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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

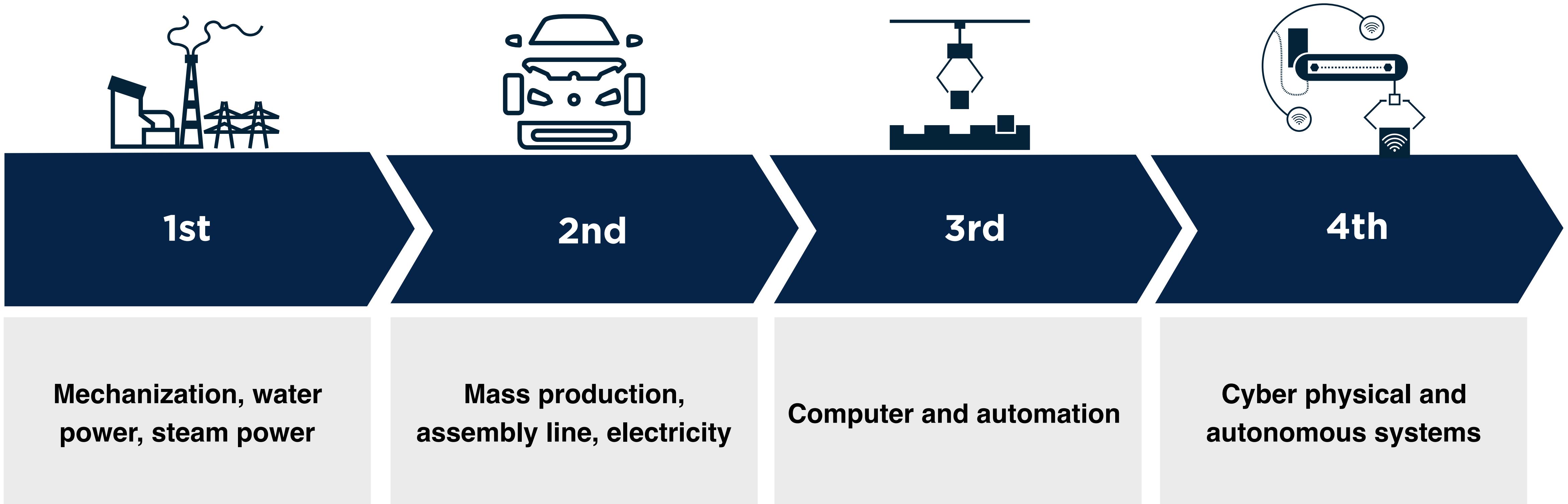


- **WHY** is it important to look at NLP technologies for requirements analysis? (NLP-RA tools)
- **WHAT** are NLP-RA tools?
- **HOW** is industry using NLP-RA tools (some use cases)?



