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international symposium

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Delivering Better Projects on Time by Ensuring Requirements Quality Upfront

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Outline

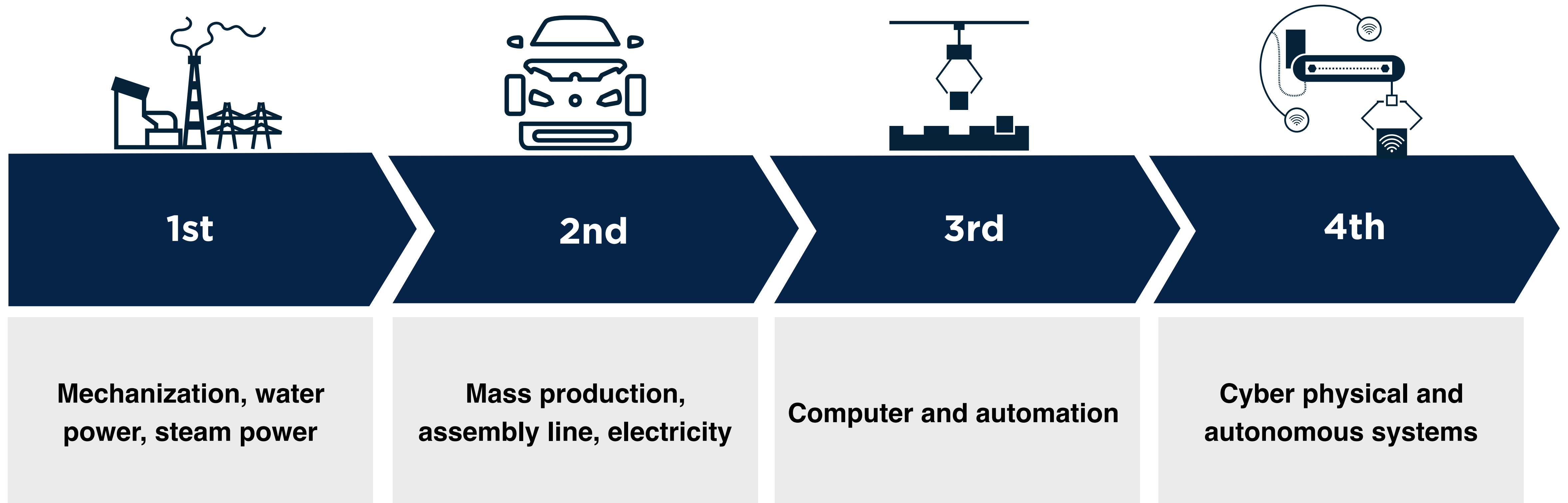


- **WHY** is it important to look at NLP technologies for requirements analysis? (NLP-RA tools)
- **WHAT** are NLP-RA tools?
- **HOW** is industry using NLP-RA tools (some use cases)?



Why NLP-RA?

History of Industrial Complexity



Why NLP-RA?



