Part 2

Fixing Terrible Requirements

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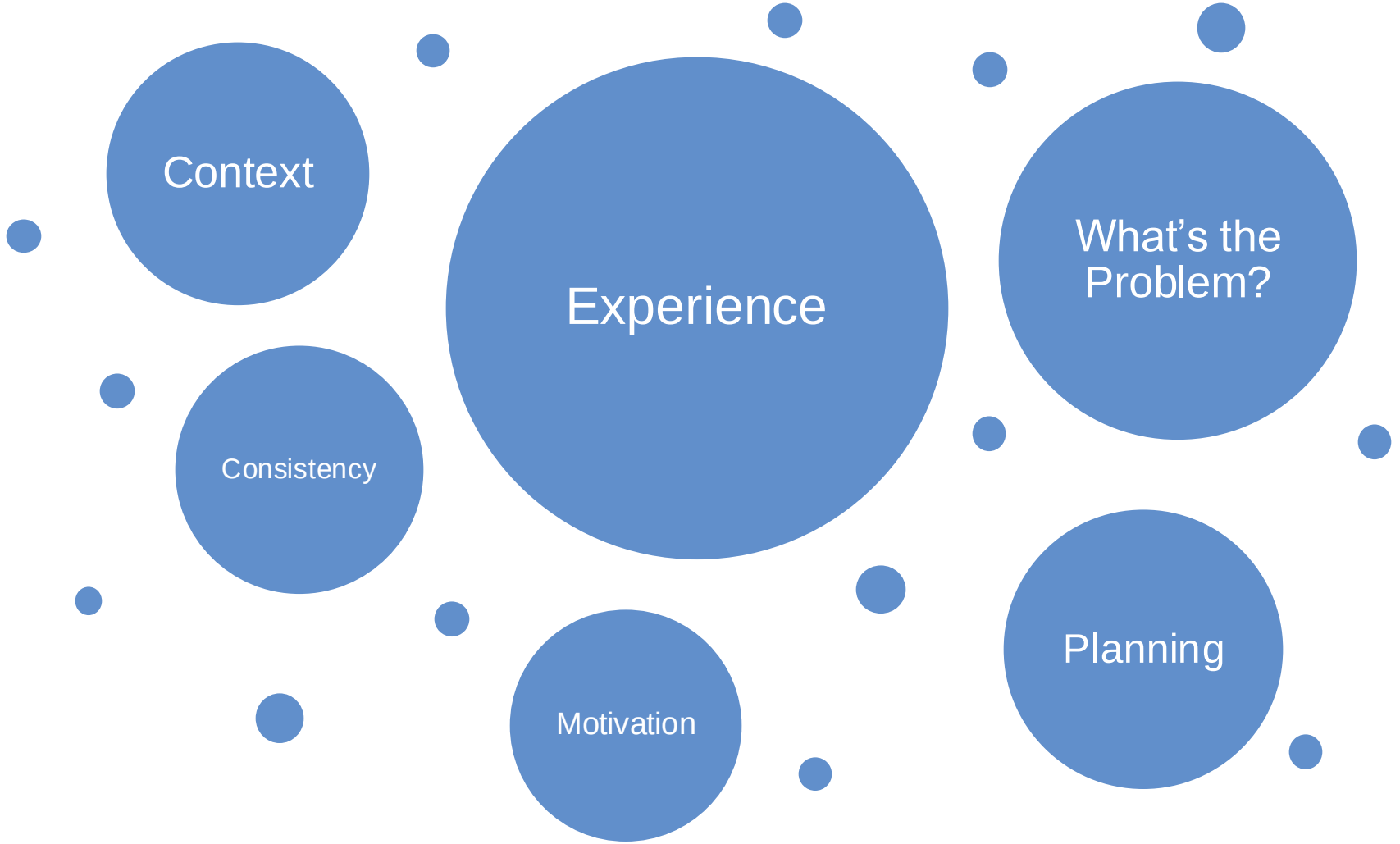
Requirements Working Group

