Requirement Working Group (RWG) Status Update

15 June 2022

RWG Charter

1 **Purpose**

The purpose of the Requirements Working Group (RWG) is to advance the practices, education, and theory of needs and requirements development and management and the relationship of needs and requirements to other systems engineering functions.

2 **Goal**

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

3 **Scope**

Activities relating to best practices for needs and requirements development and management throughout the product lifecycle including:

Elicitation	Analysis	Allocation
Traceability		
Elaboration	Management	Change
Management		
Expression	Verification	Validation

RWG is About…

- Understanding how to improve the practice of systems engineering through excellence in needs and requirements development 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 requirements development and management, including the understanding of Needs, Requirements, Verification, and Validation approaches

RWG Leadership

- **Chair**: Tami Katz; Ball Aerospace, USA
- **Co-Chair**: Lou Wheatcraft; Wheatland Consulting, USA
- **Co-Chair**: Mike Ryan; Capability Associates Pty Ltd, AU
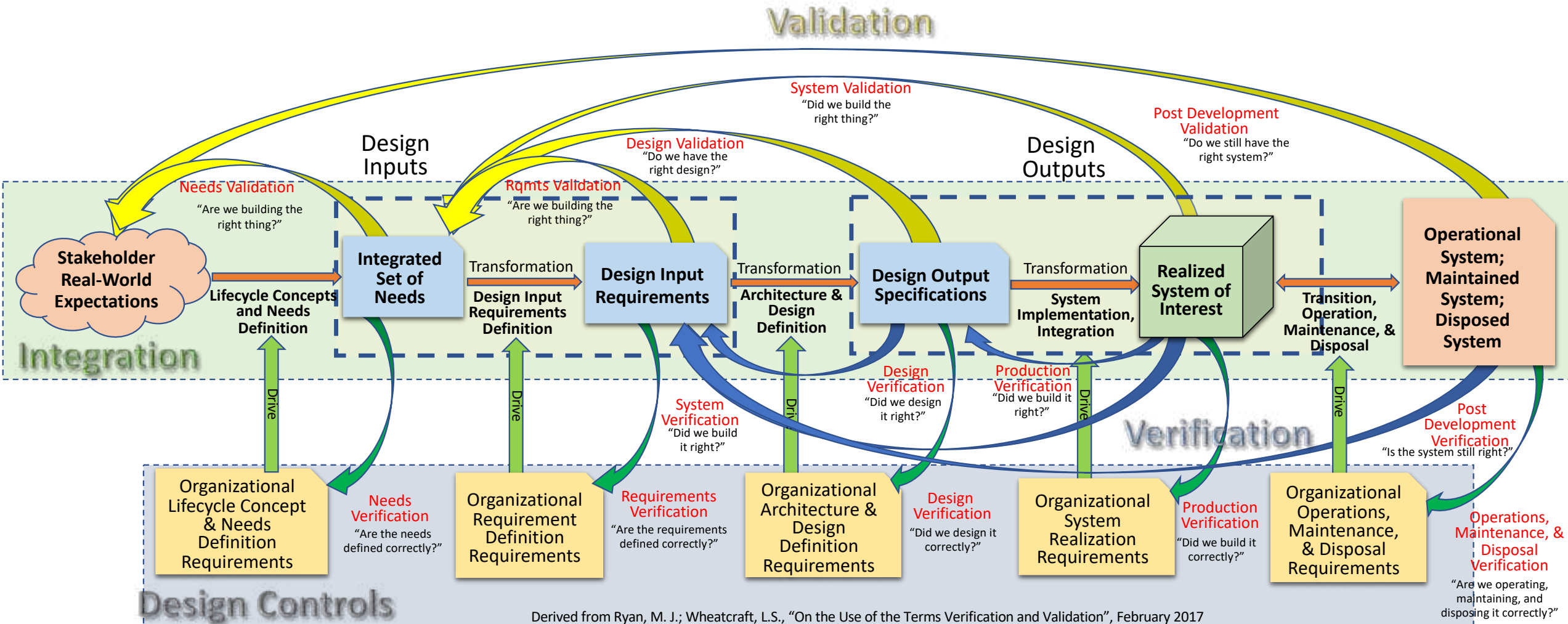- **Co-Chair**: Raymond Wolfgang; Sandia National Lab, USA

- **INCOSE Connect address:**
- **https://connect.incose.org/WorkingGroups/Requirements/Pages/Home.aspx**

- **Number of Members:** 400, 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** development and management across the system lifecycle.

