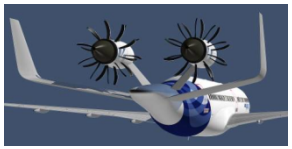


Faculty of Computing, Engineering and Mathematical Sciences

UWE BRISTOL

INCOSE International Symposium

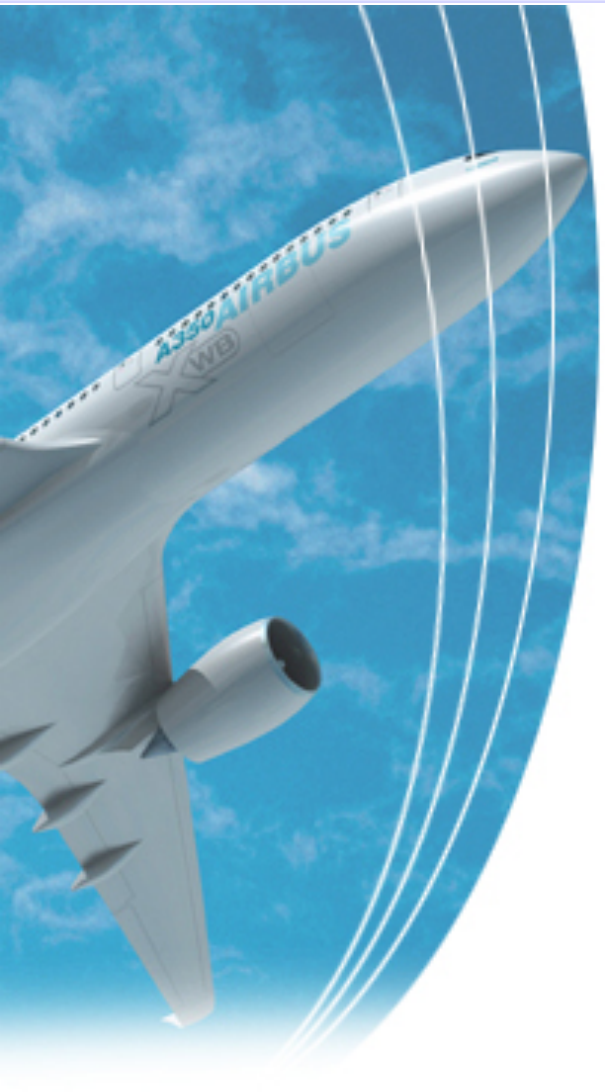
Ontology-driven Requirements Engineering – A case study in the aerospace context

Mario Kossmann (Airbus)

Dr. Mohammed Odeh (UWE)

A joint research project of Airbus and the University of the West of England (UWE)

Content



- Objectives of the OntoREM project
- Overview of OntoREM
  - Metamodel
  - Novel contributions (examples)
  - Applications of OntoREM
- Aerospace case study context
- Evaluation framework
- Findings and analysis
  - Quality
  - Time/cost
  - Additional advantages
- Conclusion

Objectives of OntoREM (Airbus)

Why OntoREM ?

=> To **comply with the Airbus strategy 2020**

=> To **reduce development cycle time** (and thereby time to market)

=> To **reduce non-recurring costs** (NRC)

=> To **improve product and programme quality** (via requirements)

=> To **enhance programme management**

Why the aerospace case study ?

=> To **investigate the potential of OntoREM** to meet the above objectives (proof of concept)

=> To **evolve/improve OntoREM** in light of experience

=> To **enable preparation of industrial scale use** of OntoREM

Ontology-driven Requirements Engineering Methodology (OntoREM)

- **Knowledge-driven** approach to RE
- For **complex**, **trans-national** and **multi-disciplinary** development environments
- Reference but **not limited** to the aerospace industry
- Emphasis on:
  - **goal aspects**
  - **role aspects**
  - **business-domain-process aspects**
  - **queries aspects**
  - Non-Functional Requirements (**NFRs**)
- Use of **ontology** to specify the OntoREM Metamodel
- **Reasoning** to analyse process status, goals/soft goals and requirements
- **Case study** within Airbus (wing) to evaluate, evolve and validate OntoREM (2009)
- Large scale OntoREM **pilot study** and **integration** into the Product Development Process