Complex systems with complex problems

40%

resources spent on
testing for complex
systems

Boeing 787

\$25B dev
\$10B testing

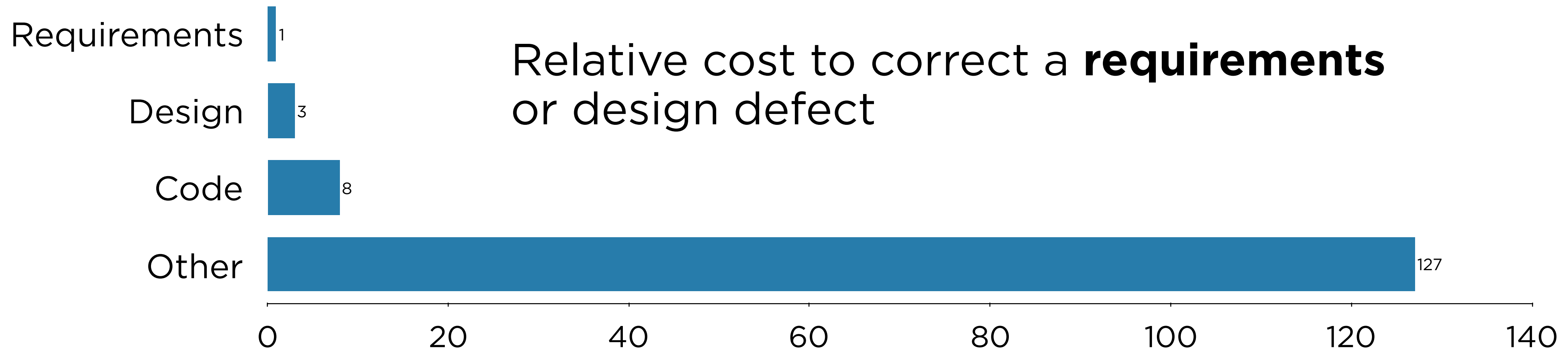
Airbus A350

\$10B dev
\$4B testing

Chevy Volt

\$1.2B dev
\$600M testing

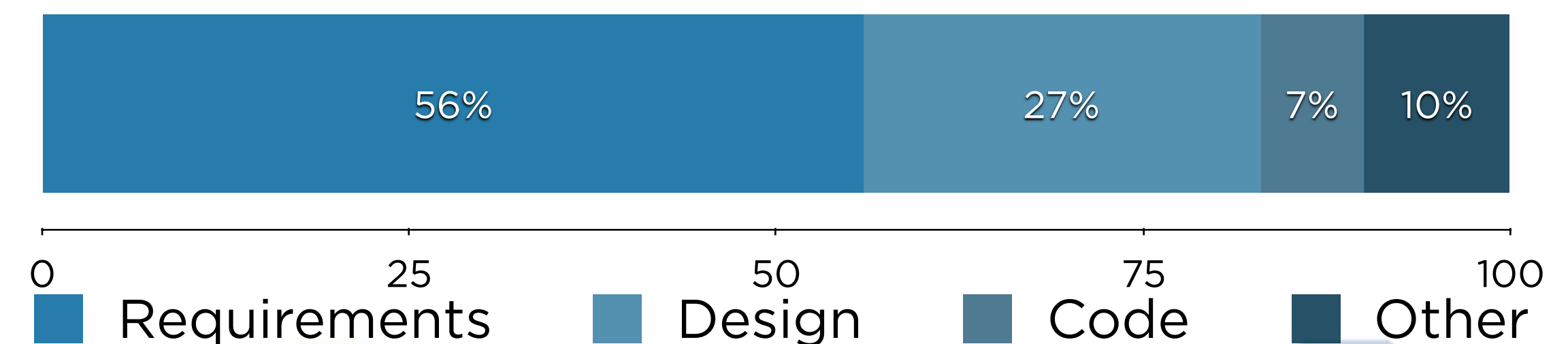
Why NLP-RA?



**Requirement defects are being found late in the development lifecycle.
Costing companies over 100 times to fix than if they were caught at early stages.**

>80% of defects in systems
are due to requirements
or design errors

Distribution of defects



How is Industry Writing Requirements?



 **79%** Common Natural Language

 **16%** Structured Natural Language, e.g. templates, forms

 **5%** Formalised Language

Natural Language Requirements



- It is the language we know best
- Highly expressive
- Semantics are well embedded

But

- Not ideal language for requirements
- High ambiguity and vagueness
- Can be difficult to assess if logic is complete
- Difficult to verify

Current Approaches to RE



Approaches

Challenges

Structured and modelling languages:

Templates, EARS, SysML

- Hard to learn and adopt
- Still requires top level NLP requirements

Formal languages: LUSTRE, Parnas tables, math

- Hard to learn and adopt
- Still requires top level NLP requirements
- Specially difficult to convey semantics

Checklists: INCOSE's (44 rules), NASA's (38 rules), QRA (21 rules)

- Time-consuming, tedious, error-prone
- Inefficient use of domain expert resources

Peer-review: multiple pairs of eyes approach

- Exacerbates the challenges of checklists times the number of reviewers



What is NLP-RA?