Verification and Validation in Context
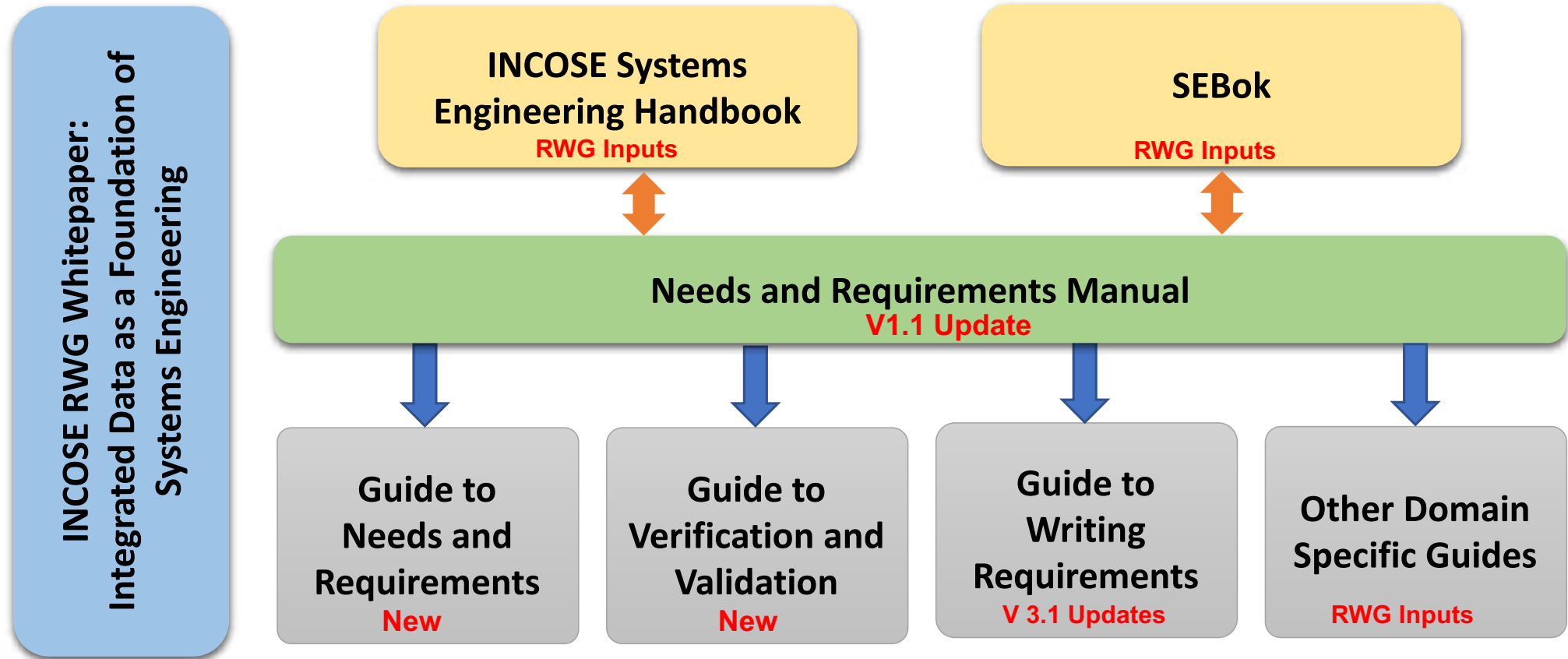

Derived from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017

https://www.dropbox.com/s/eq6k9u0fiiqp4eg/Validation%20%26%20Verification%20in%20context%20Figure%20042922.pdf?dl=0

RWG Products

- The RWG has been working on new products and supporting development of other INCOSE publications

