25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015

Implementing Structured Requirements to Improve Requirements Quality

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International Council on Systems Engineering, Bellevue, WA July, 2015.

Outline and Summary

- **Structured, natural language requirements**
- **Standard types and patterns**
- **Requirements quality – verifiability**
- **Tool implementation**
- **Quality improvement and the return on investment**

We have implemented a closed-loop feedback control process for requirements development that couples measures of requirements quality to the process of writing requirements

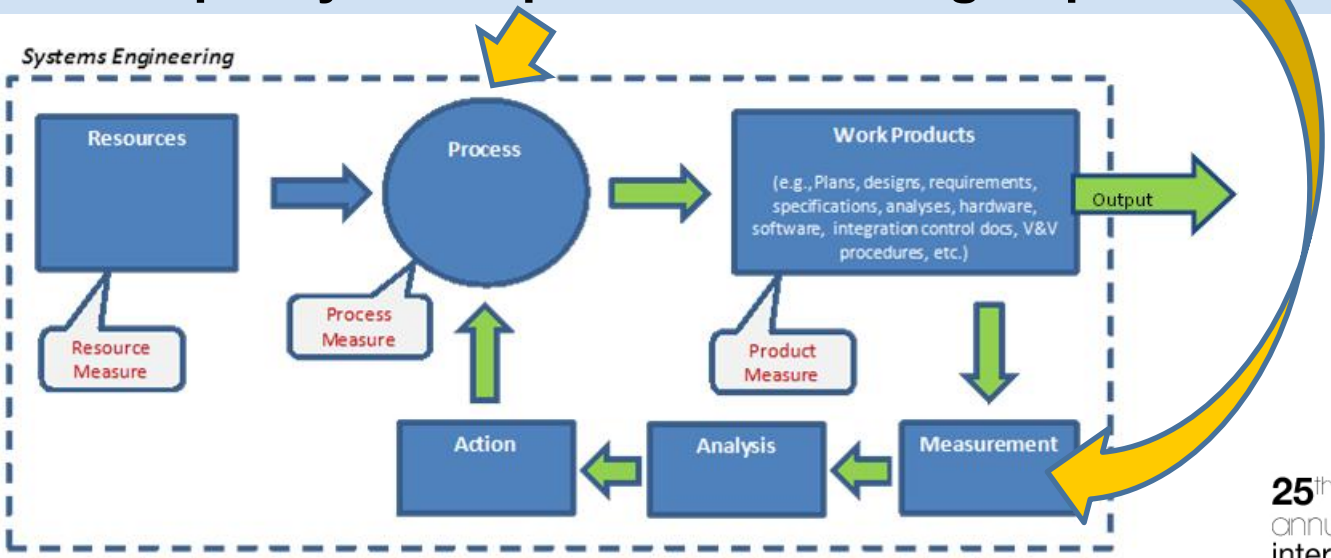

Figure adapted from INCOSE SE Measurement Primer, 2010

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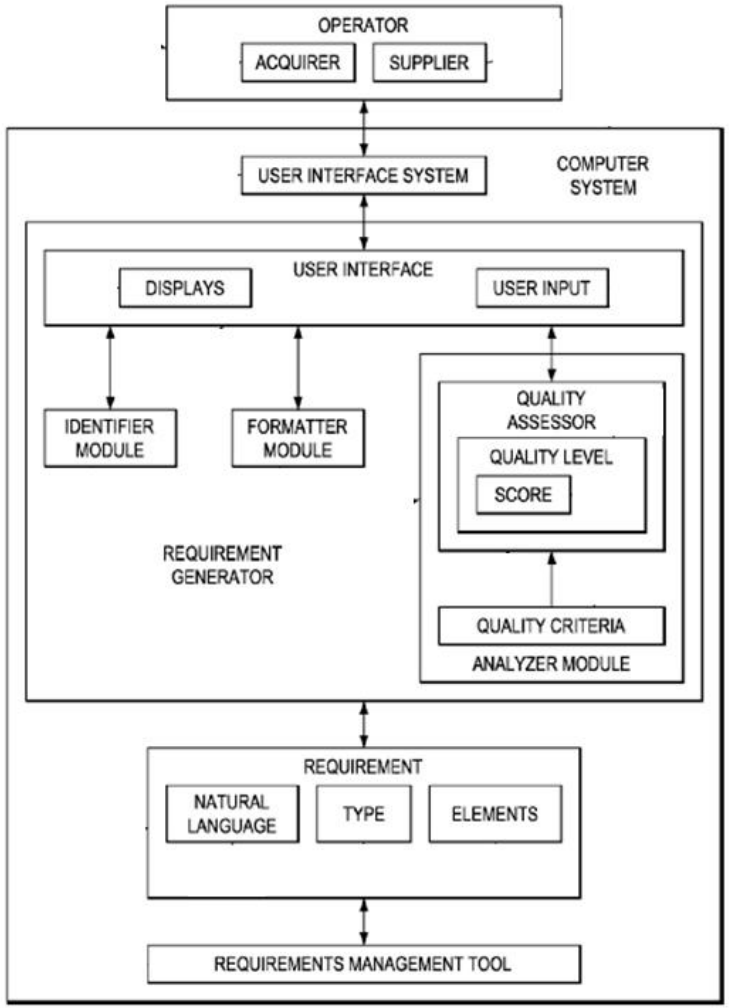
Using Structured Requirements

- The problem: ambiguous requirements
- The solutions:
  - Agile SE – user stories; avoid requirements
  - Formal Language – use mathematics
  - ➢ Structured, natural language
- This approach helps our requirements engineers write more unambiguous and verifiable requirements as required by MIL-STD-961 and related commercial standards*.
- From MIL-STD-961E, 5.8:
  - a. Each requirement shall be stated in such a way that an **objective verification** can be defined for it.
  - b. …
  - c. Only requirements that are necessary, **measurable**, achievable, and **verifiable** shall be included.
  - d. Requirements shall be worded to provide a **definitive basis for acceptance or rejectio**n.
  - e. …
  - f. Requirements shall be worded such that each paragraph only addresses **one requirement or topic.**



*ARP4754A, ISO/IEC 29148:2011
Graphics from US Patents #8,732,109, #8,886,588

Structured Requirements Syntax – Decomposition for Engineered Requirements

- The Basic Structure:
  - The *agent* shall *what, how well, under what conditions.*