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

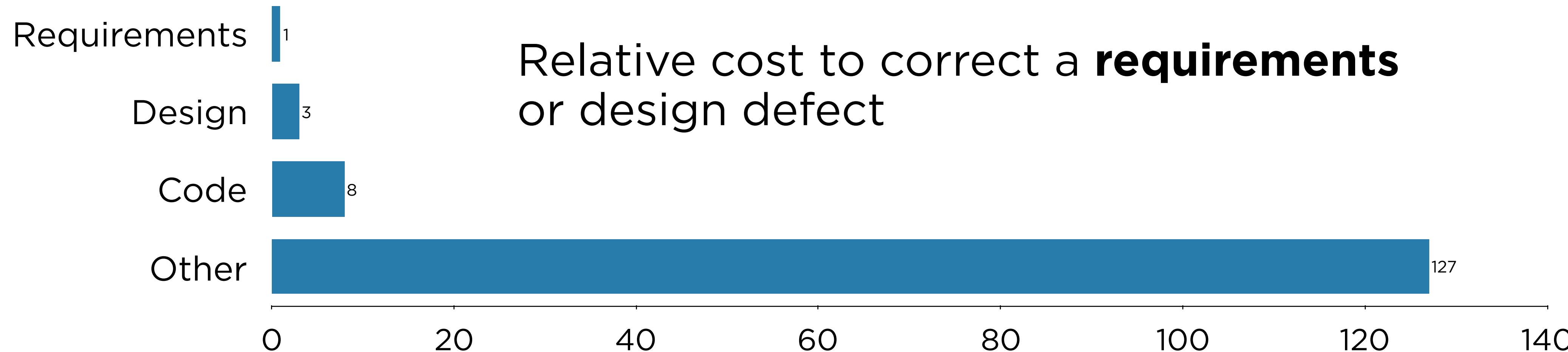
Airbus A350

\$10B dev
\$4B testing

Chevy Volt

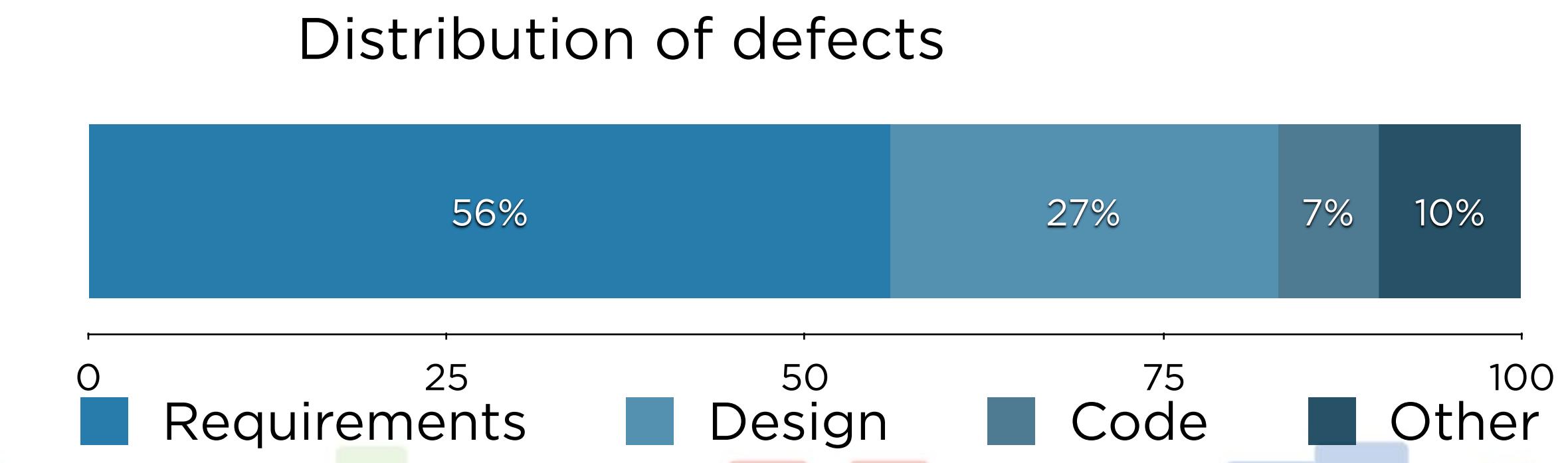
\$1.2B dev
\$600M testing

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



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	<ul style="list-style-type: none">• Hard to learn and adopt• Still requires top level NLP requirements
Formal languages: LUSTRE, Parnas tables, math	<ul style="list-style-type: none">• 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)	<ul style="list-style-type: none">• Time-consuming, tedious, error-prone• Inefficient use of domain expert resources
Peer-review: multiple pairs of eyes approach	<ul style="list-style-type: none">• 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).

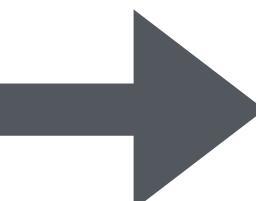
Early NLP-RA: NASA ARM



- 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

Quality Analysis | Consistency | Similarity

Units	Terms	Matching Strength	
Term Consistency	Search	Less	More
Lunar Exploration Light Rover	95	6	98.20 %
Lunar Exploration Light	8	5	88.19 %
Lunar Exploration Light Rover imaging	1	5	87.83 %
Lunar Exploration Light Rovers	1	5	98.20 %
Lunar Exploration Light Rover-mounted	1	4	86.60 %
Lunar Exploration Light Rover component	1	3	100.00 %
Lunar Exploration Light Rover component	1	3	92.58 %
Lunar Exploration Light Rover component	1	3	100.00 %
Lunar Exploration Light Rover component	1	3	80.00 %