Agenda

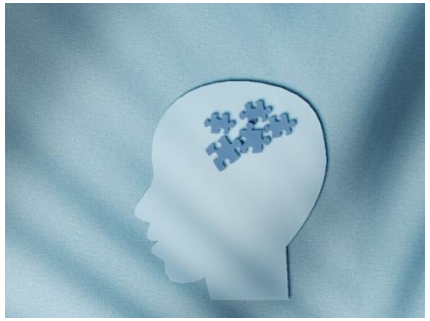
- Why is it so hard to write good requirements?
- What INCOSE resources are available?
- Requirements characteristics and rules refresher
- Interactive Example
  - Present some truly terrible requirements
  - Discuss problems and how to improve requirements (chat encouraged!)
- Crowd-Sourced Requirements Discussion
  - Show results of terrible requirements submitted by participants
  - What solutions do you employ to catch/fix bad requirements?
  - How can we make it easier to train users to write good requirements?

Writing Good Requirements is Hard



INCOSE Resources

- Systems Engineering Handbook v5
- Guide to Needs and Requirements
- Needs and Requirements Manual
- Guide to Writing Requirements
- Guide to Writing Requirements Summary Sheet
- RWG iNet Website
- Viva Engage – Requirements



Requirements Characteristics

Individual Requirement	Set of Requirements
• C1 - Necessary • C2 - Appropriate • C3 – Unambiguous • C4 – Complete • C5 – Singular • C6 – Feasible • C7 – Verifiable • C8 – Correct • C9 - Conforming	• C10 - Complete • C11 – Consistent • C12 – Feasible • C13 – Comprehensible • C14 - Able to be validated • C15 - Correct

Requirements **Characteristics** (this slide) and **Rules** (next slides) excerpt from Guide to Writing Requirements Summary Sheet

Requirements Rules

Legend: Do Don't

Accuracy

- R1 - Structured Statements
- R2 - Active Voice
- R3 - Subject-Verb
- R4 - Defined Terms
- R5 - Definite Articles
- R6 - Common Units of Measure
- R7 - Vague Terms
- R8 - Escape Clauses
- R9 - Open-Ended Clauses

Concision

- R10 - Superfluous Infinitives
- R11 - Separate Clauses

Non-Ambiguity

- R12 - Correct Grammar
- R13 - Correct Spelling
- R14 - Correct Punctuation
- R15 - Logical Expressions
- R16 - Use of "Not"
- R17 - Use of Oblique Symbol

Requirements Rules

Legend: Do Don't

Singularity	Completeness	Realism
• R18 - Single Thought Sentence • R19 - Combinators • R20 - Purpose Phrases • R21 - Parentheses • R22 - Enumeration • R23 - Supporting Diagram, Model, ICD	• R24 - Pronouns • R25 - Headings	• R26 - Absolutes

Requirements Rules (Continued)

Legend: Do Don't

Conditions

- R27 - Explicit Conditions
- R28 - Multiple Conditions

Uniqueness

- R29 - Classification
- R30 - Unique Expression

Abstraction

- R31 - Solution-Free

Quantifiers

- R32 - Universal Qualification

Tolerance

- R33 - Range of Values

Quantification

- R34 - Measurable Performance
- R35 - Temporal Dependencies

Requirements Rules (Continued)

Legend: Do Don't

Uniformity of Language

- R36 - Consistent Terms and Units
- R37 - Acronyms
- R38 - Abbreviations
- R39 - Style Guide
- R40 - Decimal Format

Modularity

- R41 - Related Needs and Requirements
- R42 - Structured Sets

Example: Terrible Requirements

1. Time shall be reported with high accuracy always.
2. The LED display shall show a time in 12-hour or 24-hour fomat
3. When the system is charging, addtl. user features are not available.
4. The system shall be portable and waterproof.
5. The system not cause a fire if damaged by water.
6. The system shall have an alarm feature so that the user can wake up on time (and the user must be able to change the volume of the alarm, etc.).
7. The system shall cost less than $1 USD, if possible.

Requirement 1 Findings

Time | shall be reported | with | high accuracy | always.