- ***Agent*** is the product or service entity which has the required characteristic or performs the intended function, e.g., a system or element thereof.
- ***Shall*** identifies the statement as a mandatory characteristic – a requirement.
- ***What*** is the *function* that describes what the agent *does that is observable at its boundary,* or another mandatory *characteristic* or attribute of the agent (e.g., size, color)
- ***How well*** *is the measurable characteristic* of the function or a design attribute. This is the *performance* attribute, and includes timing of the *function.*
- ***Under what conditions*** addresses two specific considerations
  - *Conditions* are the modes, states or environmental conditions that are present when the agent performs its function or has the stated property
  - *Inputs* are the *triggering* or *initiating* events, observable at the boundary, that cause the agent to perform the function

Limiting the Types

- Boeing has identified four types of specification requirements (plus a verification requirement type – not addressed here).
  - **Functional/Performance**
  - **Design**
  - **Environmental**
  - **Suitability**

SELECT THE STATEMENT BELOW THAT REFLECTS THE INTENT OF THE NEW REQUIREMENT

Functional/Performance Requirement

- ☐ **To define the functional behavior for an agent, i.e. something the agent does**
- ☐ To define the performance of an agent, i.e. how well the agent does something
- ☐ To identify the interface with another agent, i.e. how the agent interacts with another agent

Design Requirement

- ☐ To define how to design the agent or its elements
- ☐ To define how to fabricate the agent or its elements
- ☐ To define the specific materials, processes, or standards to be used in the design, fabrication, or testing of the agent or its elements
- ☐ To define the implementation of interfaces with another agent

