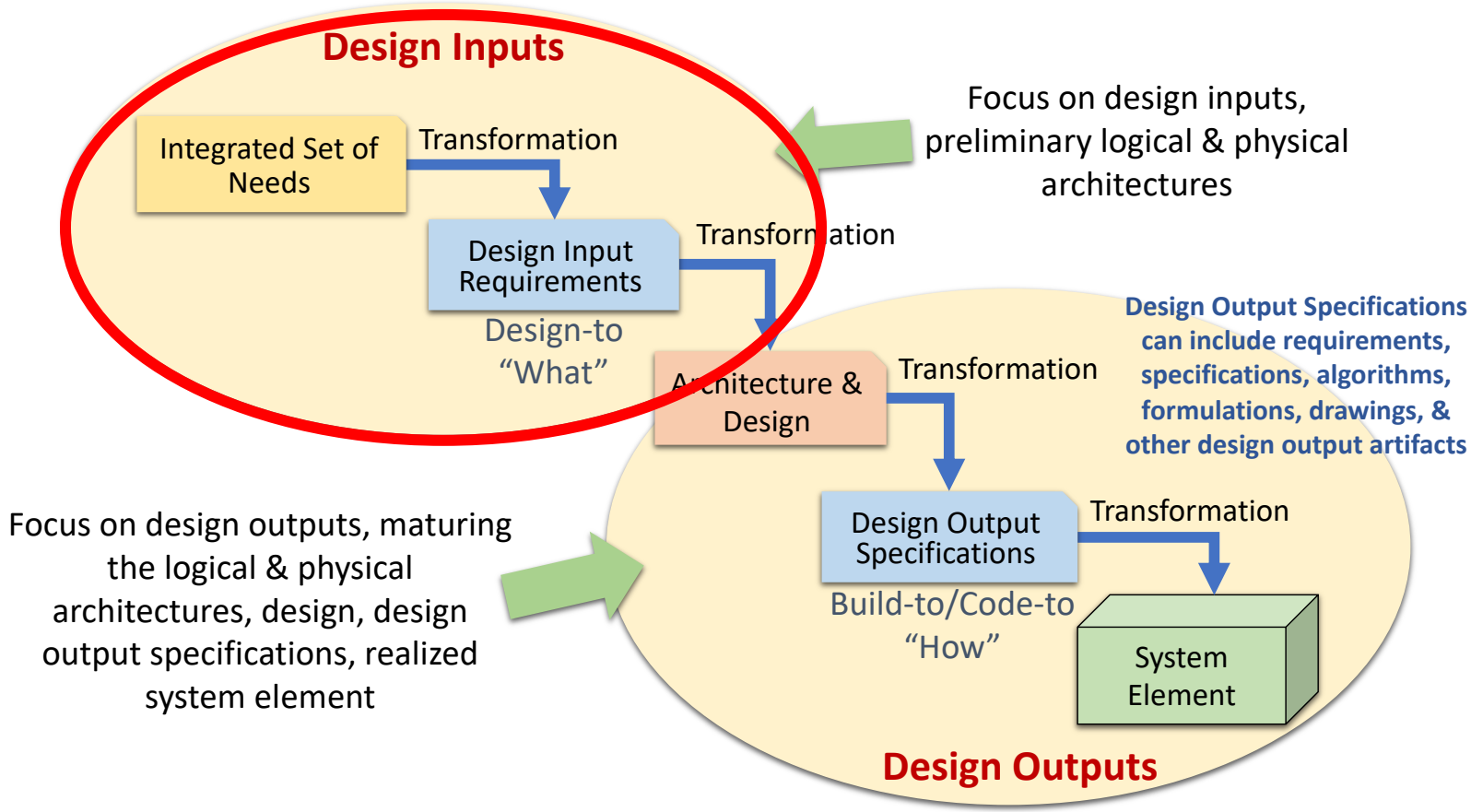
Many thanks to all those that reviewed the GtWR and supplied comments during the multiple review cycles.

Change Summary

- Updated definitions and concepts
- Added more emphasis concerning differences between needs and requirements
- Described stakeholder needs and requirements as compared to an Integrated Set of Needs and set of Design Input Requirements Transformed from those needs.
- Added new Section 1.11: Conditional Clauses and Ubiquitous Requirements
- Revised descriptions and guidance for characteristics
  - Added figures from NRM to better illustrate characteristics
  - Added new characteristic for sets of needs and requirements – C15: Correct
- Updated rules (now includes 42 rules)
  - Changed how rule titles are communicated and included distinct definition for each rule
  - Revised rule elaborations
  - Updated all rule examples
  - Added new rule - R40: Decimal Format
- Moved relationships between characteristics, rules, attributes, and NRM concepts to matrices in Appendix E.
- Updated Appendix C: Patterns
  - Added additional content for patterns for need and requirement statements
  - Increased emphasis on inclusion of conditional and qualifying clauses
- Added Appendix D for application of rules
  - To needs vs requirements
  - Which rules depend on well defined terms in glossary or data dictionary

Focus of the GtWR

- The primary focus of the GtWR is on definition of well-formed need and requirement statements and sets of needs and requirements.
- The needs are contained within an *integrated set of needs* and the requirements are contained within a set of *design input requirements* for the SOI.
- Together, the integrated set of needs and resulting set of design input requirements are considered inputs into the *Architecture Definition* and *Design Definition* processes which transform the design input requirements into sets of design output specifications to which the SOI is realized.



Section 1 Introduction

Section 1.7: Needs, Requirements, & the Entity to Which They Apply

- *Needs* and *requirements* apply to an *entity*, which could exist at any level of the organization or the system architecture in the context of a problem or opportunity fulfilled by the entity
- An **entity** is a single item to which a concept, need, or requirement applies: an organization, business unit, project, supplier, service, procedure, SOI - Physical (system, subsystem, system element), SOI – Software (application, package, module, feature), product, process, or stakeholder class (user, operator, tester, maintainer, etc.).
- There are three general types of entities
  - physical or software entities such as the engineered systems to be developed;
  - process entities such as procedures or work instructions; and
  - business or human entities such as business units, users, customers, developers, suppliers, and other stakeholders.

Section 1.7: Needs, Requirements, & the Entity to Which They Apply

- The requirement could be:
  - Project requirements (Project charter, project plan, other plans, work instructions)
    - The <project> shall …….
    - The <xxxxx team> shall…….
  - Supplier requirements (SOW – activities and deliverables)
    - The <supplier/contractor> shall …….
  - System verification or validation procedural requirements
    - The <operator, technician, engineer> shall <stimulate the SOI in some manner>.
    - The <operator, technician, engineer> shall <record the results of the stimulation>.
  - Product requirement
    - The <SOI> shall <perform some function with the desired performance under some operating condition>. (Design input)
    - The <SOI component> shall be manufactured to <the physical dimensions shown in drawing xyz?>. (Design output).

Requirements for the different entities must not be mixed together within a single set of requirements.

Each set of requirements must only include requirement statements that relate to the single entity to which the set applies.

Section 1.8: Needs vs Requirements

- The RWG NRM and GtNR define the concepts and activities in detail involved in the transformation of stakeholder needs and stakeholder requirements into an Integrated Set of Needs which are transformed into a set of system requirements.