INCOSE RWG Whitepaper: Integrated Data as a Foundation of Systems Engineering

INCOSE Systems Engineering Handbook
RWG Inputs

SEBok
RWG Inputs

Needs and Requirements Manual
V1.1 Update

Guide to Needs and Requirements
New

Guide to Verification and Validation
New

Guide to Writing Requirements
V 3.1 Updates

Other Domain Specific Guides
RWG Inputs

Needs and Requirements Manual (NRM) V1.1

V1.0 Needs, Requirements, Verification, Validation Lifecycle Manual (NRVVLM) released Jan 2022

Needs and Requirements Manual

Needs, Requirements, Verification, Validation Across the Lifecycle

May 2022

RWG Guides

All our new and updated products have been submitted to TechOps for Release

Definition:

Need statements must be written such that the stakeholder intent is clear. Requirement statements must be stated such that the requirement can be interpreted in only one way by all the intended stakeholders.

Rationale:

A need or requirement statement must lend itself to a single interpretation of intent. An agreement is difficult to enact unless both parties are clear on the exact obligation. Ambiguity leads to multiple interpretations such that the stakeholder expectations may not be met.

The intent of a need or requirement must be understood in the same way by the writer, the designer, and those doing verification and validation activities across the lifecycle following the "reasonable person" guideline. Ambiguity leads to interpretations of a need or requirement not intended by the author leading to problems such schedule slips, budget overruns, or a failure of the SOI to pass system validation and not be accepted for its intended use; which could result in litigation and financial loss.

An ambiguous need is not correct nor able to be validated. An ambiguous requirement is not Verifiable (C7) nor Correct (C8).

Guidance:

When writing a need or requirement statement, ask whether it could be interpreted more than one way. For needs, ask whether it can be validated, i.e., whether it is stated in such a way that evidence can be obtained that the stakeholder need has been met based on the wording of the need statement without having to interpret the stakeholder intent or make assumptions of that intent.

For a requirement ask whether the requirement is verifiable, i.e., whether it is stated in such a way that evidence can be obtained that the requirement has been met based on the wording of the requirement without having to interpret the meaning or make assumptions as to the meaning.

The possibility of ambiguity is reduced by addressing these questions and applying the rules in this Guide.

Additionally, it is useful for the parties (stakeholders) who are involved in the implementation of the needs and resulting requirements or system verification and system validation to be involved in the development, review, and baseline of the needs and resulting requirements. When they see needs or requirements that are ambiguous and their intent not clear, they can identify the issue and suggest an alternate, unambiguous wording of the need or requirement statement. As a minimum, it is recommended that the need or requirement owner(s) take the development team and those involved in system verification and system validation on a walkthrough of the need or requirement set to ensure that needs and requirements are understood, individually and as a set. As discussed in Section 1.8, this activity is referred to as need or design input requirement validation.

Due to the limitations of language, it may prove difficult to completely remove all ambiguity. In this case the use of the attribute, A1- Rationale, to include contextual information to better understand the reason, and source of the requirement may provide additional insight of the intent, helping to reduce ambiguity. This may include supporting information or commentary on how the requirement was formed.

When text only makes it difficult to communicate the intent of complex requirement, the inclusion of a diagram may help remove the ambiguity. See R23.

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

Rules that help establish this characteristic:

R1 - /Accuracy/SentenceStructure
R2 - /Accuracy/UseActiveVoice
R3 - /Accuracy/SubjectVerb
R4 - /Accuracy/UseDefinedTerms
R5 - /Accuracy/UseDefiniteArticles
R6 - /Accuracy/Units
R7 - /Accuracy/AvoidVagueTerms
R8 - /Accuracy/NoEscapeClauses
R9 - /Accuracy/NoOpenEnded
R10 - /Concision/SuperfluousInfinitives
R11 - /Concision/SeparateClauses
R12 - /NonAmbiguity/CorrectGrammar
R13 - /NonAmbiguity/CorrectSpelling
R14 - /NonAmbiguity/CorrectPunctuation
R15 - /NonAmbiguity/LogicalCondition
R16 - /NonAmbiguity/AvoidNot
R17 - /NonAmbiguity/Oblique
R18 - /Singularity/SingleSentence
R19 - /Singularity/AvoidCombinators
R22 - /Singularity/Enumeration
R23 - /Singularity/Context
R24 - /Completeness/AvoidPronouns
R28 - /Conditions/ExplicitLists
R32 - /Quantifiers/Universals
R33 - /Tolerance/ValueRange
R34 - /Quantification/Measurable
R35 - /Quantification/TemporalIndefinite
R36 - /UniformLanguage/UseConsistentTerms
R37 - /UniformLanguage/DefineAcronyms

Attributes that help establish this characteristic: (Refer to the NRM Section 15.)