Rules Broken	Explanation	How to Fix
R27 - Explicit Conditions	No conditions = no context.	Analyze system boundary and operating conditions. Add conditions to requirement.
R28 - Multiple Conditions	Don't forget to include ALL conditions.	What must be true to perform the action? Use a list for many or complex conditions.
R2 - Active Voice	Using passive voice "shall be" is ambiguous.	Rewrite with a subject and active voice "shall" followed by a verb.
R7 - Vague Terms	What is "high" accuracy?	Quantify accuracy based on stakeholder need and available technology.
R26 - Absolutes	Can any system "always" function?	Fixing the conditions per R27 and R28 will help resolve this too.

Requirement 1 Improvements

The system shall report the Current_Time with an accuracy of Clock_Accuracy when the following conditions are true:

- The Input_Voltage is within the Operating_Voltage_Range;
- The Ambient_Temperature is within the Operating_Temperature_Range.

Note 1:

The following terms should be defined in a glossary or data dictionary, per R4 - Defined Terms:

- Current_Time
- Input_Voltage
- Ambient_Temperature

Note 2:

The following terms are parameters, and must be defined with values, units, and other relevant properties per R6 - Common Units of Measure:

- Clock_Accuracy
- Operating_Voltage_Range
- Operating_Temperature_Range

Requirement 2 Findings

The LED screen shall display a time in 12-hour or 24-hour fomat

Rules Broken	Explanation	How to Fix
R3 - Appropriate Subject-Verb	Where did the LED screen come from?	Respect the system boundary. Don't specify component requirements at system level.
R31 - Solution-Free	That darn LED screen again…so troublesome!	Don't write solutions as requirements, unless there is a valid reason.
R37 - Acronyms	What does LED mean?	Define acronyms in glossary/data dictionary.
R5 – Definite Articles	Does "a" mean any time?	Use "the" instead of "a" or "an".
R19 - Combinators	Is this an either or situation, or both?	Split requirements that contain combinators, except when used in conditions.
R13 - Correct Spelling R14 - Correction Punctuation	A spelling and grammar check goes a long way.	Mistakes can distract readers and reduce credibility. Check your requirements for mistakes and fix them before publishing.

Requirement 2 Improvements

If the Hour_Option is 12H, the system report the Current_Time with an hour range from 1 to 12.

If the Hour_Option is 12H, the system shall display AM during morning hours.

If the Hour_Option is 12H, the system shall display PM during evening hours.

If the Hour_Option is 24H, the system shall report the Current_Time with an hour range from 1 to 24.

Note 1:

- These improvements also comply with R33 - Range of Values by specifying the appropriate range for the hour display.

Requirement 3 Findings

When the system is charging, addtl. user features are not available.

Rules Broken	Explanation	How to Fix
R38 - Abbreviations	“addtl” should not be used.	Abbreviations can be confusing or appear unprofessional. Spell out “additional” instead of abbreviating.
C1 - Necessary	This is a “do nothing” requirement.	Reframe requirements to clearly state what the system does, not what it doesn’t do.
R1 - Structured Statements	Having common requirements patterns helps identify problems like this requirement.	Commonality helps comprehension. Use agreed patterns to write different types of requirements. If a requirement doesn’t fit a pattern, it may still be valid, but give it a closer inspection to be sure.

Requirement 3 Improvements

When the Input_Voltage is within the Operating_Voltage_Range, the system shall set the Current_Time based on the Selected_Time.

When the Input_Voltage is within the Operating_Voltage_Range, the system shall adjust the Alarm_Volume based on the user input.

Note 1:

- To fully improve requirement 3, we need to specify all the system functionality and the conditions under which it is available.

Requirement 4 Findings

The system shall be portable and waterproof.

Rules Broken	Explanation	How to Fix
R34 - Measurable Performance	How can we quantify “portable” and “waterproof”?	If a requirement is clear, all users will interpret it the same way. If not, revise until a common understanding is achieved.
R18 - Single Thought Sentence	Specifies 2 separate characteristics of the system.	Separate multiple thoughts into multiple requirements.

Requirement 4 Improvements

The system shall measure less than or equal to 10 in long by 4 in wide by 2 in high.

The system shall weigh less than or equal to 1 lb.

The system shall have an IP rating that meets or exceeds IP75.