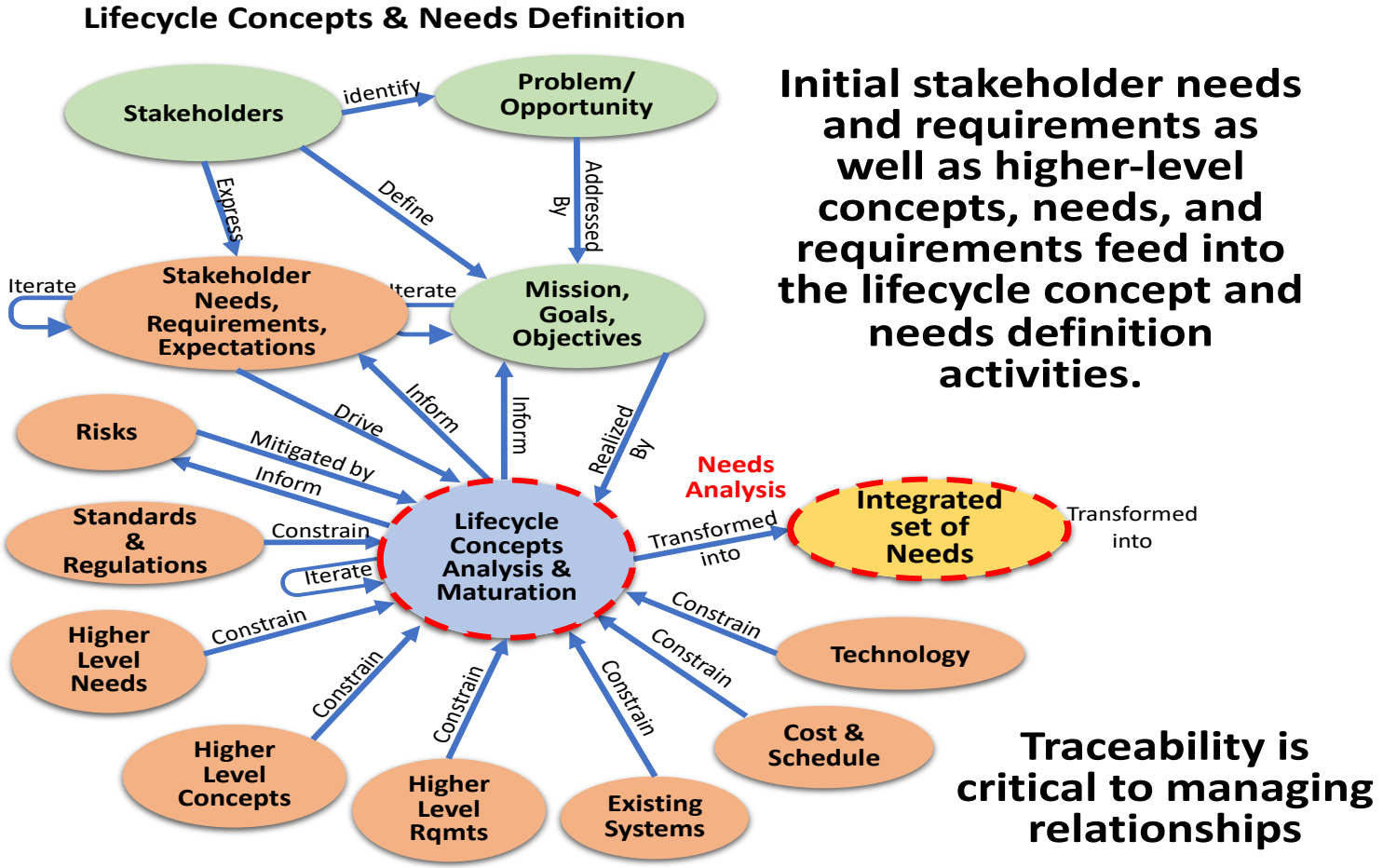
- Unlike stakeholder needs, the Integrated Set of Needs are well-formed having the characteristics defined in the GtWR.

Stakeholder needs and requirements are not the same as the Integrated set of Needs.

They are two different concepts.

Approach Taken in the RWG Products

Stakeholder real-world expectations in the form of stakeholder needs and requirements (or other forms of expression), problem, mission statement, goals, objectives defined by the Business or Mission Analysis and Stakeholder Needs and Requirements Definition Processes **are treated as inputs into the lifecycle concepts analysis and maturation activities conducted at the system level.**



Stakeholder/customer-owned system requirements are treated as higher level requirements that are inputs into the lifecycle concepts analysis and maturation activities.

Integrated Set of Needs

- The Integrated Set of Needs represent an integrated stakeholder, customer/acquirer view of the system of interest (SOI)
  - Communicates the perspective of the system as viewed externally (black box).
  - Communicates the stakeholder real-world expectations for the end-state once the SOI is delivered.
    - In the end what will final acceptance be based on?
    - What is needed to show the delivered system is fit for use in its operational environment?
  - The integrated set of needs must be well-formed having the characterizes defined in the GtWR.
  - The baselined Integrated Set of Needs represents the agreed-to scope of the project.
  - The requirements, design, and SOI will be validated against its Integrated Set of Needs.

A key point is that the Integrated Sets of Needs is defined, owned, and managed by the customer.

It is only the customer that has a right to define what their needs are - not the suppliers or developers.