What is NLP-RA?



- Computational NLP technologies focus on automated language understanding:
 - **Lexical** (assess specific terminology)
 - **Syntactic** (assess terminology and sentence structure)
 - **Semantic** (assess relationships to other text)
- Many of the advances in NLP have come about from industry-led research for consumer electronics and social media platforms (Siri, Alexa, Google, Facebook).
- The focus of NLP-RA tools is on automating what can be automated (verification), and use the domain expert for the right tasks (validation).

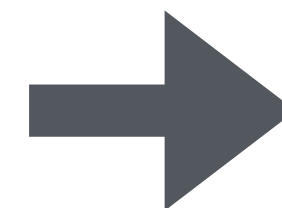
Early NLP-RA: NASA ARM



- In the late 1990s NASA worked on a tool they called the Automated Requirements Measurement (ARM) tool.
- They determined that good requirements had a set of quality attributes:

Quality Attributes (hard to measure)

- **Complete**
- **Consistent**
- **Correct**
- **Modifiable**
- **Ranked**
- **Traceable**
- **Unambiguous**
- **Valid**
- **Verifiable**



Quality Indicators (easy to measure)

- **Imperatives**
 - **Continuances**
 - **Directives**
 - **Options**
 - **Weak phrases**
 - **Size**
 - **Readability**
 - **Specification depth**
 - **Text structure**
- Lexical

New-Generation NLP-RA Tools



- Smart detection and delineation of requirements
- Quality analysis for best practice compliance
- Domain specific ontologies
- Terminology analysis
- Measurement unit analysis
- Requirements similarity analysis
- Requirements export
- Enterprise and team collaboration
- Reporting

The screenshots illustrate the NLP-RA Tools interface, which is divided into three main sections: Quality Analysis, Consistency, and Similarity.

Quality Analysis Screenshot: This view shows a table of requirements with columns for Requirement, Score & Warnings, and a status icon. The 'Overall Quality Score' is displayed as a bar chart with a warning icon and '20 Quality Warnings'. The requirements listed include various tasks like Crew Transportation, EVA Embarcation, and Cargo Transportation, each with a score and a warning icon.

Term Consistency Screenshot: This view shows a table of terms with columns for Term, # of Req., # of Similar, and Highest Matched %. The terms listed include 'Lunar Exploration Light Rover', 'Lunar Exploration Light', 'Lunar Exploration Light Rover imaging', and 'Lunar Exploration Light Rovers', each with a count of requirements and a similarity percentage.

Requirement Similarity Screenshot: This view shows a table of requirements with columns for Requirement, # of Similar Req., and Matching Percentage. The requirements listed include 'Remote Commanding', 'Rover-to-ExDOC bit rate limit', 'Remote Control Station Usability', and 'Self-test', each with a count of similar requirements and a matching percentage.

New-Generation NLP-RA Tools





CSA-ESM-RD-0004_Rev A_Prototype Lunar Exploration Light Rover_Requirements Document Eduardo Vaz

File Home Insert Design Layout References Mailings Review View Add-ins Help Search

Clipboard Font Paragraph Styles Editing Requirements

Times New Ro 10 A A Aa B I U abc x₂ x² A a b A 1. AaBb AaBbCcDc AaBbCcDc 1. AaB 1. AaB Heading 6 Normal No Spac... Heading 1 Heading 2 Find Replace Select Configuration Export Remove Marks

[EC-LMR-RES-040] Power self-sufficiency: The Lunar Exploration Light Rover shall have sufficient power generation and storage capabilities in order to meet mission requirements without requiring power from ancillary sources.

Rationale: The intention is that the Lunar Exploration Light Rover be completely self-sufficient during execution of the analogue mission scenarios and tests, including providing power to payloads, but not during ancillary activities.