Note 1:

Separating the requirements and quantifying the meaning of “portable” and “waterproof” will ensure the right system is designed and can be verified.

Note 2:

With the improvements to requirement 4, it becomes obvious that requirement 5 is not valid and should be removed.

Requirement 6 Findings

The system shall have an alarm feature so that the user can wake up on time (and the user must be able to change the volume of the alarm, etc.).

Rules Broken	Explanation	How to Fix
R21 - Purpose Phrases	Don't specify why the requirement is needed.	Trace the requirement back to a stakeholder need instead of explaining this in the requirement.
R10 - Superfluous Infinitives	Avoid "be able to".	State the capability or action of the system and the conditions under which it must be satisfied.
R21 - Parentheses	Avoid parentheses.	Ensure the wording is clear. As in R18 - Single Thought Sentence, split multiple thoughts into multiple requirements. Put supporting explanations in separate information statements.
R9 - Open-Ended Clauses	Should not use "etc."	Clarify the scope of the requirement and clearly state a single thought.

Requirement 7 Findings

The system shall cost less than $1 USD, if possible.

Rules Broken	Explanation	How to Fix
C6 - Feasible	$1 USD sounds like a pretty good deal…	Analyze the costs, capabilities, and needs. Based on the stakeholder priorities, we may have to compromise in one or more of these areas.
R8 - Escape Clauses	Sadly, there's no "A" for effort.	If we try our best but the system cannot meet the requirement, will our stakeholders accept that? It's better to understand the needs and write a requirement that can be met.

Set of Requirements Findings

Rules Broken	Explanation	How to resolve?
C10 - Complete	Missing requirements. How is the system powered? How do you set the time? Can you turn off the alarm?	Add missing requirements based on the stakeholder needs and system boundary. This could drive us to a specific design solution, such as a watch, a portable alarm clock, a cell phone feature, etc.
C11 - Consistent	Requirements 4 and 5 are contradictory.	If the system is waterproof, how could water damage that lead to a fire?
C12 - Feasible	Is the cost requirement realistic, taken in context with the rest of the requirements?	We may not be able to meet all requirements. Analyze and prioritize requirements. Where conflicts exist, discuss possible solutions with stakeholders and obtain agreement.

Crowd-Sourced Examples Word Cloud

Crowd-Sourced Examples

Bad Requirement	Rules Broken
The system shall fulfill the same requirements as its predecessor product.	R34 - Measurable Performance
The design shall utilize COTS products to the maximum extent possible.	R8 - Escape Clauses
Drawings of the system shall be provided by CDR	R2 - Active Voice
The system shall operate within operational charts.	R34 - Measurable Performance
The user shall be able to always enter data quickly using several different means of interaction.	R7 - Vague Terms R10 - Superfluous Infinitives R26 - Absolutes
The system shall be intuitive and easy-to-use.	R7 - Vague Terms

Crowd-Sourced Examples (Continued)

Bad Requirement	Rules Broken
The system shall utilize DataBus XYZ manufactured by ABC.	R31 - Solution-Free
".....If the accuracy of temperature difference is not yet or not more guaranteed"	R9 - Open-Ended Clauses
The system shall allow for ... / The system shall handle ...	R10 - Superfluous Infinitives
User Need: Must have non-inferior performance compared to closest competitive options	R7 - Vague Terms R34 - Measurable Performance
Any requirement written as a run-on sentence or short story. These are difficult to interpret and verify.	R18 - Single Thought Sentence
The ones that are not specific	R34 - Measurable Performance

Crowd-Sourced Examples (Continued)

Bad Requirement	Rules Broken
The <product> shall be serviceable with standard tools	R2 - Active Voice R7 - Vague Terms
Any Requirement with enclosed "Explanation" ...	R20 - Purpose Phrases
The weather shall not affect component's function.	R16 - Use of “Not” R27 - Explicit Conditions
Requirements that encompass everything... ie xxx needs to fulfil requirements inclusive but not limited to abc	R9 - Open-Ended Clauses
the system <performance> shall not exceed a 0.13E-4 lcl 95% c.l. and 1E-3 ucl 95% c.l.	R16 - Use of “Not” R38 - Abbreviations
This "detector's" probability of detection will be 100%.	R2 - Active Voice R26 - Absolutes