A1 - Rationale
A6 – System Verification or System Validation Success Criteria
A8 – System Verification or System Validation Method

Activities and concepts associated with this characteristic: (Sections within the NRM)

3.2.1.1 – Communication; 3.2.1.2 – Power of Expression; 3.2.1.6 – Formal, Binding Agreement; 4.4.3 – Get Stakeholder Agreement; 4.6.3.1 – Managing Unknowns; 4.8 – Baseline and Manage Lifecycle Concepts and Needs Definition Outputs; 5.1.2 – Perform Needs Verification; 5.2.2 – Perform Needs Validation; 6.2.1.5 – Managing Unknowns; 6.3 – Baseline and Manage Design Input Requirements; 7.1.2 – Perform Design Input Requirements Verification; 7.2.2 – Perform Design Input Requirements Validation; 8.1 – Design Definition Process Overview, 8.2 – Early System Verification and System Validation; 8.4 – Design Verification, 14.2.1 – Baseline Needs, Requirements, and Specifications; 14.2.4 – Managing Unknowns

Guide to Writing Requirements

8

Rules to Characteristics Cross Reference Matrix

Quality Focus	Rule	Subject	Necessary (C1)	Appropriate (C2)	Unambiguous (C3)	Complete (C4)	Singular (C5)	Feasible (C6)	Verifiable (C7)	Correct (C8)	Conforming (C9)	Complete (C10)	Consistent (C11)	Feasible (C12)	Comprehensible (C13)	Able to be validated (C14)
Accuracy	R1	Structured, complete sentence			X	X			X	X	X					
	R2	Use active voice		X	X	X			X							
	R3	Use appropriate subject verb		X	X				X				X			X
	R4	Define terms			X				X					X	X	X
	R5	Use definite article "the" vs "a"			X				X							
	R6	Use appropriate units			X	X			X	X						
	R7	Avoid vague terms			X	X			X							
	R8	Avoid escape clauses			X				X							
	R9	Avoid open-ended clauses			X	X	X		X							
Concision	R10	Avoid superfluous infinitives			X				X							
	R11	Use a separate clause			X	X			X	X						
Non-ambiguity	R12	Use correct grammar			X				X	X	X					
	R13	Use correct spelling			X				X							
	R14	Use correct punctuation			X					X						
	R15	Logical expressions			X				X							
	R16	Avoid the use of "not."			X				X	X						
	R17	Avoid the oblique ("/") symbol			X				X							
Singularity	R18	Use sngle thought sentence			X		X		X		X				X	
	R19	Avoid combinators			X		X									
	R20	Avoid phrases of purpose or reason	X				X									
	R21	Avoid parentheses & brackets					X									
	R22	Enumerate sets explicitly				X	X									
	R23	Supporting diagram or model				X	X	X								
Completeness	R24	Avoid pronouns & indefinite pronouns			X	X			X							
	R25	Avoid relying on headings					X									
Realism	R26	Avoid using unachievable absolutes						X	X	X					X	
Conditions	R27	State applicability conditions explicitly				X			X	X						
	R28	Single condition for a specific action				X			X							
Uniqueness	R29	Classifyi by type or category										X	X			
	R30	Express once and only once	X								X		X			
Abstraction	R31	Avoid stating a solution			X											
Quantifiers	R32	Use "each" for universal quantification				X			X	X						
Tolerance	R33	Define quantities with a range of values			X	X		X	X	X					X	
Quantification	R34	Specific measurable performance targets			X	X			X						X	
	R35	Define temporal dependencies explicitly			X	X			X							
Uniformity of Language	R36	Use terms & units of measure consistently			X					X	X		X		X	X
	R37	Use a consistent set of acronyms			X						X		X		X	X
	R38	Avoid the use of abbreviations									X		X		X	X
	R39	Use a project-wide style guide				X	X				X		X		X	X
Modularity	R40	Group related needs & requirements				X					X	X	X		X	
	R41	Conform to a defined structure or template										X	X		X	X