Environmental Requirement

- ☐ To define the natural environments that the agent must survive
- ☐ To define an induced environment that the agent must survive

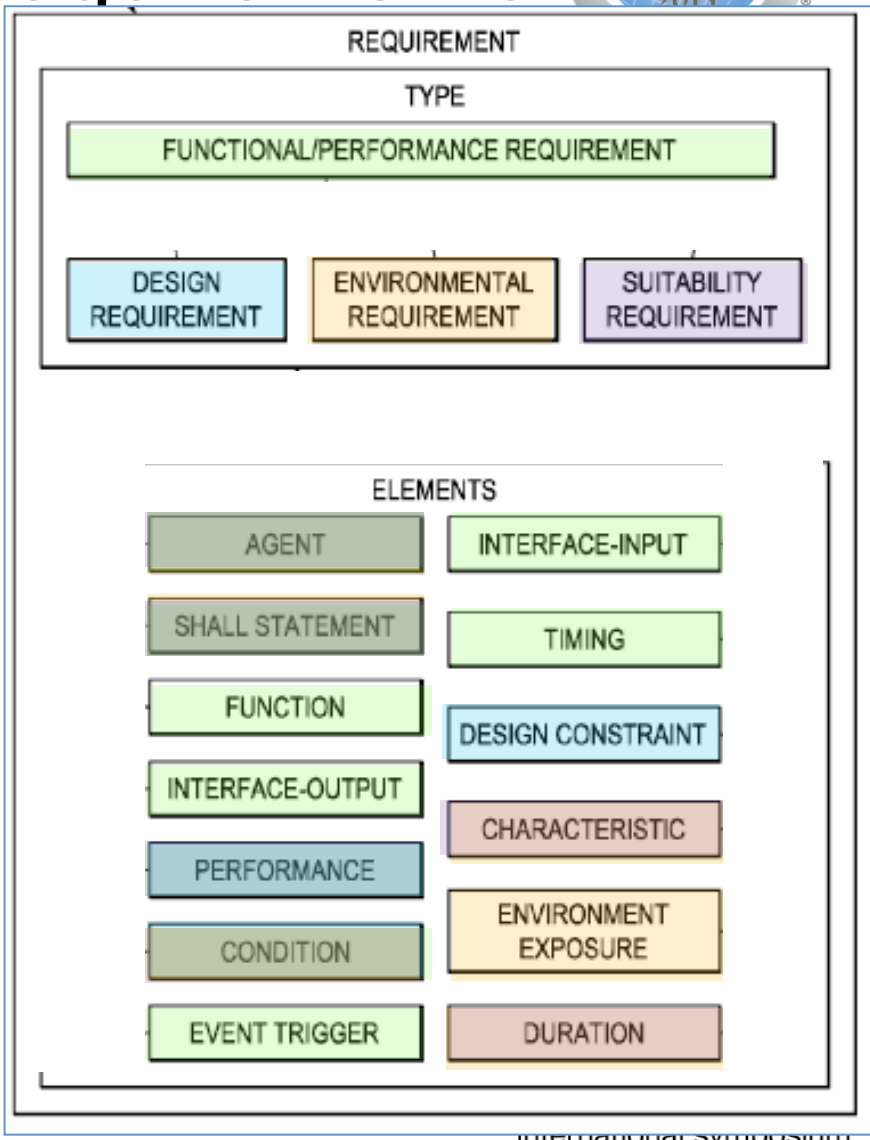
Suitability Requirement

- ☐ To define the performance required of the agent for any of the specialty engineering 'ilities' such as reliability, maintainability, supportability, availability
- ☐ To define the performance required of the agent for other specialty engineering such as safety, human factors, training, logistics

Elements vs. Types of Requirements

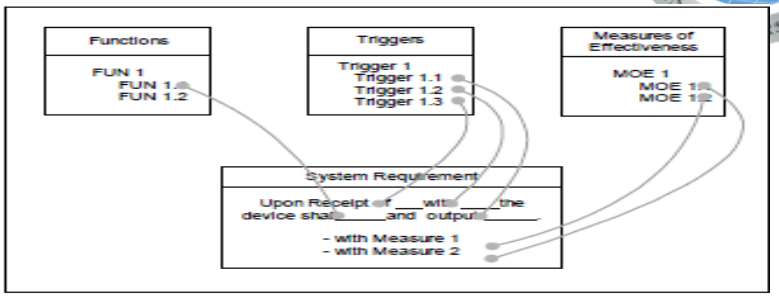
- Each type of requirement has a standard grammar: a set of mandatory and optional elements that ensure verifiability related to the type.