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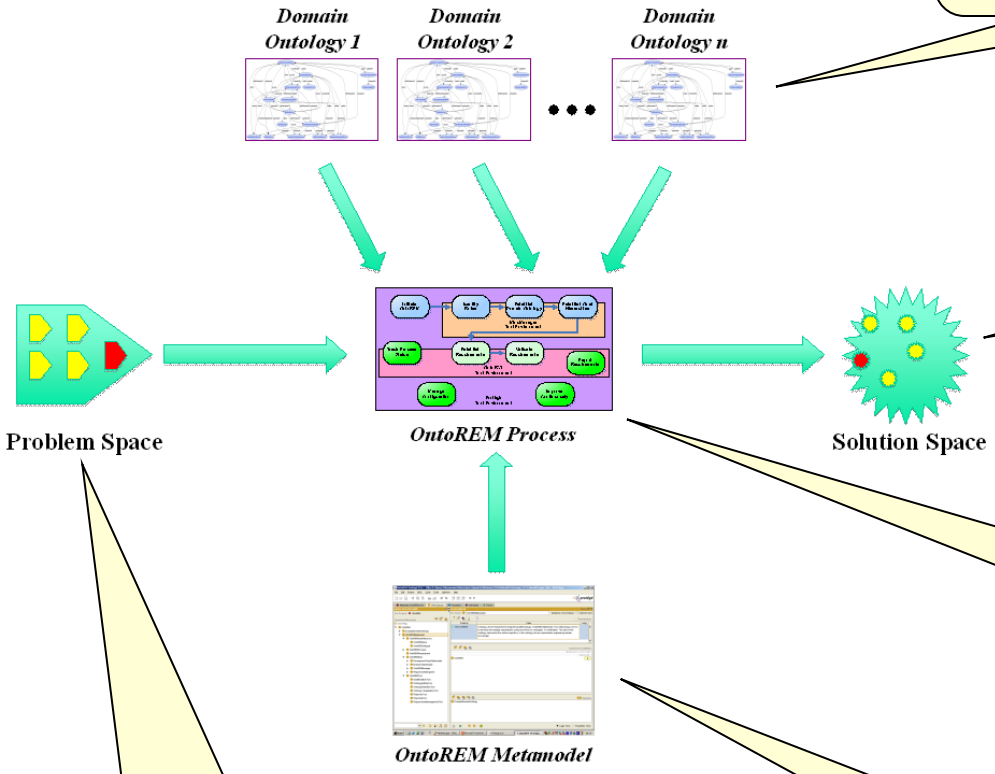
Ontology-driven Requirements Engineering Methodology (OntoREM)

'…specification of conceptualization' (Gruber, 1993)

specification = formal and declarative representation, ***conceptualization*** = abstract, simplified view of the world

'…the ontology of a certain domain is about its terminology (domain vocabulary), all essential concepts in the domain, their classification, their taxonomy, their relations (including all important hierarchies and constraints), and domain axioms' (Gasevic et al., 2006)



Existing other domain ontologies may be used during the process

Complete specification of the domain requirements that need to be satisfied

OntoREM process that is conducted to specify the solution space

Complete domain problem space including needs, constraints etc. for which a solution has to be found

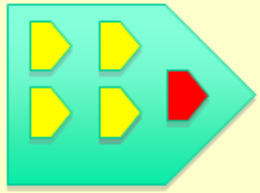
Describes the RE domain with all entities, relations and instances (e.g. process and roles)

Other specific domain ontologies

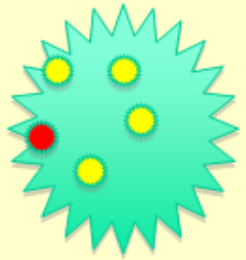
Domain Ontology 1 *Domain Ontology 2* ... *Domain Ontology n*