Quality Analysis | Consistency | Similarity

Overall Quality Score: 20 Quality Warnings

Requirement	Score & Warnings
[EC-LMR-FNC-002] Crew Transportation: Nominal: The Lunar Exploration Li...	Green
[EC-LMR-FNC-008] EVA Embarkation: When upgrade to transport astronau...	Green
[EC-LMR-FNC-003] Cargo Transportation: The Lunar Exploration Light Rov...	Red
[EC-LMR-FNC-006] EVA Tool Storage: The Lunar Exploration Light Rover sh...	Yellow
[ESM-LMR-DES-001] Propulsion: The rover shall use electric propulsion.	Green
[EC-LMR-FNC-200] Motion: Upon command, the Lunar Exploration Light R...	Green
[EC-LMR-FNC-017] Precision Drive: The Lunar Exploration Light Rover shall...	Green
[EC-LMR-FNC-180] Park: Upon command, the Lunar Exploration Light Rov...	Red
Quality Score	
Contains multiple imperatives	Green
Contains vague words	Green
Quality Warnings	
Contains universal quantifiers	Yellow
[EC-LMR-PRF-010] Range: The Lunar Exploration Light Rover shall have a r...	Yellow
[EC-LMR-PRF-018] Maximum Speed on Prepared Surface: The Lunar Explor...	Yellow
[EC-LMR-PRF-120] Maximum Speed on Natural Terrain: The Lunar Explorat...	Red
[EC-LMR-PRF-068] Rock Hazard: The Lunar Exploration Light Rover runnin...	Red
[EC-LMR-PRF-069] Soil Properties: The Lunar Exploration Light Rover sha...	Red
[EC-LMR-PRF-150] Reverse speed: The speed requirements apply in forwar...	Red
[EC-LMR-PRF-063] Minimum Speed: The Lunar Exploration Light Rover sha...	Yellow
Back to Marking Reanalyze Selected Generate Report Reanalyze All	

Quality Analysis | Consistency | Similarity

Requirement Similarity

Requirement	# of Similar Req.
[EC-LMR-RCS-030] Remote Commanding: The Remote Control Station shall accept an...	1
[EC-LMR-COM-030] Rover-to-ExDOC bit rate limit: The Lunar Exploration Light Rover...	1
[EC-LMR-RCS-040] Remote Control Station Usability: The Remote Control Station hum...	1
[EC-LMR-FNC-011] Self-test: Upon command, the Lunar Exploration Light Rover shall...	1
Matched Requirement	
[EC-LMR-FNC-012] Power-up: Upon command, the Lunar Exploration Light Rover shall...	83.61 %
[EC-LMR-COM-040] ExDOC-to-Rover bit rate limit: The Lunar Exploration Light Rover...	1
[EC-LMR-FNC-012] Power-up: Upon command, the Lunar Exploration Light Rover shall...	1
[EC-LMR-HSI-110] Minimum Crew Loads: If applicable, Lunar Exploration Light Rover...	1
[EC-LMR-HSI-100] Maximum Crew Loads: If applicable, Lunar Exploration Light Rover...	1
[EC-LMR-SMA-015] Seat Belt Assemblies: If the Lunar Exploration Light Rover is equip...	0
[EC-LMR-SMA-016] Seat Belt Anchorage: If the Lunar Exploration Light Rover is equip...	0
[EC-LMR-HSI-070] Anthropometrics: If applicable, the Lunar Exploration Light Rover...	0
[EC-LMR-SMA-270] Standard Tools: The standard and non-standard tools from the list...	0
[EC-LMR-INT-010] Payload power: The Lunar Exploration Light Rover shall be capable...	0
[EC-LMR-FNC-150] Standby: The Lunar Exploration Light Rover shall be configurable t...	0
[EC-LMR-SMA-010] Driver Impact Protection: If the Lunar Exploration Light Rover is e...	0
[EC-LMR-RES-046] Electrical Utility Converter: The Lunar Exploration Light Rover shall...	0
[EC-LMR-SMA-150] Remote restart: The Lunar Exploration Light Rover shall provide th...	0
[EC-LMR-ENV-004] Sand and Dust: The Lunar Exploration Light Rover shall meet its re...	0
[EC-LMR-SMA-011] Anchorage of Seats: When upgraded to transport astronaut, the...	0

Quality Analysis | Consistency | Similarity

Requirement Similarity

Requirement	Matching Percentage
[EC-LMR-FNC-012] Power-up: Upon command, the Lunar Exploration Light Rover shall...	83.61 %
[EC-LMR-COM-040] ExDOC-to-Rover bit rate limit: The Lunar Exploration Light Rover...	1
[EC-LMR-FNC-012] Power-up: Upon command, the Lunar Exploration Light Rover shall...	1
[EC-LMR-HSI-110] Minimum Crew Loads: If applicable, Lunar Exploration Light Rover...	1
[EC-LMR-HSI-100] Maximum Crew Loads: If applicable, Lunar Exploration Light Rover...	1
[EC-LMR-SMA-015] Seat Belt Assemblies: If the Lunar Exploration Light Rover is equip...	0
[EC-LMR-SMA-016] Seat Belt Anchorage: If the Lunar Exploration Light Rover is equip...	0
[EC-LMR-HSI-070] Anthropometrics: If applicable, the Lunar Exploration Light Rover...	0
[EC-LMR-SMA-270] Standard Tools: The standard and non-standard tools from the list...	0
[EC-LMR-INT-010] Payload power: The Lunar Exploration Light Rover shall be capable...	0
[EC-LMR-FNC-150] Standby: The Lunar Exploration Light Rover shall be configurable t...	0
[EC-LMR-SMA-010] Driver Impact Protection: If the Lunar Exploration Light Rover is e...	0
[EC-LMR-RES-046] Electrical Utility Converter: The Lunar Exploration Light Rover shall...	0
[EC-LMR-SMA-150] Remote restart: The Lunar Exploration Light Rover shall provide th...	0
[EC-LMR-ENV-004] Sand and Dust: The Lunar Exploration Light Rover shall meet its re...	0
[EC-LMR-SMA-011] Anchorage of Seats: When upgraded to transport astronaut, the...	0