- Functional/Performance - The AGENT shall FUNCTION in accordance with INTERFACE-OUTPUT with PERFORMANCE [and TIMING upon EVENT TRIGGER in accordance with INTERFACE-INPUT] while in CONDITION.
- Design - The AGENT shall exhibit DESIGN CONSTRAINTS [in accordance with PERFORMANCE while in CONDITION].
- Environmental - The AGENT shall exhibit CHARACTERISTIC during/after exposure to ENVIRONMENT [for EXPOSURE DURATION].
- Suitability - The AGENT shall exhibit CHARACTERISTIC with PERFORMANCE while CONDITION [for CONDITION DURATION].



Other Approaches to Patterns

Piraino et al., “Putting It All Together: Entity Relationships Between Requirements, Components of System Design, and Verification to Requirements”, Proceedings of INCOSE 2001. Used by permission.



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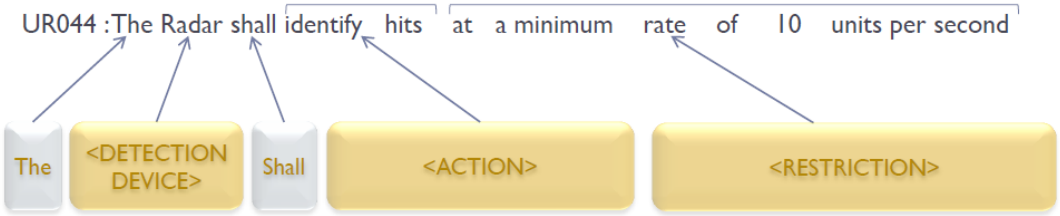


ISO/IEC/IEEE 29148:2011, “Systems and software engineering — Life cycle processes — Requirements Engineering”, 5.2.4

[Condition] [Subject] [Action] [Object] [Constraint]

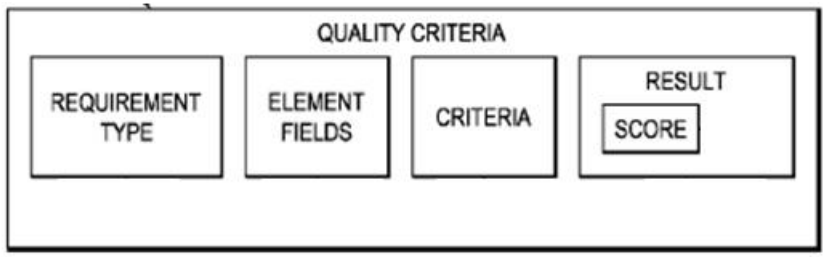
EXAMPLE: When signal x is received [Condition], the system [Subject] shall set [Action] the signal x-received bit [Object] within 2 seconds [Constraint].