QVscribe Marked Requirement

[EC-LMR-RES-045] Charging Equipment: The Lunar Exploration Light Rover shall include equipment to recharge the power supply.

Comment: The charging equipment is not expected to be part of the Rover unless this can be achieved with minimal penalties of mass, volume and other issues.

Rationale: Recharging the system will be necessary under all foreseeable rover designs. This will have to be done in remote locations without electrical service, but where such service is available, it will be very convenient to use it.

1. Remote Locations: The equipment shall recharge the system in remote locations without support from electrical utility infrastructure.
2. Use of Infrastructure: The equipment shall use electrical utility infrastructure when it is available.

[EC-LMR-RES-046] Electrical Utility Converter: The Lunar Exploration Light Rover shall include equipment to convert electrical utility power for input to the external power feed described in RD-2 [ESM-IRD-ELE-015].

Rationale: The capability to use electrical utility power will allow test, debugging and evaluation without using up battery life cycles or using consumable fuel. It is not expected that conversion equipment would be part of the Rover. This capability implies an umbilical which means locomotion would have to be minimal. Payload integration testing will benefit from this capability.

3.8 Human-Systems Integration Requirements

Note: The human-system integration requirements are applicable only if the rover is upgraded to have crew

[EC-LMR-HSI-190] Operators: If applicable, the Lunar Exploration Light Rover shall be compatible with

QVscribe

Quality Analysis Consistency Similarity

Last Analyzed: June 15, 2018 at 3:44PM Issues: All Viewing 115 of 115

Overall Quality Score 29 Quality Warnings

Requirement	Score & Warnings
[EC-LMR-RES-050] Recharge time: Lunar Exploration Light Rover battery r...	Score: 0/5 Warnings: 1
[EC-LMR-RES-060] Deployment Time: The time to assemble the Lunar Exp...	Score: 0/5 Warnings: 1
[EC-LMR-RES-040] Power self-sufficiency: The Lunar Exploration Light Rov...	Score: 0/5 Warnings: 1
[EC-LMR-RES-045] Charging Equipment: The Lunar Exploration Light Rov...	Score: 0/5 Warnings: 1
Quality Score	
Contains multiple imperatives	
Contains optional words	
Contains vague words	
[EC-LMR-RES-046] Electrical Utility Converter: The Lunar Exploration Light...	Score: 0/5 Warnings: 1
[EC-LMR-HSI-190] Operators: If applicable, the Lunar Exploration Light Ro...	Score: 0/5 Warnings: 1
[EC-LMR-HSI-060] Operator display: If applicable, the Lunar Exploration Li...	Score: 5/5 Warnings: 0
[EC-LMR-HSI-070] Anthropometrics: If applicable, the Lunar Exploration L...	Score: 4/5 Warnings: 1
[EC-LMR-HSI-090] Crew Mass: If applicable, aspects of the Lunar Explorati...	Score: 4/5 Warnings: 1
[EC-LMR-HSI-100] Maximum Crew Loads: If applicable, Lunar Exploration...	Score: 4/5 Warnings: 1
[EC-LMR-HSI-110] Minimum Crew Loads: If applicable, Lunar Exploration...	Score: 0/5 Warnings: 1
[EC-LMR-HSI-120] Crew Contact Loads: If applicable, Lunar Exploration Li...	Score: 4/5 Warnings: 1

Back to Marking Reanalyze Selected Generate Report Reanalyze All

Page 17 of 26 10179 words Display Settings 96%

FILEHOMEINSERTDESIGNPAGE LAYOUTREFERENCESMAILINGSREVIEWVIEWADD-INS

1234567891011121314151617

CSA-ESM-RD-0004

Canadian Space Agency

Exploration Surface Mobility Project

Prototype Lunar Exploration Light Rover Requirements Document

10227 WORDS

ENGLISH (UNITED STATES)

CSA-ESM-RD-0004_Rev A_Prototype Lunar Exploration Light Rover_Requirements Document.docx - Word

Sign in

QVscribe

Your Requirements ?