New-Generation NLP-RA Tools





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

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Clipboard Paste Font Paragraph Styles Editing Requirements

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1. AaBb 1. AaI 1. AaB

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Configuration Export Remove Marks QVscribe

[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...	Red
[EC-LMR-RES-060] Deployment Time: The time to assemble the Lunar Exp...	Orange
[EC-LMR-RES-040] Power self-sufficiency: The Lunar Exploration Light Rov...	Orange
[EC-LMR-RES-045] Charging Equipment: The Lunar Exploration Light Rov...	Red
Quality Score	
Contains multiple imperatives	Red
Contains optional words	Red
Contains vague words	Red
[EC-LMR-RES-046] Electrical Utility Converter: The Lunar Exploration Light...	Red
[EC-LMR-HSI-190] Operators: If applicable, the Lunar Exploration Light Ro...	Red
[EC-LMR-HSI-060] Operator display: If applicable, the Lunar Exploration Li...	Green
[EC-LMR-HSI-070] Anthropometrics: If applicable, the Lunar Exploration L...	Yellow
[EC-LMR-HSI-090] Crew Mass: If applicable, aspects of the Lunar Explorati...	Yellow
[EC-LMR-HSI-100] Maximum Crew Loads: If applicable, Lunar Exploratio...	Yellow
[EC-LMR-HSI-110] Minimum Crew Loads: If applicable, Lunar Exploratio...	Red
[EC-LMR-HSI-120] Crew Contact Loads: If applicable, Lunar Exploratio...	Yellow

Back to Marking Reanalyze Selected Generate Report Reanalyze All

Page 17 of 26 10179 words Display Settings

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

FILE HOME INSERT DESIGN PAGE LAYOUT REFERENCES MAILINGS REVIEW VIEW ADD-INS

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Your Requirements ⓘ

+ Add - Remove Undo Redo Use Requirement Finder

CSA-ESM-RD-0004

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

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10227 WORDS ENGLISH (UNITED STATES)

Canadian Space Agency
Exploration Surface Mobility Project

Prototype Lunar Exploration Light Rover Requirements Document



QVscribe for Microsoft Word

ion Light Rover_Requirements Document.docx Date Analyzed: April 16, 2018 at 3:21PM Total Requirements Analyzed: 115

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.

Rethink Your Requirements

Page 2 of 26



Document Name: CSA-ESM-RD-0004_Rev A_Prototype Lunar Exploration Light Rover_Requirements Document.docx Date Analyzed: April 16, 2018 at 3:21PM Total Requirements Analyzed: 115

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 Embarkation: 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.

Rethink Your Requirements

Page 3 of 26





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



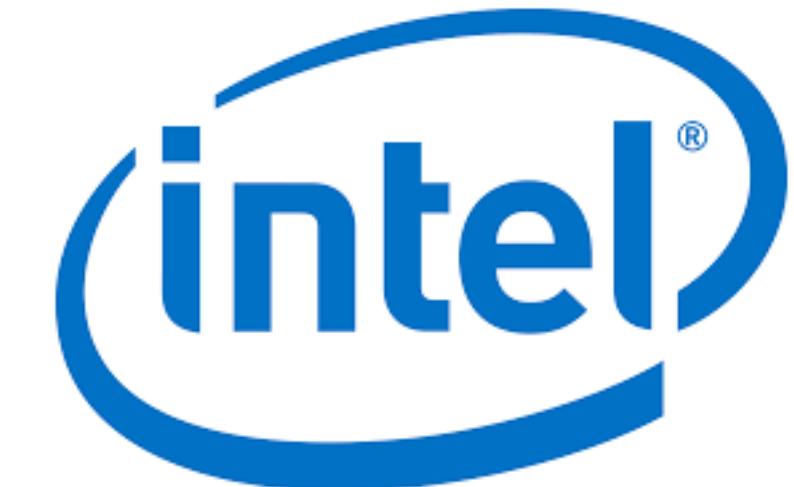
- Analysis and risk profile of RFPs
- Correctness and clarity of RFP response
- RE training for engineers
- Ambiguity reduction
- Requirement similarity
- Time/cost savings in procurement process 30%