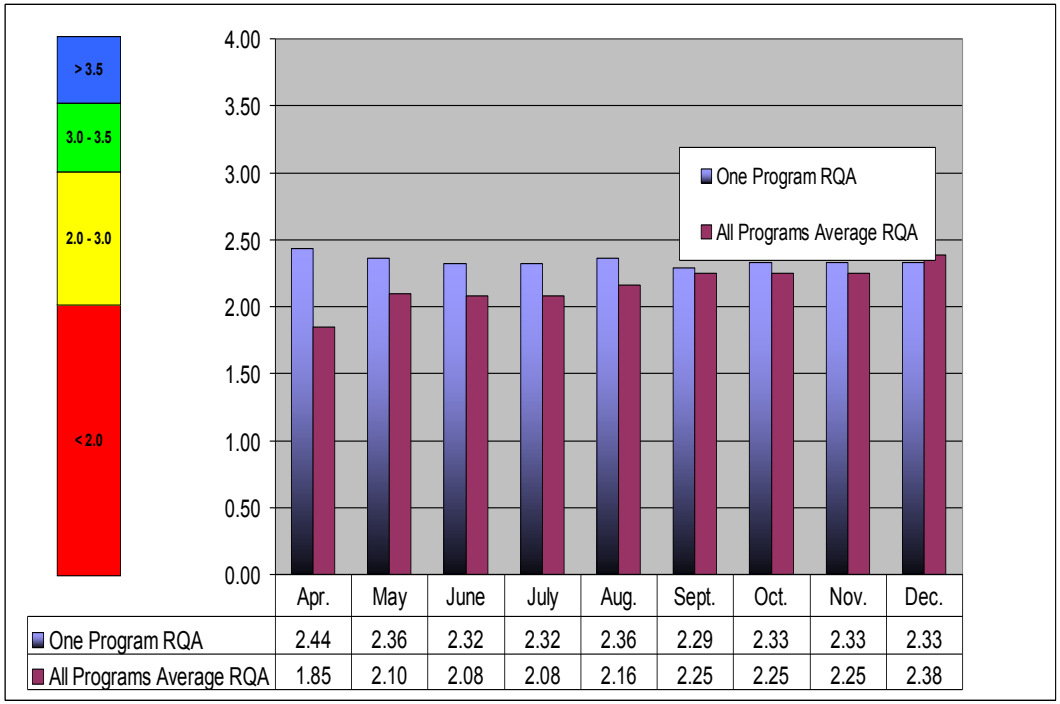
INCOSE “Guide for Writing Requirements”, 5.4.1, 2012

The <subject clause> shall <action verb clause> <object clause> <optional qualifying clause>, when <condition clause>.’).

Measuring Requirements Quality

- Quality measures for requirements address each element of the individual type, and the average. Risk is identified based on how well an instance conforms to the template.





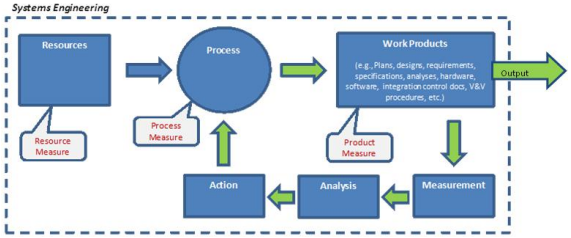
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
One Program RQA	2.44	2.36	2.32	2.32	2.36	2.29	2.33	2.33	2.33
All Programs Average RQA	1.85	2.10	2.08	2.08	2.16	2.25	2.25	2.25	2.38

A "graded" (0 to 4) vs. "binary" score is used to clarify required improvements and residual risk, "based on whether or not content is missing in elements and whether or not the content that is present in elements is correct for the identified type of requirement." (US Patent #8,732,109)