+ Add

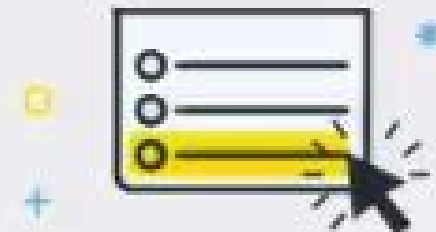
Remove

Undo

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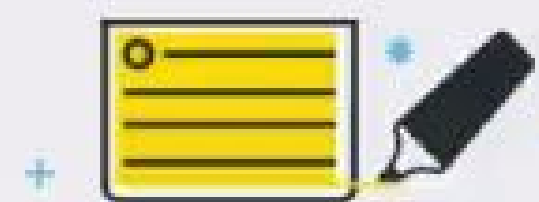
Use Requirement Finder

Add your requirements here...



Double-click on single-paragraph requirements

OR



Select multi-paragraph requirements and press "Add Requirement"

[Customize Your Analysis ?](#)

Analyze 0 Requirements

See Previous Analysis

QVscribe Help Center

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100%

Number of Quality Warnings: 21

Score	# of Reqs.	Percentage	What should I do?
5	0	0%	Very Low Risk Includes clear and unambiguous terminology to express the requirement.
4	36	31%	Low Risk May include excessive use of continuances, and/or No directives. Check the flow and clarity of the requirement.
3	29	25%	Medium Risk Includes a single instance of a vague, subjective, or weak term, and/or a single negative imperative. Replace the negative or ambiguous term with a clear and concise term.
2	6	5%	High Risk Includes multiple instances of vague, subjective, or weak terms, and/or negative imperatives. Replace negative or ambiguous terms with clear and concise terms.
1	44	38%	Very High Risk The requirement lacks an imperative, or contains multiple imperatives, and/or contains excessive vague terms. Consider rewriting the requirement or separating into multiple concise requirements.

Analysis Breakdown

Quality Score	Percentage*	# of Occurrences
No Directives	94%	109
Vague Words	46%	53
Multiple Imperatives	24%	28
Optional Words	18%	21
Negative Imperatives	12%	14
No Imperatives	8%	10
Excessive Continuances	6%	8

Quality Warnings	Percentage*	# of Occurrences
Universal Quantifiers	18%	21

* Percentage is based on how many of the occurrences appear within the document. Some different warnings, and issues may overlap in different percentages since some requirements may contain both.

Individual Requirements

Score: 4
No Directives
[EC-LMR-FNC-002] Crew Transportation: Nominal: The Lunar Exploration Light Rover shall be designed to be upgradeable to transport one EVA-suited crew member.

Score: 4
No Directives
[EC-LMR-FNC-008] EVA Embarcation: When upgrade to transport astronaut, the Lunar Exploration Light Rover shall provide convenient access for EVA crew to embark and disembark.

Score: 1
No Directives
Multiple Imperatives
Vague Words
Unit(s) Found
[EC-LMR-FNC-003] Cargo Transportation: The Lunar Exploration Light Rover shall transport cargo items. 1. Cargo mass: The Lunar Exploration Light Rover shall transport up to 300 kg, including cargo, attached payloads and the nominal passenger complement. 2. Cargo Volume: The Lunar Exploration Light Rover shall transport cargo and attached payloads up to a volume of 1 m x 1.5 m x 1.5 m high.

Score: 3
No Directives
Optional Words
[EC-LMR-FNC-006] EVA Tool Storage: The Lunar Exploration Light Rover should provide a location for storing EVA tools. 1. EVA Access: EVA tools shall be accessible to the EVA crew.

Score: 4
No Directives
[ESM-LMR-DES-001] Propulsion: The rover shall use electric propulsion.

Score: 4
No Directives
[EC-LMR-FNC-200] Motion: Upon command, the Lunar Exploration Light Rover shall move forward, reverse, and steer.