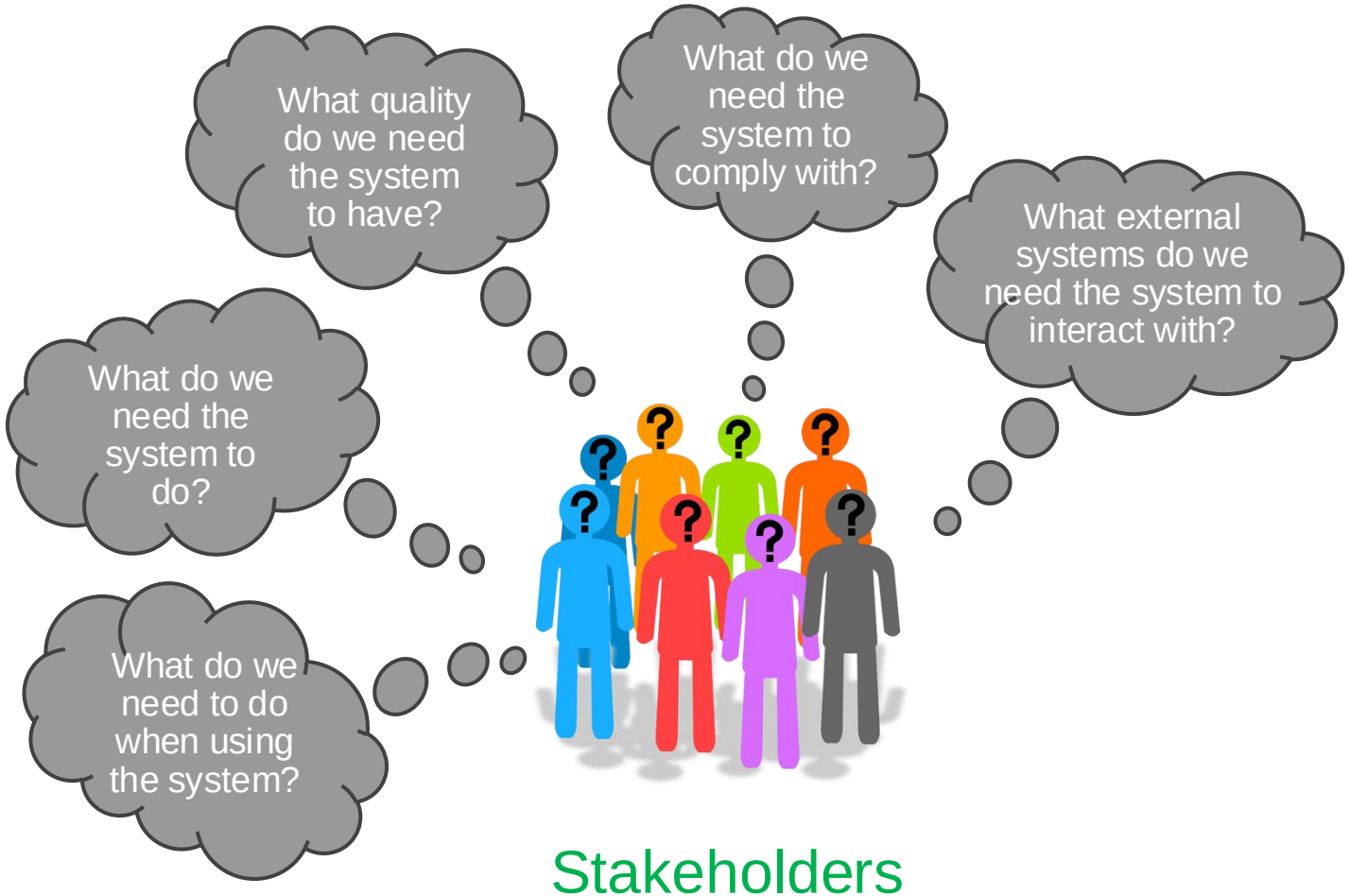
Design Input Requirements

- Design input requirements represent the technical, developer view of the SOI referred to as the “System Requirements”.
  - Transformed from the Integrated Set of Needs.
  - Communicates the perspective of the system as viewed by the developers (transparent box).
  - Expressed as “shall” statements,
    - “The SOI “shall” …”
    - or for a goal, expressed as a “should” statement, “The SOI “should” ……”
  - Inputs to the architecture and design definition processes.
  - The design input requirements are validated against the integrated set of needs.
  - Both the design and realized SOI will be verified against its design input requirements.

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

If the Integrated Set of Needs does not have the characteristics defined in the GtWR, neither will the resulting set of design input requirements.

Two Different Perspectives



Stakeholders

Customer and/or Developing Organization

Integrated Set of Needs

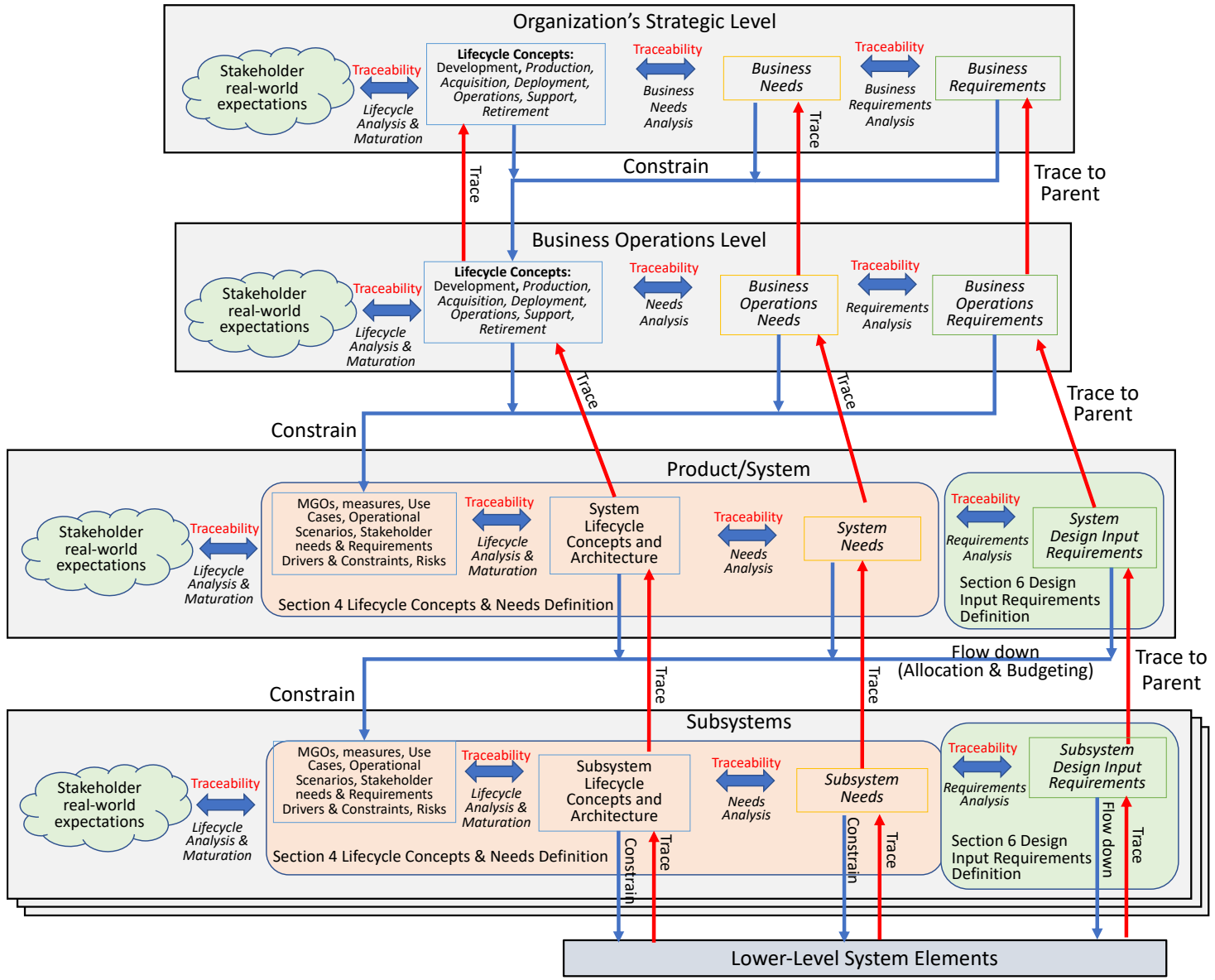
Vs.