NLP-RA Use Cases



Intel / Honeywell

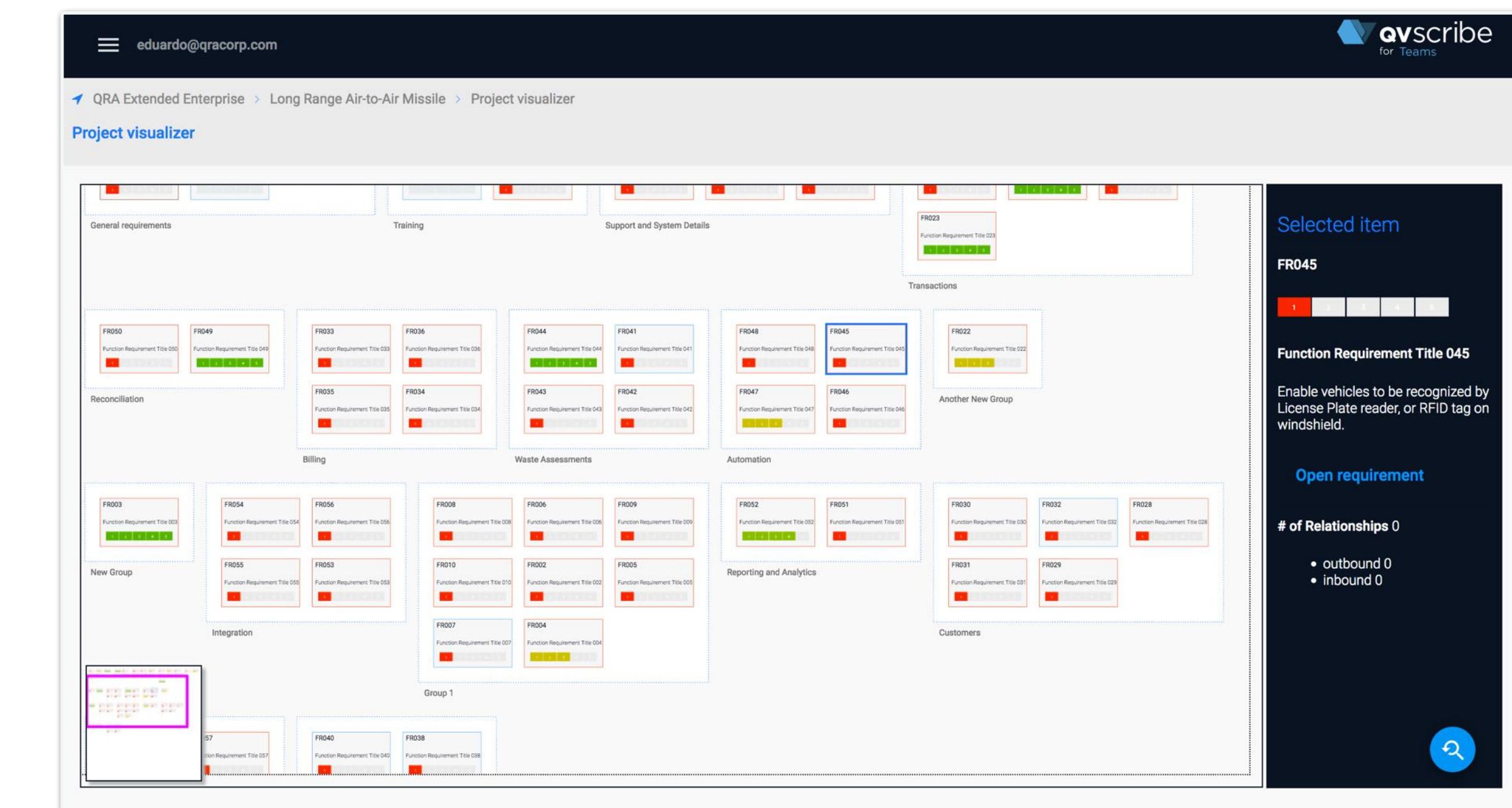
- Encoding of institutional knowledge
- Enforcement of internal practices
- DSTs for consistency across teams (in development)
- RE training
- Glossary creation
- Time/cost savings in requirement authoring stages... unknown



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



28th Annual **INCOSE**
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www.incose.org/symp2018

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