NRM Concepts and Activities to Characteristics Cross Reference Matrix (1)

NRM Concepts and Activities		Necessary C1	Appropriate C2	Unambiguous C3	Complete C4	Singular C5	Feasible C6	Verifiable C7	Correct C8	Conforming C9	Complete C10	Consistent C11	Feasible C12	Comprehensible C13	Able to be validated C14
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 ae Derived	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
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
4.4.4	Completeness										X				
4.5	Lifecycle Concepts Analysis and Maturation	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			
4.5.4	Levels of Detail and Abstraction		X												
4.5.7.1	Model Development, Analysis, and Maturation	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						
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
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

NRM Concepts and Activities to Characteristics Cross Reference Matrix (2)

NRM Concepts and Activities		Necessary C1	Appropriate C2	Unambiguous C3	Complete C4	Singular C5	Feasible C6	Verifiable C7	Correct C8	Conforming C9	Complete C10	Consistent C11	Feasible C12	Comprehensible C13	Able to be validated C14
SECTION 6: DESIGN INPUT REQUIREMENTS DEFINITION															
6.2	Perform Design Input Requirements Definition	X	X					X	X		X	X	X	X	X
6.2.1	Transforming Needs into Design Input Requirements	X			X						X				
6.2.1.1	Organizing Sets of Design Input Requirements		X							X	X				
6.2.1.2	Considerations For Each Type Of Requirement				X			X	X		X				
6.2.1.4	Appropriate to Level		X												
6.2.1.5	Managing Unknowns			X	X		X	X	X						
6.2.2	Establish Traceability	X									X	X			
6.2.2.1	Establishing Traceability Between Dependent Peer Requirements											X			
6.2.3.6	Interface Requirements Audit	X			X			X	X		X	X			X
6.2.5	Plan for System Verification							X							
6.2.6.2	Completeness, Correctness, and Consistency								X		X	X			
6.2.6.3	Requirements Feasibility and Risk	X	X				X							X	
6.3	Baseline and Manage Design Input Requirements	X		X	X		X		X		X	X	X	X	X
6.4.3	Allocation – Flow Down of Requirements		X								X	X			
6.4.4	Defining Child Requirements that Meet the Intent of the Allocated Parents										X				
6.4.5	Budgeting of Performance, Resource, and Quality Requirements										X	X			
6.4.7 .	Use of Traceability and Allocation to Manage Requirements	X							X		X	X			X
SECTION 7: DESIGN INPUT REQUIREMENTS VERIFICATION & VALIDATION															
7.1.2	Perform Design Input Requirements Verification	X		X	X			X		X	X	X			X
7.2	Design Input Requirements Validation														X
7.2.2	Perform Design Input Requirements Validation	X		X	X		X		X		X	X	X	X	X
SECTION 8: DESIGN VERIFICATION AND DESIGN VALIDATION															
8.1	Design Definition Process Overview			X	X		X	X	X		X	X	X	X	X
8.2	Early System Verification and System Validation			X	X		X	X	X		X	X	X	X	X
8.4	Design Verification			X	X		X	X	X			X			
8.5	Design Validation										X	X	X	X	X
SECTION 14: NEEDS, REQUIREMENTS, VERIFICATION, & VALIDATION MANAGEMENT															
14.2.1	Baseline Needs, Requirements, and Specifications	X		X	X		X		X		X	X	X	X	X
14.2.4	Managing Unknowns			X	X		X	X	X			X			
14.2.7	Combine Allocation and Traceability to Manage Requirements	X							X		X				X
14.2.8	Managing Interfaces										X	X			X
14.2.9	Managing System Verification and System Validation							X							X
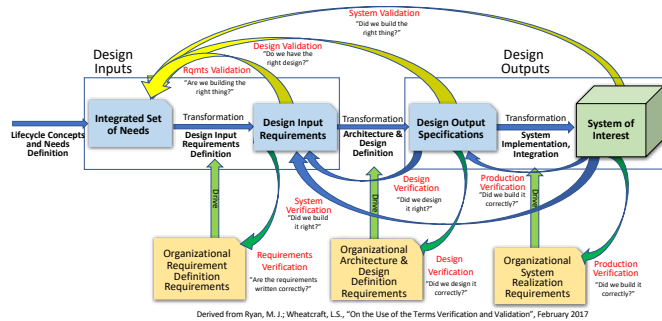
Also Updated the GtWR Summary Sheet