Design Input Requirements

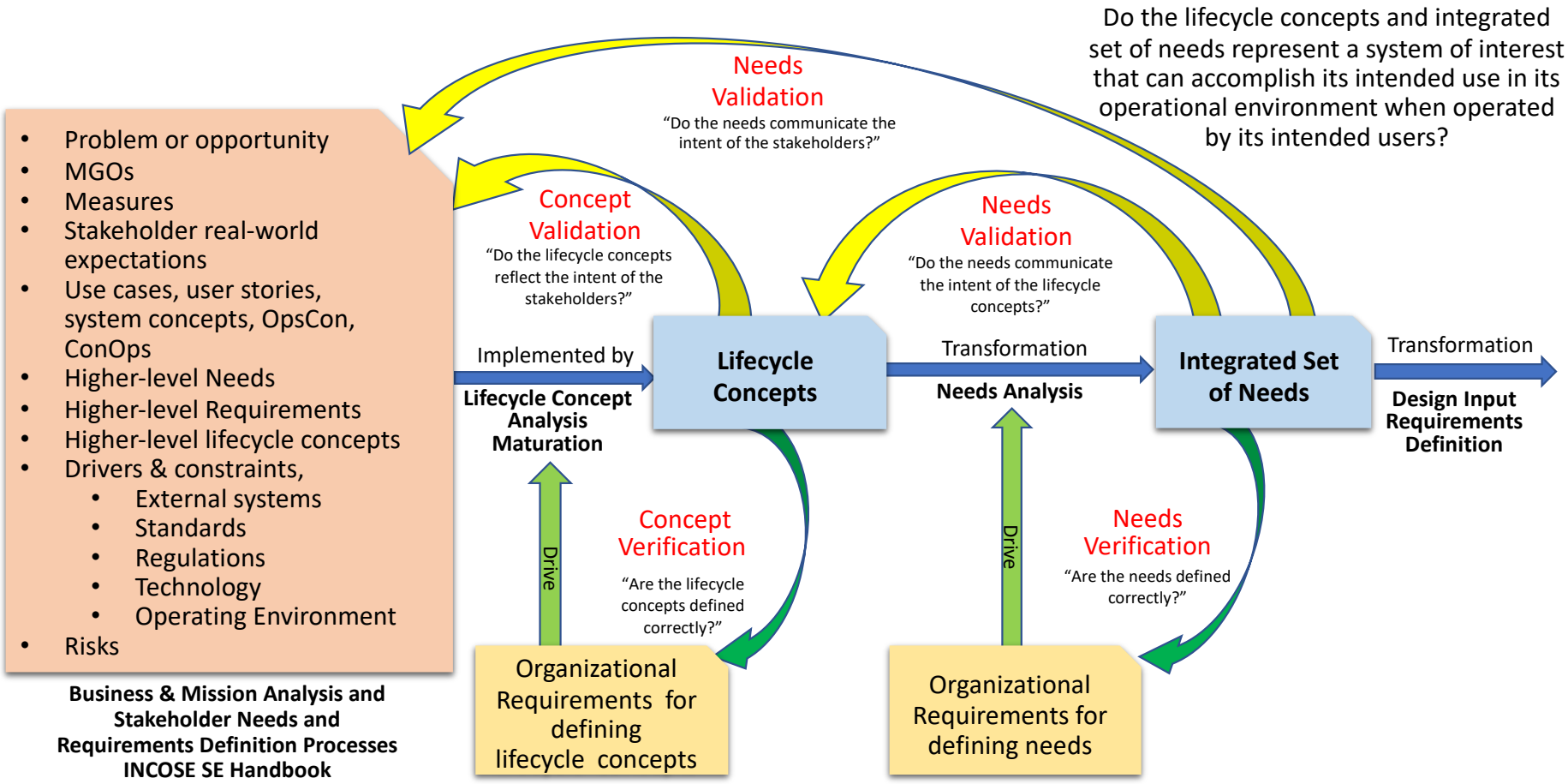
Levels of lifecycle concepts, needs, and requirements

Stakeholder real-world expectations, lifecycle concepts, needs, and requirements exist at each level.

Stakeholders communicate their expectations in various forms: needs, requirements, use cases, user stories, operational scenarios.



Defining an Integrated Set of Needs for an SOI



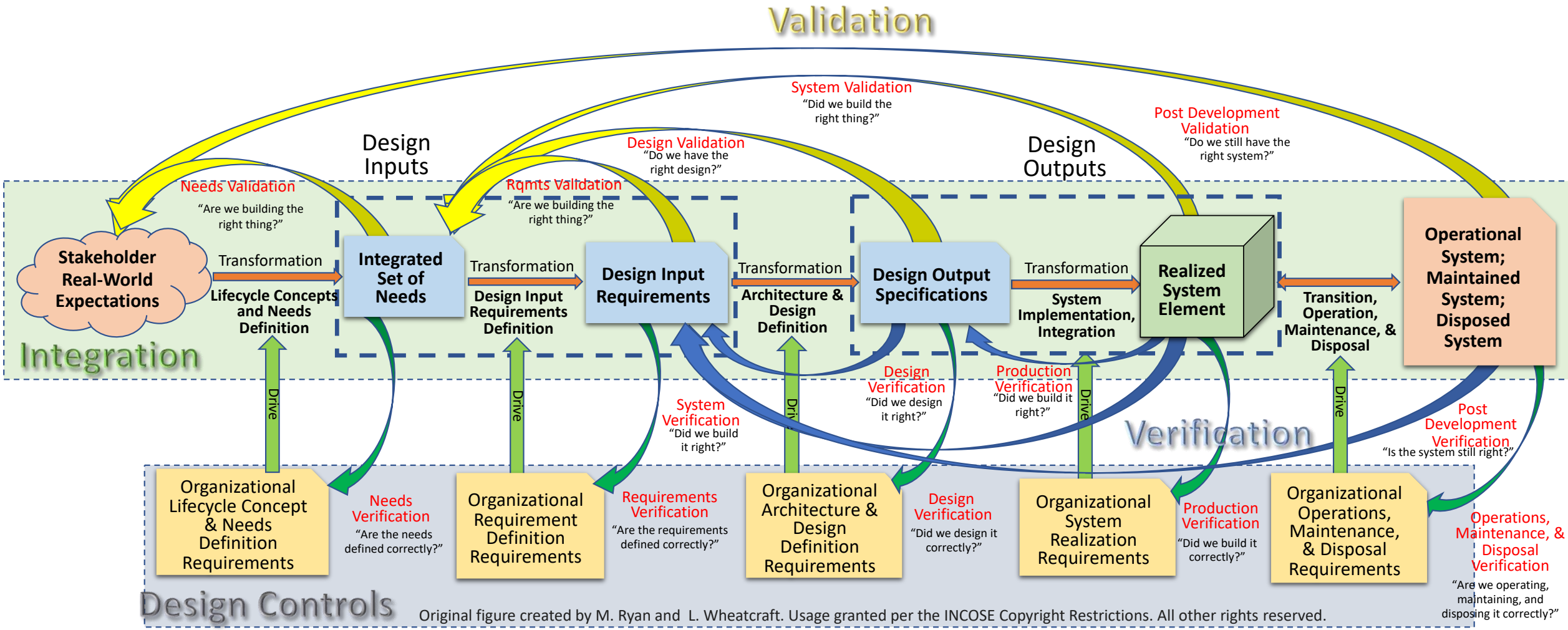
Stakeholder real-world expectations include stakeholder needs and requirements as well as higher-level needs and requirements defined during the Business and Mission Analysis and Stakeholder Needs and Requirements Definition processes.

Section 1.9 Quality of Needs & Requirements

- When defining needs and requirements, it is important that they have the characteristics of well-formed needs and requirements as defined in this Guide.
  - These characteristics are a result of
    - following the rules defined in this Guide
    - **as well as** performing the activities associated with the definition of the needs and requirements as discussed in the NRM and GtNR.
  - The underlying analysis from which a need or requirement was derived is as important as how well the need or requirement statement is formed.
  - A requirement can be well-formed following the rules in this guide, but yet not be correct nor feasible.
- To help ensure needs and requirements and sets of needs and requirements have the characteristics defined in this Guide, for each characteristic there is traceability between both the rules in this Guide and the concepts and activities discussed in the NRM.

“Writing needs and requirements is not an exercise in writing, but an exercise in engineering.”

Section 1.10: Needs and Requirements In The Context of Verification & Validation



Section 1.11: Conditional Clauses and Ubiquitous Requirements

- As defined in ISO/IEC/IEEE 29148 a requirement is a statement which translates or expresses a need and its associated constraints and ***conditions***.
- Requirements *without a condition* are referred to as “Ubiquitous” requirements which are requirements that do not require a condition or context which triggers the desired system response.
- Requirement sets will contain both ubiquitous and non-ubiquitous requirements.
- It is a common error when defining requirements to treat non-ubiquitous requirements as ubiquitous - failing to clearly communicate the condition in which the requirement applies or context which triggers the desired system response.
  - This results in requirements that are not Unambiguous (C3), Complete (C4), Correct (C8), nor Verifiable (C7).
- When defining requirements describing a desired system response for an action performed by a system, subsystem or system elements, it is necessary to avoid the use of ubiquitous requirements as much as possible.
- The use of conditional clauses also aids in consistency of requirements and the models they were derived, when addressing state definitions and transitions, enabling the development of simulations of the system behavior.