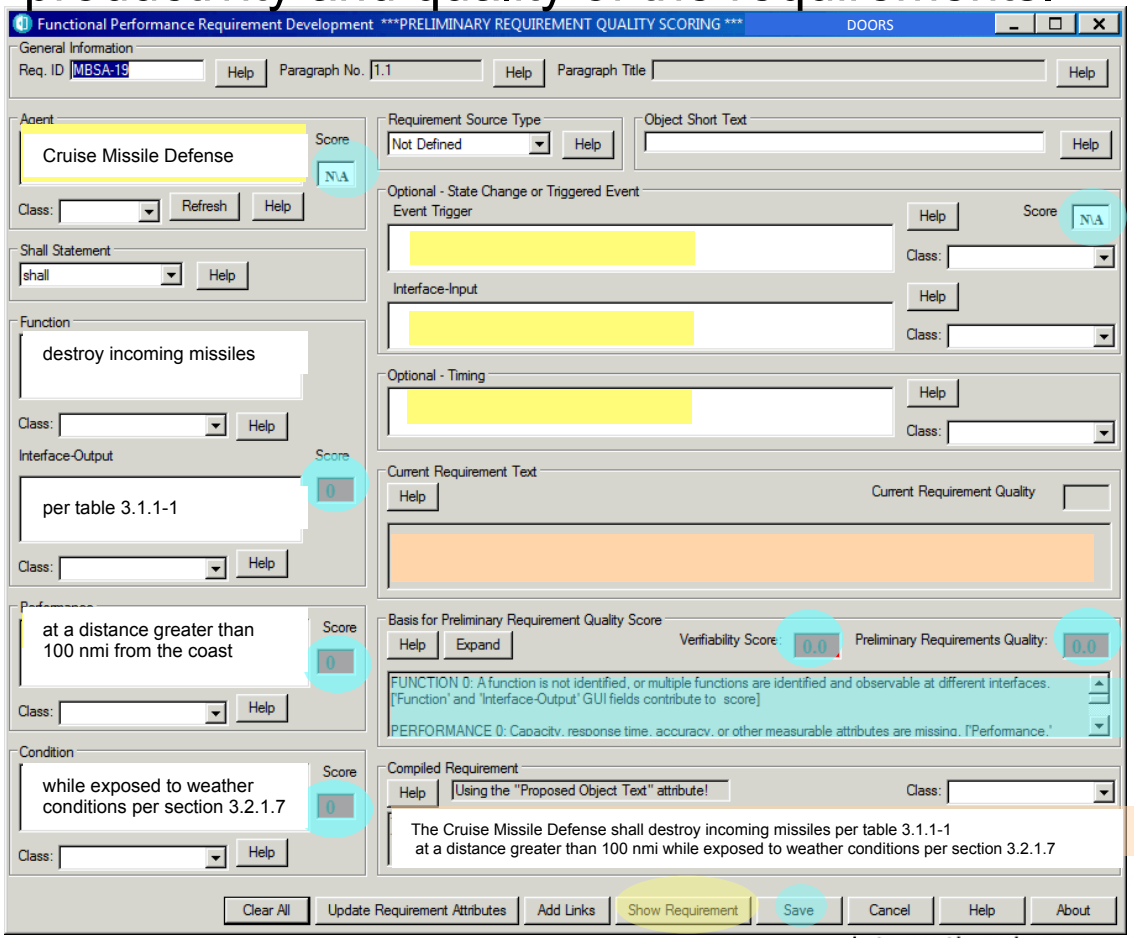
Figure from Carson & Zlicaric, "Using Performance-Based Earned Value for Measuring Systems Engineering Effectiveness", Proceedings of INCOSE 2008

Implementing Functional/Performance Requirement – Closed-loop Improvement

This combinational approach has been implemented in requirements management tools to improve productivity and quality of the requirements.