Score: 4
No Directives
[EC-LMR-FNC-017] Precision Drive: The Lunar Exploration Light Rover shall, upon command, place itself so that a target of interest is within the workspace of a contact sensor or sampling device.

Score: 1
No Directives
Multiple Imperatives
Vague Words
Universal Quantifiers
Unit(s) Found
[EC-LMR-FNC-180] Park: Upon command, the Lunar Exploration Light Rover shall put itself in a safe waiting state ("parked") in which locomotion is inhibited. 1. Parking Brake: The parked state shall hold the vehicle, at maximum gross vehicle weight, on a 31 degree slope facing in any direction. The vehicle shall be stopped on the slope, wheel motors or their equivalent turned off completely, and the rover held by the parking brake for no less than one minute in each direction.

Score: 1
Excessive Continuances
No Directives
Vague Words
Unit(s) Found
[EC-LMR-PRF-010] Range: The Lunar Exploration Light Rover shall have a range of at least 15 km with a target of 30 km between refueling or recharging stops on a traverse where the vehicle is loaded to maximum gross vehicle weight, it is traveling over level terrain with a surface roughness defined using the equation in [EC-LMR-PRF-120] Maximum Speed on Natural Terrain with C=3.0E-05 and N=2.0, it travels at a constant speed of 10 km/h between stops and it makes 50 starts and stops.

Score: 3
No Directives
Vague Words
Unit(s) Found
[EC-LMR-PRF-018] Maximum Speed on Prepared Surface: The Lunar Exploration Light Rover, loaded to maximum gross vehicle weight, shall be capable of maintaining a speed of not less than 15 km/h on a smooth, level, prepared surface.





How is industry using NLP RA tools?

NLP-RA Use Cases



Royal Canadian Air Force



- Document and requirements restructuring
- RE training for procurement personnel and BAs
- Ambiguity reduction
- Requirement similarity
- Requirements extraction from Word documents to compliance matrices
- Time savings in requirements review process of 60%-75%

NLP-RA Use Cases



Ultra Electronics Maritime Systems

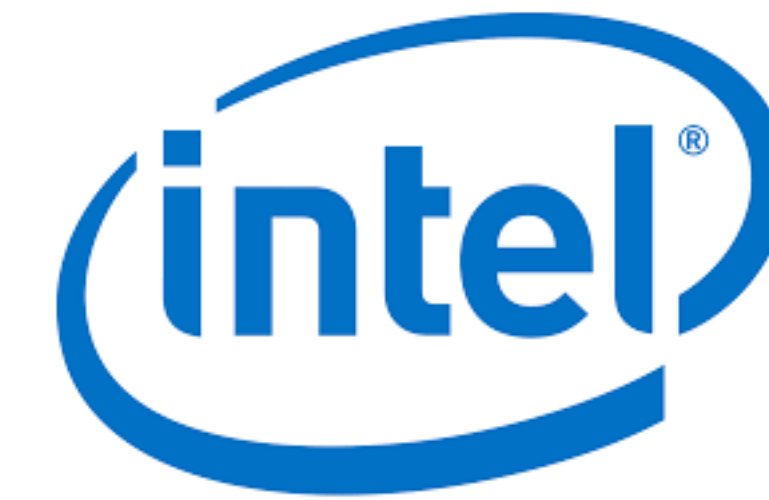


- Analysis and risk profile of RFPs
- Correctness and clarity of RFP response
- RE training for engineers
- Ambiguity reduction
- Requirement similarity
- Time/cost savings in procurement process 30%