The update includes these matrices

INCOSE Guide to Writing Requirements V3.1 – Summary Sheet

Needs and Requirements are the common threads that tie all lifecycle activities and artifacts together. When formulating the needs and requirements it is important to understand the role of needs and requirements within the context of verification and validation. 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.

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

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.

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 capability in terms of people, process, and products.

A **set of lifecycle** concepts includes multiple concepts across the lifecycle of how the organization (and stakeholders within an organization) expect 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 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 needs or parent requirements into an agreed-to obligation for an entity to perform some function or possess some quality within specified constraints with acceptable risk.

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:	*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.
• C1 - Necessary: The need or requirement statement defines an essential capability, characteristic, constraint, or quality factor needed to satisfy a lifecycle concept, need, source, or parent 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 stakeholder 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 parent requirement from which it was transformed. • C9 - Conforming: Individual needs and requirements should conform to an approved standard pattern and style guide or standard for writing and managing needs and requirements.	• C3 - Unambiguous: Need statements must be written such that the stakeholder intent is clear. Requirement statements must be stated such that the requirement can be interpreted in only one way by all the intended stakeholders. • C4 - Complete: The requirement statement sufficiently describes the necessary capability, characteristic, constraint, or quality factor to meet the need, source, or parent requirement from which it was transformed without needing other information to understand the requirement. • 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 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.

INCOSE RWG YouTube Channel

- The INCOSE RWG chairs have created a YouTube channel to post recordings of meetings and presentations to the broader community.

- This is available to everyone that would like to catch up on events and learn more about the RWG efforts and products.

- This is also available to non-INCOSE members as a method to attract interest in potentially joining INCOSE and the RWG and share good options to all that engage in needs and requirements efforts.