Conditional Clauses and Ubiquitous Requirements

- This concept has been commercialized in approaches such as “EARS” (*Easy Approach to Requirements Syntax*) (Mavin 2009) and within several NLP/AI tools that are used to access requirements quality.
- The GtWR addresses the use of conditional clauses in several of the rules:
  - R1 – Structured Statements
  - R11 –Separate Clauses
  - R18 –Single Thought Sentence
  - R27 –Explicit Conditions
  - R28 – Multiple Conditions
- Appendix C, Requirement Patterns, also addresses the use of conditional clauses.

Section 2: Characteristics of Individual Need and Requirement Expressions

Formal Transformation. Given the need and requirement is a result of a formal transformation, the following characteristics of a well-formed need or requirement have been derived:

C1 - Necessary: The need requirement statement defines capability, characteristic, constraint, or quality factor needed or required to satisfy a lifecycle concept, need, source, or higher-level requirement.

C2 - Appropriate: The specific intent and amount of detail of the need or requirement statement is appropriate to the level (the level of abstraction, organization, or system architecture) of the entity to which it refers.

C5 - Singular: The need or requirement statement should state a single capability, characteristic, constraint, or quality factor.

C8 - Correct: The need statement must be an accurate representation of the lifecycle concept or source from which it was transformed. The requirement statement must be an accurate representation of the need, source, or higher-level requirement from which it was transformed.

C9 - Conforming: Statements and expressions of individual needs and requirements should conform to an approved standard pattern and style guide or standard for writing and managing needs and requirements.

Agreed-to Obligation. Since the need and requirement is to be a part of a fair agreement to meet an obligation, the following characteristics of a need or requirement have been derived.

C3 - Unambiguous: Need and requirement statements must be stated such that their intent is clear and can be interpreted in only one way by all intended audiences.

C4 - Complete: The need statement sufficiently describes the necessary capability, characteristic, constraint, conditions, or quality factor to meet the lifecycle concept or source from which it was transformed. The requirement statement sufficiently describes the necessary capability, characteristic, constraint, conditions, or quality factor to meet the need, source, or higher-level requirement from which it was transformed.

C6 - Feasible: The need or requirement can be realized within entity constraints (for example: cost, schedule, technical, legal, ethical, safety) with acceptable risk.

C7 - Verifiable: The need statement is structured and worded such that its realization can be validated to the approving authority's satisfaction. The requirement statement is structured and worded such that its realization can be verified to the approving authority's satisfaction.

Section 3: Characteristics of Sets of Needs and Sets of Requirements

Formal Transformation. Given the set of needs and requirements is the result of a formal transformation, the following characteristics of the need and requirement set have been derived:

C10 - Complete: The set of needs and set of requirements for an entity should stand alone such that it sufficiently describes the necessary capabilities, characteristics, functionality, performance, drivers, constraints, conditions, interactions, standards, regulations, safety, security, resilience, and quality factors without requiring other sets of needs or sets of requirements at the appropriate level of abstraction.

C11 - Consistent: A set of needs and a set of requirements is consistent if contains individual needs or requirements that are:

- unique;
- do not conflict with or overlap with others in the set;
- makes use of homogeneous units and measurement systems; and
- are developed using a consistent language (that is, the same words are used throughout the set to mean the same thing); and use terms that are consistent with the architectural model, project glossary, and project data dictionary.

C15 - Correct: The set of needs must be an accurate representation of the lifecycle concepts or sources from which it was transformed. The set of requirements must be an accurate representation of the needs, sources, or higher-level requirements from which it was transformed.

Agreed-to Obligation. Since the set of need and requirements is to be a result of a fair agreement to meet an obligation, the following characteristics of the set have been derived:

C12 - Feasible: A set of needs and a set of requirements is feasible if it can be realized within entity constraints (such as cost, schedule, technical) with acceptable risk.

C13 - Comprehensible: The set of needs and the set of resulting requirements must each be written such that it is clear as to what is expected of the entity and its relation to the macro system of which it is a part.

C14 - Able to be validated: It must be possible to validate that the set of needs will lead to the achievement of the product goals and objectives, stakeholder expectations, risks, and lifecycle concepts within the constraints (such as cost, schedule, technical, legal and regulatory compliance) with acceptable risk.

It must be possible to validate that the set of requirements will lead to the achievement of the set of needs and higher-level requirements within the constraints (such as cost, schedule, technical, and regulatory compliance) with acceptable risk.

Characteristics Format

2.9 C8 - Correct

Definition:

The need statement must be an accurate representation of the lifecycle concept or source from which it was transformed.

The requirement statement must be an accurate representation of the need, source, or higher-level requirement from which it was transformed.

Rationale:

Correct implies "no errors" both from the perspective of the inclusion of incorrect information, the omission of required information, and avoidance of ambiguous wording. These aspects are similar to those in other disciplines such as NLP with the classical human filters of generalization, deletion, and distortion.

Incorrect information can mean having the wrong:

- values,
- functions,
- conditions, or
- other characteristics identified in the need or requirement.

An incorrect need can result in a need that does not reflect the intent of the lifecycle concept or sources from which it was transformed. An incorrect need can result in incorrect requirements transformed from that need. An incorrect requirement can result in a requirement that does not reflect the intent of the need, source, or higher-level requirement from which it was transformed.

The need or requirement cannot be correct if it does not have the characteristics: Necessary (C1), Unambiguous (C3), Complete (C4), Feasible (C6), Verifiable/Validatable (C7), and Conforming (C9).

Guidance:

Needs are transformed from a source (such as lifecycle concepts, stakeholder expectations, drivers and constraints, goals, objectives, and risks) defined as part of the lifecycle concept and needs definition activities discussed in the NRM and GtNR.

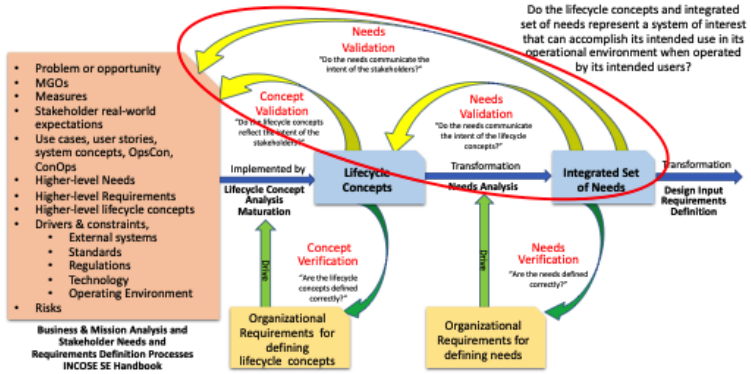


Figure 14: Needs Validation

As shown in Figure 14, the resulting needs transformed from these sources must be validated to ensure that the need statement communicates the right thing (intent) and reflects an accurate and unambiguous:

- interpretation of the concept, stakeholder expectation, drivers and constraints, goals, objectives, risks, and other sources from which it was transformed;
- understanding of the problem or opportunity and underlying goals and objectives;
- representation of any model or diagram from which the need was extracted so the need traces to the model; and
- representation of any underlying analysis and assumptions that were part of the transformation.

Use a defined development and management process to ensure accuracy of the transformation in the context of the individual need as well as the other needs in the set.

Requirements are transformed from a need, source, or higher-level requirement. The resulting requirements must be validated to ensure that the requirement statement communicates the right thing and that achievement of the requirement, as written, will result in meeting the intent of the need, source, or higher-level requirement from which it was transformed.