NLP-RA Use Cases



Intel / Honeywell



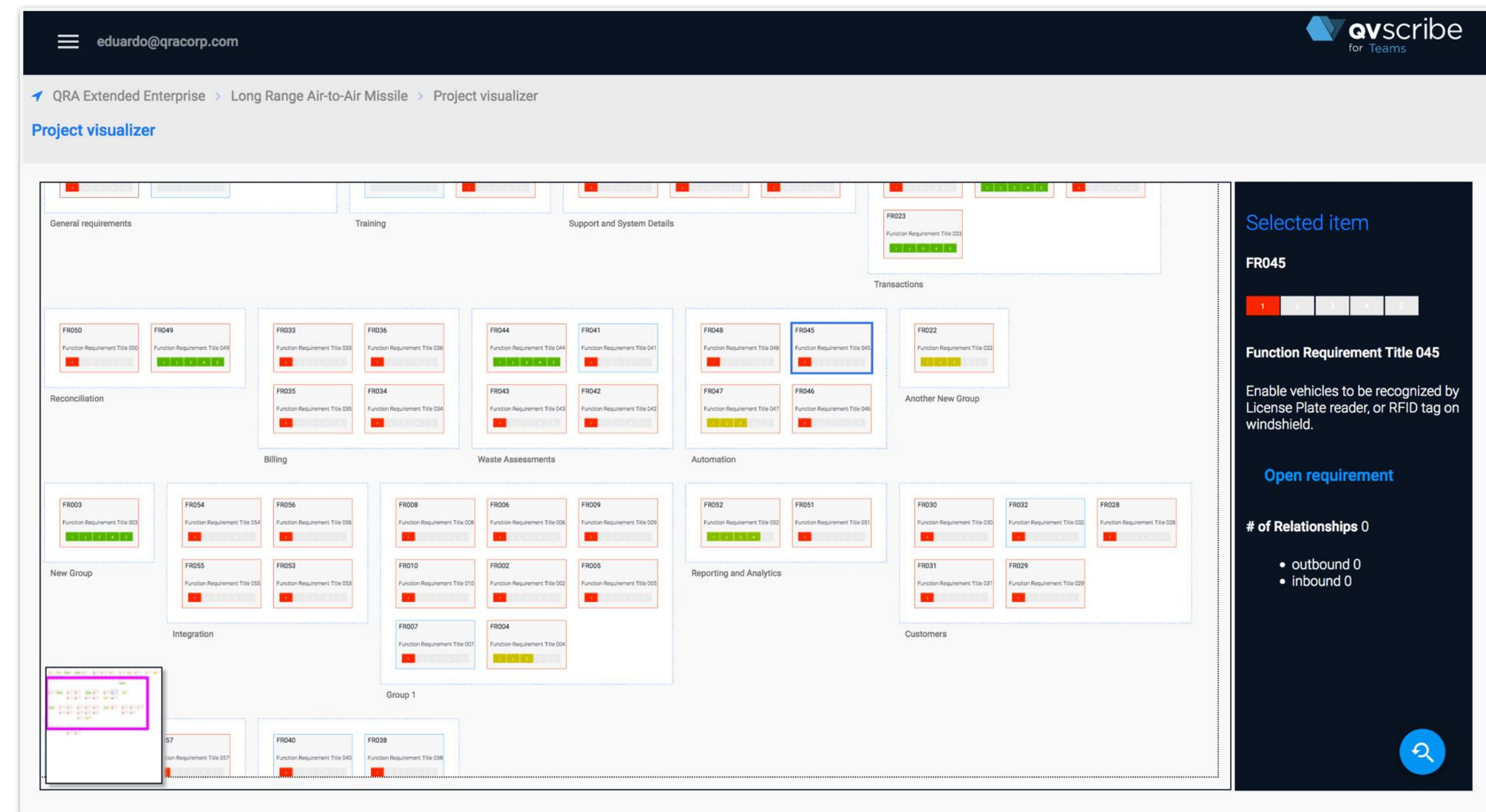
Honeywell

- Encoding of institutional knowledge
- Enforcement of internal practices
- DSTs for consistency across teams (in development)
- RE training
- Glossary creation
- Time/cost savings in requirement authoring stages... unknown

Next-Gen NLP-RA



- Semantic analysis for version control and requirements classification
- Domain specific ontology (via machine learning)
- Web-based centralized analysis and collaboration
- Assistant for formalization of reqs (for completeness analysis)



Thank you



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