Crowd-Sourced Examples (Continued)

Bad Requirement	Rules Broken
nested roll up requirements that have infinite regression depth	R42 - Structured Sets
No. 2D Finish	R16 - Use of “Not” R37 - Acronyms
The consumer appliance shall require PPAP approval by the PPAP approval milestone.	R2 - Active Voice R37 - Acronyms
The rail cars shall be aesthetically pleasing.	R2 - Active Voice R7 - Vague Terms
System ABC shall be designed and tested according to process XYZ.	R2 - Active Voice R10 - Superfluous Infinitives R37 - Acronyms
Anything with the word "subjective" is a good start ! A good example of that being noise related requirements.	R7 - Vague Terms

Crowd-Sourced Examples (Continued)

Bad Requirement	Rules Broken
XXXX shall be as robust as possible	R2 - Active Voice R8 - Escape Clauses
Workstation 1 shall be able to control a UGS with limited capacity if situation deems it necessary	R2 - Active Voice R10 - Superfluous Infinitives R8 - Escape Clauses
The user shall be able to enter data quickly using several means of data entry.	R2 - Active Voice R7 - Vague Terms
Listing titles of CFRs	R18 - Single Thought Sentence
Valid torque request shall be provided. The system X shall reliably compute phase voltage to achieve the requested torque.	R2 - Active Voice R18 - Single Thought Sentence
The system shall check for data errors.	R34 - Measurable Performance

Attendee Examples

- The system shall fulfill the same requirements as its predecessor product.
- The design shall utilize COTS products to the maximum extent possible.
- Drawings of the system shall be provided by CDR.
- The system shall operate within operational charts.
- The user shall be able to always enter data quickly using several different means of interaction.
- The system shall be intuitive and easy-to-use.
- The system shall utilize DataBus XYZ manufactured by ABC.
- ".....If the accuracy of temperature difference is not yet or not more guaranteed."
- The system shall allow for ... / The system shall handle ...
- User Need: Must have non-inferior performance compared to closest competitive options
- Any requirement written as a run-on sentence or short story. These are difficult to interpret and verify.

Attendee Examples (cont.)

- The ones that are not specific.
- The <product> shall be serviceable with standard tools
- Any Requirement with enclosed "Explanation" ...
- The weather shall not affect component's function.
- Requirements that encompass everything... ie xxx needs to fulfil requirements inclusive but not limited to abc.
- The system <performance> shall not exceed a 0.13E-4 lcl 95% c.l. and 1E-3 ucl 95% c.l.
- This "detector's" probability of detection will be 100%.
- nested roll up requirements that have infinite regression depth No. 2D Finish
- The consumer appliance shall require PPAP approval by the PPAP approval milestone.
- The rail cars shall be aesthetically pleasing.
- System ABC shall be designed and tested according to process XYZ.
- Anything with the word "subjective" is a good start ! A good example of that being noise related requirements.

Sarah Vazquez

- Sarah Vazquez is a Senior Systems Engineer at Veoneer, with 17 years of experience in the automotive and aerospace industries.
- She has been a member of INCOSE since 2012 and currently serves as the INCOSE CAB Representative for Veoneer.
- Sarah specializes in requirements management and systems engineering process development, providing mentoring and training to users within her organization.
- With a degree in Aerospace Engineering, she briefly worked with propulsion systems at Orbital Sciences Corporation, now part of Northrup Grumman, before a cross-country move early in her career introduced her to the automotive industry.
- Sarah performed requirements management and system development for Electric Power Steering systems at TRW automotive, now part of ZF.
- In her current role at Veoneer, Sarah supports platform development for the restraint control ECU, which determines how airbags should be deployed in an automotive crash.
- Sarah's mission is to promote systems engineering best practices in a way that makes it easy and intuitive for uses to follow in their daily work.
- When not managing requirements and system development, Sarah enjoys reading and teaching her son that being an engineer is way cooler than being a YouTuber!

Requirements Working Group