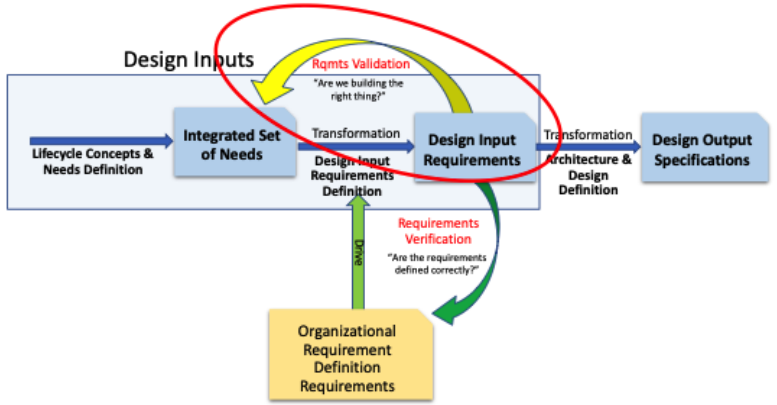


Figure 15: Requirements Validation

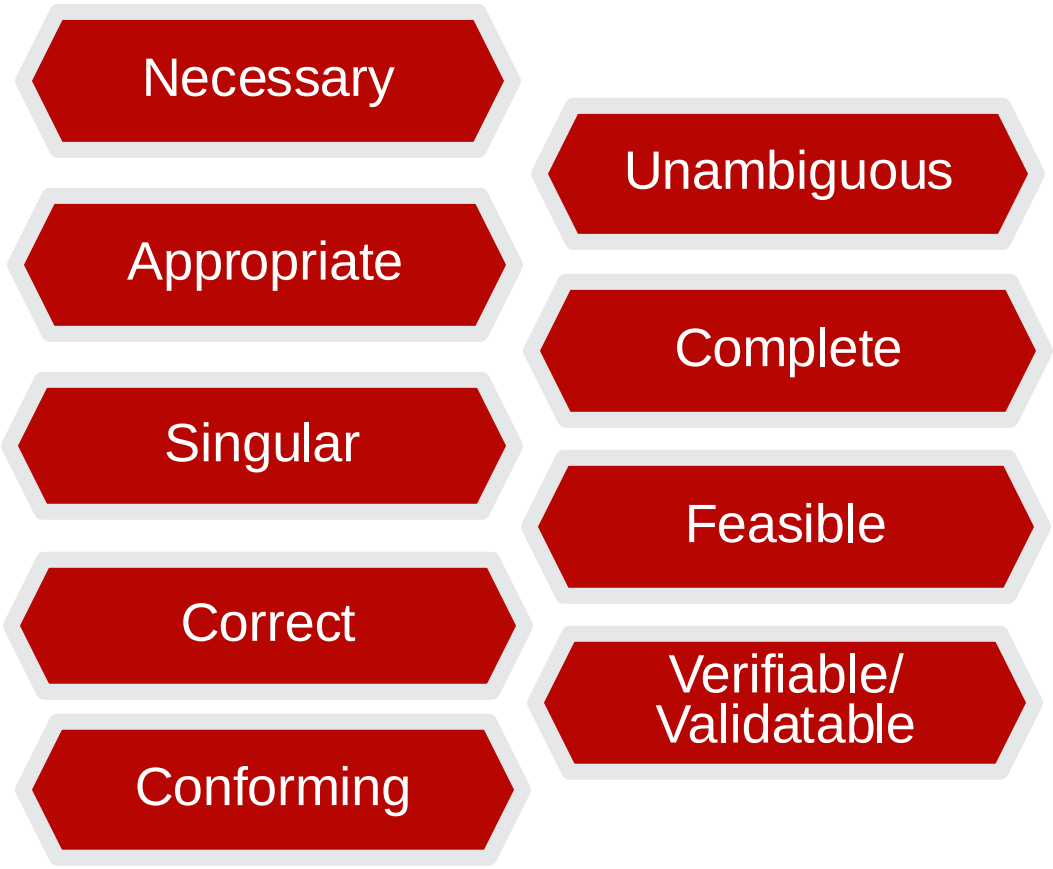
As shown in Figure 15, validate that the requirement statement reflects an accurate and unambiguous:

- interpretation of the need, source, or higher-level requirement from which it was transformed;
- representation of the model or diagram from which the requirement was extracted so the requirement traces to the model or diagram; and
- representation of the underlying analysis and assumptions that were part of the transformation.

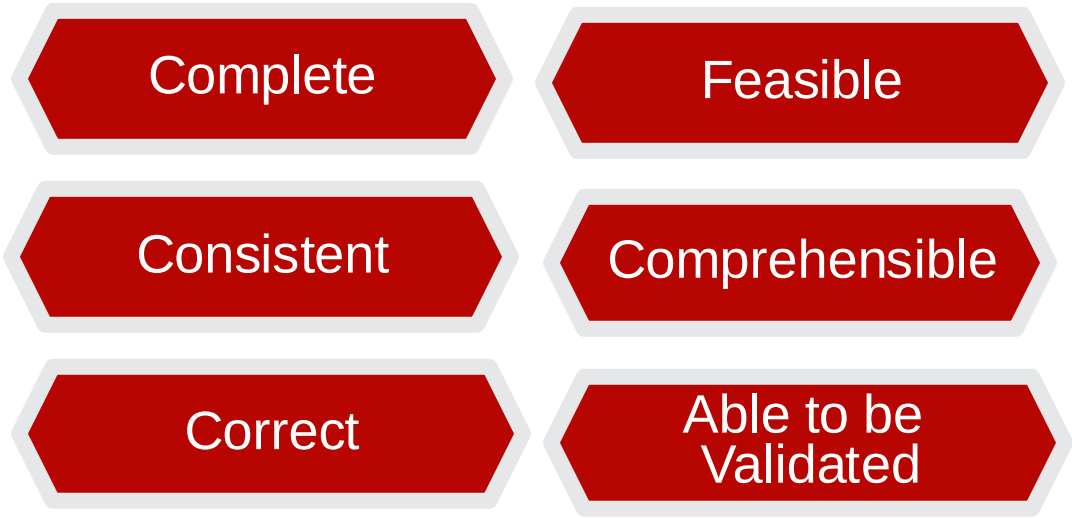
As discussed in Section 1.9, perform the needs and requirements validation described in the NRM and GtNR to ensure correctness of the transformation in the context of the individual need and requirement statements as well as the complete sets of needs and requirements.

Correctness of individual need and requirement statements can also be assessed during early system verification and design verification activities discussed in the NRM and GtVV.

Lots of Characteristics!!!!



Need and Requirement Statements



Sets of Needs and Requirements

SMART

- **Specific** - Singular (C5), concise, simple, clear, Complete (C4 individual), Consistent (C11 Set use of terms), Unambiguous (C3), understood one way, Conforming (C9)
- **Measurable** - testable, Verifiable/Validatable (C7), Correct (C8), Unambiguous (C3), Comprehensible (C13 - Set), and Able to be Validated (C14 - Set), Correct (C15 – Set)
- **Appropriate (C2)** - Appropriate to level
- **Realistic** – Feasible *(C6 Individual) and (C12 - Set)* achievable within constraints (cost, schedule, technology, ethics, legal, regulatory, resources, risk)
- **Traceable** – Necessary (C1), Complete (C10 set), identifiable, linked, sufficient, Consistent (C11 with other related requirements).

- Originally applied to goals and objectives – modified to be more applicable to needs and requirements based on characteristics discussed in this Guide.