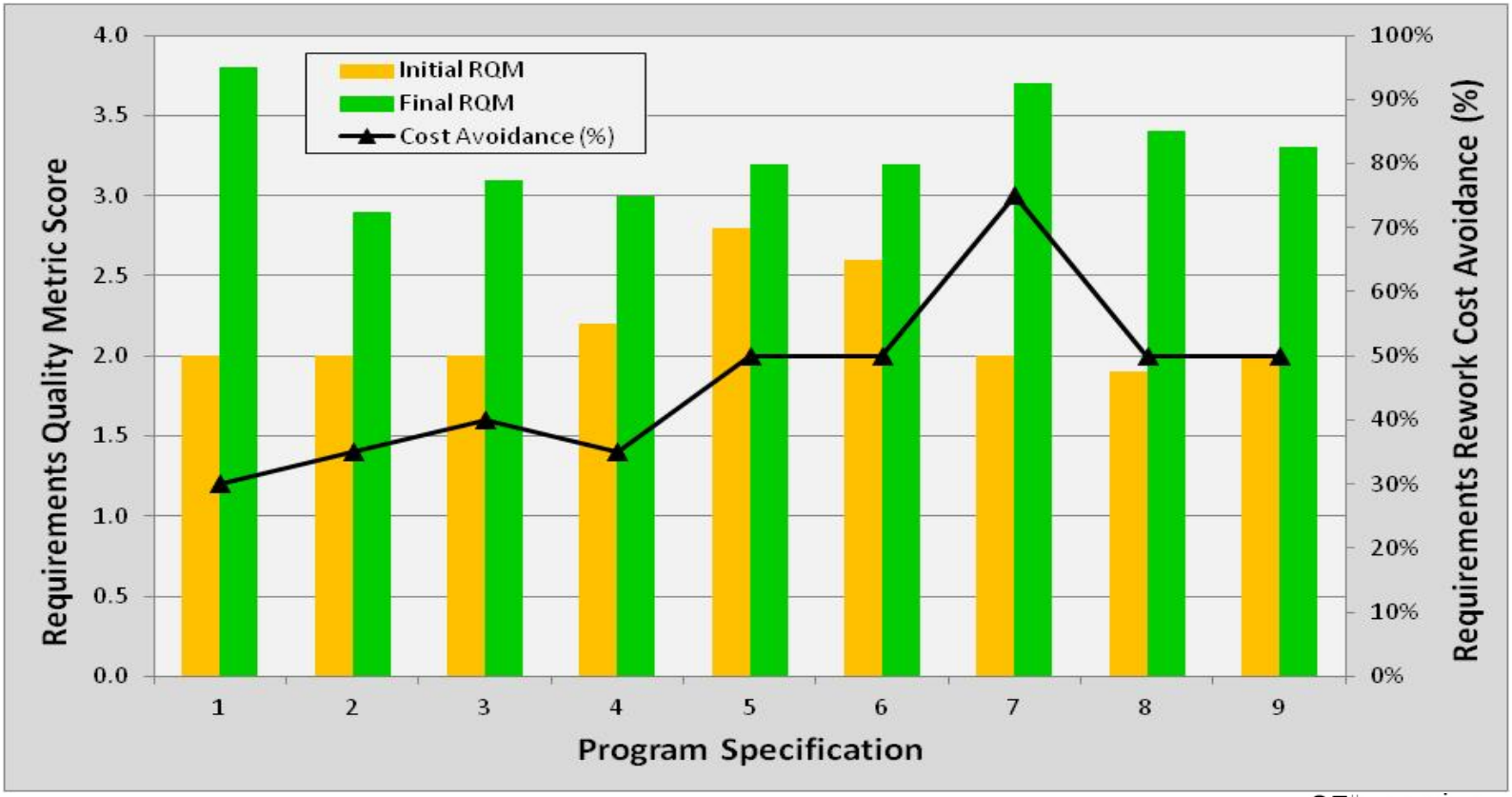


1. User selects a requirement type: "Functional/ Performance" – current requirement and required pattern are displayed
2. Allow user to add/replace text →
3. "Show Requirement" displays the concatenated result
4. Preliminary "RQ" scoring and rationale displayed
5. User updates as necessary
6. Select "Save" when done



Benefits: Return on Investment

- We are seeing SE cost avoidance as the process is used to improve the quality of requirements.
  - Weighted averages over nine specifications: ΔRQM=1.0; Requirements rework cost avoided: 44%



Summary

- **We have implemented a closed-loop feedback control process and tools for requirements development that couples measures of requirements quality to the process of writing requirements (US Patents #8,732,109, #8,886,588)**
  - **Uses four broad types of requirements with individual patterns**
  - **Augments structured, natural language requirements with a multi-level quality measurement for the elements of the structured requirements.**
  - **Implemented in DOORS®, Excel® and Teamcenter for Systems Engineering®**
- **Benefit is realized immediately in identifying requirements deficiencies while writing each requirement**
- **Earlier identification of ambiguous and unverifiable requirements reduces program risk and yields cost avoidance compared with later discovery**
- **For further information contact**
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