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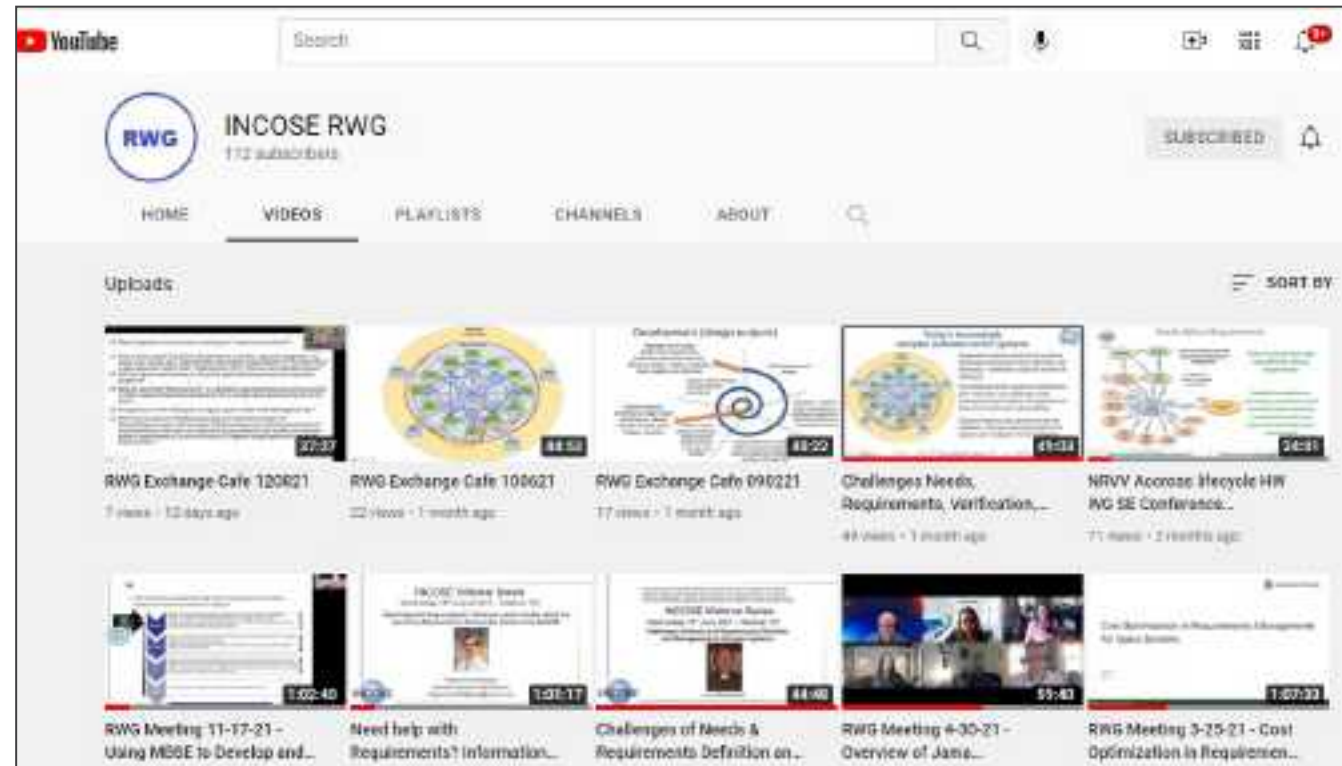
RWG Events

- RWG engages the INCOSE community through regular events around the topic of Needs and Requirements
  - Guest speakers on Requirements Topics
  - RWG Exchange Cafés
- RWG members contribute ideas towards topics discussed and are encouraged to share their experiences and questions with the broad working group community.

Past Events 2022:

- January 25 & 26, 2022 IW2022 pre-event sessions.

    Recordings: https://www.youtube.com/playlist?list=PLVfZ7HbxxzBXTd8vieYUbHU-RCYTSfbcS

- January 30, 2022 IW2022 hybrid event.

    Recording: https://youtu.be/lsIs08AjA9M

- February 23, 2022 - RWG Exchange Cafe.
  Recording: https://youtu.be/HZo2jR-zDFY

- March 24, 2022 - Using Model-Based Systems Engineering Techniques to support Requirements Generation for the Design of New Generation Armored Combat Vehicle Systems (Mark Eggler)
  Slides: Presentation-INCOSE-MBSE in Combat Vehicle Design-1hr-Mar 22-v1.0.pdf
  Recording: https://youtu.be/bMtoDvsKB84

- April 27, 2022 - RWG Exchange Cafe.
  Slides: RWG Exchange Cafe 042722.pdf
  Recording: https://youtu.be/Ei81HLUxxAE

- May 25, 2022 - Demonstrating SE Value Using Traceability Measurement
  Slides: INCOSE RWG Jama Software Measurement May 2022.pdf
  Recording: https://youtu.be/GSpQdachXZU

Schedule of upcoming Events

- June 25 – 30: IS2022 - We are holding an RWG Session at IS2022 for Tuesday, June 28 in the afternoon 1:30-2:55 pm EST.

- July 20: Presentation by Beth Wilson on Systems of Systems (SoS) challenges.

- August 24, 3 pm: RWG Exchange Café – Beth Wilson lead on SoS vs the NRM, GtNR, GtVV

- September 28: RWG Exchange Café – General discission focusing on interfaces

- October 26: Presentation by Beth Wilson – System Security Challenges

- November 16: RWG Exchange Café – Beth Wilson lead on System Security vs NRM, GtNR, GtVV

- December 14: Presentation by Henrik Mattfolk – "Configuration Management Across the Digital Thread"

- January 2023: IW 2023 RWG prevent sessions - TBD

Biography

- 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.

- 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.