C^3F – Sets of Needs and Requirements

- **Correct (C15) -** Appropriate (C2), Unambiguous (C3), Complete (C4), Singular (C5), Verifiable/validatable (C7), Correct (C8 - individual), Conforming (C9), Comprehensible (C13), and Able to be Validated (C14).
- **Complete (C10) -** N*ecessary* (C1) - needed, traceable, sufficient
- **Consistent (C11)** – use of terminology and with other related requirements.
- **Feasible (C12) -** Feasible *(C6 Individual),* Achievable within constraints (cost, schedule, technology, ethics, legal, regulatory, resources, risk)

- C^3F used frequently within the NRM when referring to well-formed sets of needs and requirements.
- Correctness, completeness, and consistency are the three most common characteristics used to assess requirements quality by NLP/AI applications, e.g., The Reuse Company.

VAN

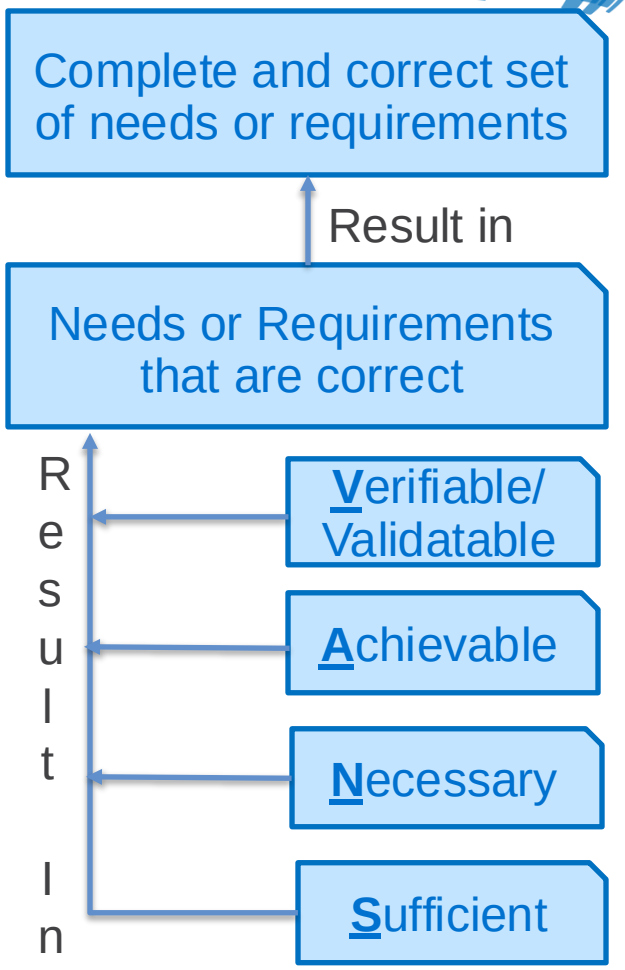
- **Verifiable/Validatable *(C7)* -** Appropriate (C2), Unambiguous (C3), Complete (C4 individual), Singular (C5), Correct (C8 - Individual), Conforming (C9), Consistent (C11 Set), Comprehensible (C13 - Set), and Able to be Validated (C14 - Set), Correct (C15 – Set).
- **Achievable** – Feasible *(C6 Individual) and (C12 - Set)* within constraints (cost, schedule, technology, ethics, legal, regulatory, resources, risk)
- **Necessary (C1)** - needed, traceable, sufficient, Complete (C10 set)

- Presented in Ivy Hooks/Lou Wheatcraft requirements training classes.

VANS

- ***Verifiable/validatable (C7) -*** Appropriate (C2), Unambiguous (C3), Complete (C4), Singular (C5), Conforming (C9), Consistent (C11), Comprehensible (C13), and Able to be Validated (C14).
- **Achievable** - Feasible *(C6 and C12)* within constraints (cost, schedule, technology, ethics, legal, regulatory, resources, risk)
- ***Necessary*** (C1) - needed, traceable, Complete (C10) (set)
- ***Sufficient -*** Complete (C4 and C10).

- Derived from (Carson 2018)
- Represents four main characteristics proposed by Ron Carson making a distinction between “necessary” and “sufficient”.
  - These four characteristics take into consideration the dependencies and overlap of the 15 characteristics discussed in this Guide.
- Carson proposes that these four characteristics result in need and requirement statements that are Correct (C8).
- Carson also proposes that, collectively, if each need and requirement statement is Correct (C8), then the integrated set of needs and set of requirements in which it is a part will be both Complete (C10) and Correct (C15).



Derived from Carson 2018 – Figure 2. Usage granted per the INCOSE Copyright Restrictions. All other rights reserved.

Carson, R. S., Noel, R. A., “Formal Requirements Verification and Validation,” INCOSE IS 2018.

Section 4: Rules for writing well-formed Need and Requirement Statements and Sets of Needs and Requirements

The GtWR provides a set of rules that **contribute to** requirement statements having the desired characteristics of well-formed individual requirements and sets of needs and requirements.

- While following the rules is necessary, it is not sufficient.
- The overall quality of the requirements is also dependent on the concepts and activities defined in the INCOSE Needs and Requirements Manual (NRM).

The rules for needs and requirements discussed in the GtWR apply to needs and requirements for any entity no matter the level within an organization or system architecture.

Rule Format

Title
Definition
Elaboration
Examples
Exceptions and Relationships

1.1.1 R34 – MEASURABLE PERFORMANCE

Definition:
Provide specific measurable performance targets appropriate to the entity to which the need or requirement is stated and against which the entity will be verified to meet.

Elaboration:
Some words signal unmeasured quantification, such as "prompt", “fast", “routine”, “maximum”, “minimum”, “optimum”, “nominal”, “easy to use”, “close quickly”, “high speed”, “medium-sized”, “best practices”, and “user-friendly.” These are ambiguous and need to be replaced by specific quantities within feasible ranges that can be measured.

Examples:
Unacceptable: The <SOI> shall use minimum power. [This is unacceptable because both words “use” and “minimum” are ambiguous and unverifiable.] Improved: The <SOI> shall consume less than or equal to 50W of mains power. [This both considers the underlying goal—to minimize power consumption—and provides a measurable target.] Unacceptable: The engine shall achieve an emissions level that is at least 5% less than the competition’s emission levels 2 years from now. [This is an actual requirement from marketing to an engineering department. The statement sets a completely unmeasurable end state.] Improved: The Engine shall achieve an emissions level that is less than or equal to xxx. [where xxx represents the required threshold value, including the appropriate units.] Unacceptable: The <SOI> shall conform to best practices for spurious emissions. [This statement is vague and unverifiable from number of specifics] Improved: The <SOI> shall limit Spurious_Emissions in accordance with <Clause xab of Standard XYZ>.

Exceptions and relationships:
Some quantification terms such as “minimum”, “maximum”, “optimal” are almost always ambiguous. Other terms may be ambiguous at lower levels but sufficient at the higher levels and as need statements. For example, it may be appropriate that the business state that “The Aircraft shall provide class-leading comfort.”—while such a requirement is not quantifiable and therefore not measurable, it may be sufficient for the business to communicate its intentions as a need statement to developers who can then turn comfort into such measurable quantities such as seat dimensions and leg length. This exception also applies to needs stated at the system or system element levels.

Rules to Characteristics Cross Reference Matrix

			Characteristics for Individual needs and requirements									Characteristics for Sets of needs requirements					
			Necessary	Appropriate	Unambiguous	Complete	Singular	Feasible	Verifiable	Correct	Conforming	Complete	Consistent	Feasible	Comprehensible	Able to be validated	Correct
Quality Focus	Rule	Subject	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Accuracy	R1	Structured Statements			X	X			X	X	X						
	R2	Active Voice		X	X	X			X								
	R3	Appropriate Subject-Verb		X	X				X			X				X	
	R4	Defined Terms			X				X				X		X	X	X
	R5	Definite Articles			X				X								
	R6	Common Units of Measure			X	X			X	X							
	R7	Vague Terms			X	X			X								
	R8	Escape Clauses			X				X								
	R9	Open-ended Clauses			X	X	X		X								
Concision	R10	Superfluous infinitives			X				X								
	R11	Separate Clauses			X	X			X	X							
Non-ambiguity	R12	Correct Grammar			X				X	X	X						
	R13	Correct Spelling			X				X								
	R14	Correct Condition			X					X							
	R15	Logical Expressions			X				X								
	R16	Use of “Not”			X				X	X							
	R17	Use of Oblique Symbol			X				X								
Singularity	R18	Single-thought Sentence			X		X		X		X				X		
	R19	Combinators			X		X										
	R20	Purpose Phrases	X				X										
	R21	Parentheses					X										
	R22	Enumeration			X		X										
	R23	Supporting Diagram, Model or ICD			X	X	X										
Completeness	R24	Pronouns			X	X			X								
	R25	Headings				X											
Realism	R26	Absolutes						X	X	X				X			
Conditions	R27	Explicit Conditions				X			X	X							
	R28	Multiple Conditions			X				X								
Uniqueness	R29	Classification										X	X				
	R30	Unique Expression	X								X		X				
Abstraction	R31	Solution Free		X													
Quantifiers	R32	Universal Qualification			X				X	X							
Tolerance	R33	Range of Values			X	X		X	X	X				X			
Quantification	R34	Measurable Performance			X	X			X					X			
	R35	Temporal Dependencies			X	X			X								
Uniformity of Language	R36	Consistent Terms and Units			X					X	X		X		X	X	X
	R37	Acronyms			X						X		X		X	X	X
	R38	Abbreviations									X		X		X	X	X
	R39	Style Guide				X	X				X		X		X	X	X
	R40	Decimal Format			X	X					X		X				
Modularity	R41	Related Needs and Requirements				X					X	X	X		X		X
	R42	Structured Sets										X	X		X	X	X

NRM Concepts and Activities to Characteristics Cross Reference Matrix (partial)

		Characteristics for Individual needs and requirements									Characteristics for Sets of needs requirements					
		Necessary	Appropriate	Unambiguous	Complete	Singular	Feasible	Verifiable	Correct	Conforming	Complete	Consistent	Feasible	Comprehensible	Able to be validated	Correct
NRM Concepts and Activities		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
SECTION 3: INFORMATION-BASED NEEDS AND REQUIREMENT DEVELOPMENT AND MANAGEMENT																
3.2.1.1	Communication			X				X							X	
3.2.1.2	Power of Expression			X	X			X						X	X	
3.2.1.3	Managing Sets of Needs And Requirements				X									X		
3.2.1.5	Attributes	X												X		
3.2.1.6	Formal, Binding Agreement	X		X	X		X	X						X	X	
3.2.1.7	System Verification and System Validation							X							X	
3.2.2.1	Analysis from Which Needs and Requirements are Derived	X					X		X		X	X	X	X	X	X
3.2.2.2	Completeness										X			X	X	
3.2.2.3	Consistency											X		X	X	
3.2.2.4	Identity and Manage Interdependencies								X			X		X	X	X
3.2.2.5	Support Simulations							X						X	X	
3.2.2.6	Key to Understanding													X	X	
SECTION 4: LIFECYCLE CONCEPTS AND NEEDS DEFINITION																
4.3.3	Identify External and Internal Stakeholders										X					
4.3.6.2	Technology Maturity						X						X			
4.3.7.1	Classes of Risk - Development Risk						X						X			
4.4.3	Get Stakeholder Agreement	X		X	X			X	X		X	X		X	X	X
4.4.4	Completeness										X					
4.5	Lifecycle Concepts Analysis and Maturation	X			X		X	X	X			X				X
4.5.1	Feasibility						X						X			
4.5.3	User of Diagrams and Models for Analysis	X							X		X	X				X
4.5.4	Levels of Detail and Abstraction		X													
4.5.7.1	Model Development, Analysis, and Maturation	X							X		X	X				X
4.5.7.4	Zeroing in on a Feasible Architecture and Design						X						X			
4.6.2.3	Organizing the Integrated Set of Needs									X	X					
4.6.3.1	Managing Unknowns			X	X		X	X	X							X
4.6.3.2	Appropriate to Level		X													
4.6.3.3	Completeness of the Integrated Set of Needs										X					
4.6.3.4	Needs Feasibility and Risk	X	X				X						X			
4.7	Plan for System Validation														X	
4.8	Baseline & Manage Lifecycle Concepts & Needs Definition Outputs	X		X	X		X		X		X	X	X	X	X	X
SECTION 5: NEEDS VERIFICATION AND NEEDS VALIDATION																
5.1.2	Perform Needs Verification	X		X	X					X	X	X			X	
5.2	Needs Validation														X	
5.2.2	Perform Needs Validation			X			X		X		X		X	X	X	X

Rule Applicability: Needs vs Requirements

Appendix D: Rule Applicability Matrix

- Help SE practitioners tailor the rule set to be used to either assess the quality of need statements or requirement statements, providing them with guidance about optional or recommended rules applicable to needs before being applied to the requirements transformed from those needs.
  - Guidance as to the selection of the appropriate set of rules when they are applied to need statements versus requirement statements.
  - Each rule is assigned a specific level of applicability:
    - **CNCR:** Compulsory for Needs and Compulsory for Requirements,
    - **RNCR:** Recommended for Needs and Compulsory for Requirements,
    - **CR:** Compulsory for Requirements (Optional for Needs).
- Provide guidance about the need for a Project Data Dictionary, which can be organized either as a glossary, a model, or an ontology, among other kinds of data models.
  - Defined at organizational level, which enables SE practitioners to process those data inputs into engineered knowledge that will then be used across the lifecycle by the organizational project teams that may be using different tools.
  - Can include terms and definitions, but also relationships that help precisely define a consistent terminology to describe the SOI, its operating environment, and interactions with other external systems in the operational environment.

Rule #	Rule Name	Rule Short Description	Rule Applicability*	Applicability Comments	Requires Project Data Dictionary, Glossary, Models or Ontology? (Y/N)	Scope Comments
R1	Structured Statements	Need statements and requirement statements must conform to one of the agreed patterns, thus resulting in a well-structured complete statement.	CNCR		N	
R2	Active Voice	Use the active voice in the need statement or requirement statement with the responsible entity clearly identified as the subject of the sentence.	RNCR	Needs: The use of active voice can have a higher tolerance when considering needs, although it is recommended to avoid it in both cases.	N	
R3	Appropriate Subject-Verb	Ensure the subject and verb of the need or requirement statement are appropriate to the entity to which the statement refers.	CNCR		Y	The subject should be the entity rather than a characteristic of the entity.
R4	Defined Terms	Define all terms used within the need statement and requirement statement within an associated glossary and/or data dictionary.	CNCR		Y	
R5	Definite Articles	Use definite article "the" rather than the indefinite article "a."	RNCR	Needs: Some concepts with a higher level of abstraction might be expressed indefinitely in need statements as they are still not clearly defined. Also see R08 and R09.	N	

Appendix D: Rule Applicability Matrix

Questions and Discussion

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 and product scope; defining and maturing system concepts; assessing, mitigating, and managing risk; documenting stakeholder needs; transforming needs into well formed design input requirements; allocation, budgeting, and traceability; interface management, requirement management; and verification and validation.
- Lou's goal is to help clients practice better systems engineering from a needs and requirements perspective across all life cycle stages of system/product development. Getting the needs and 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.