+

Specific application domain ontology



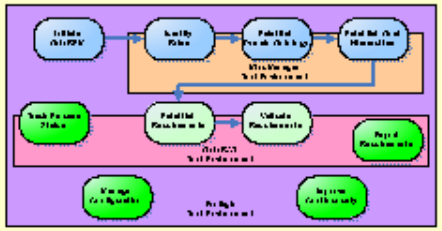
Problem Space



Solution Space

+

Generic OntoREM process ontology



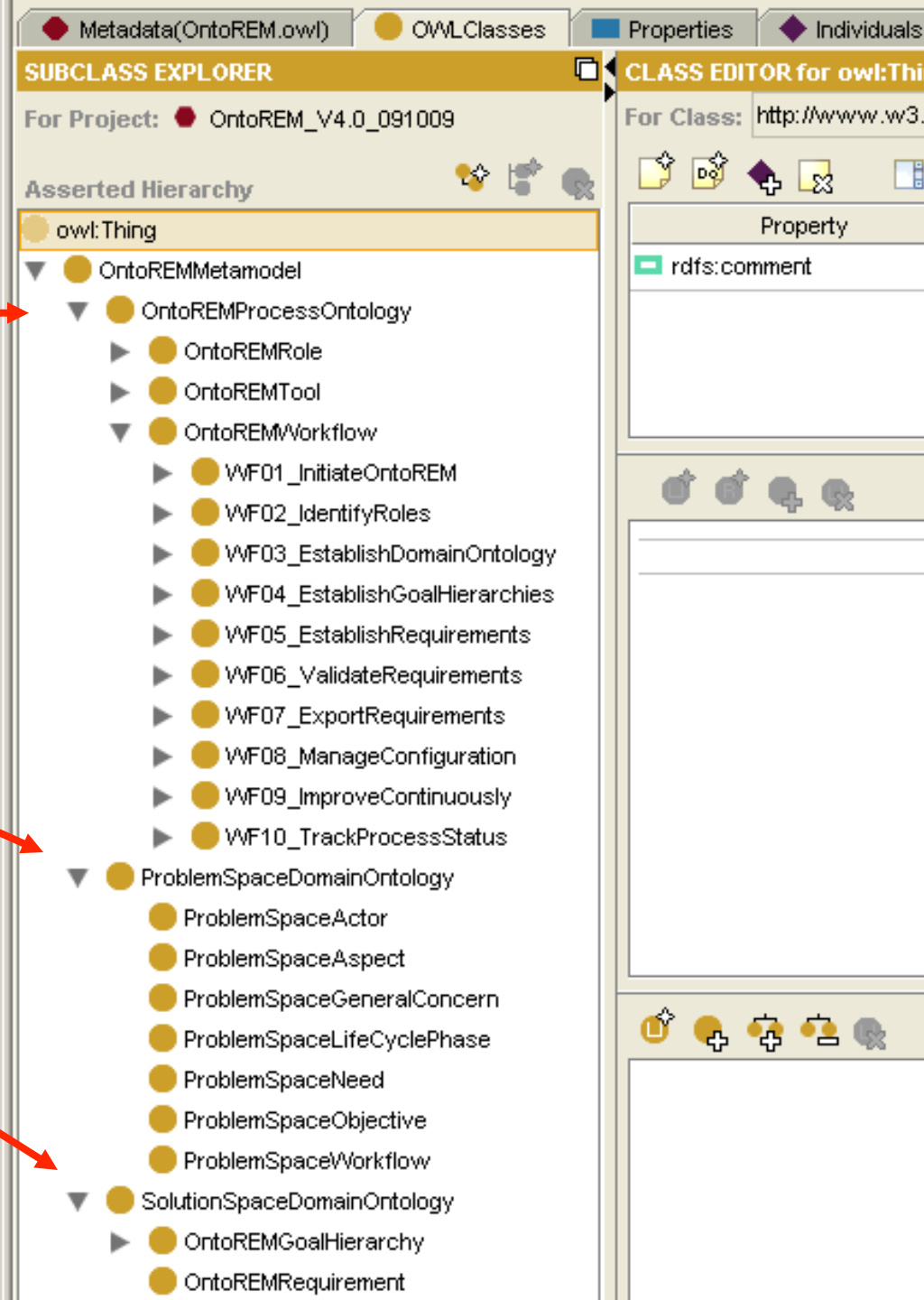
OntoREM Process

OntoREM Metamodel

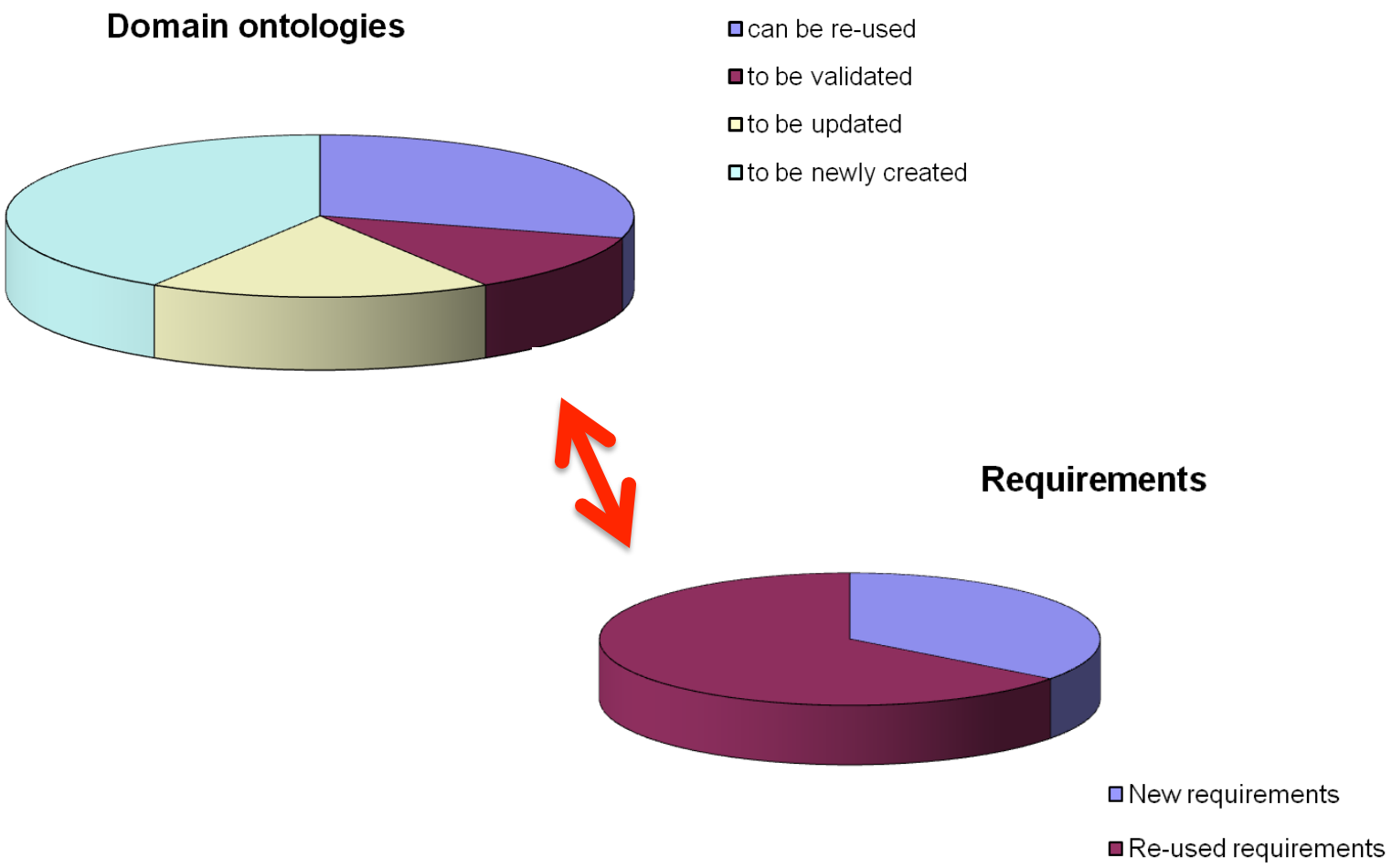
OntoREM process domain ontology

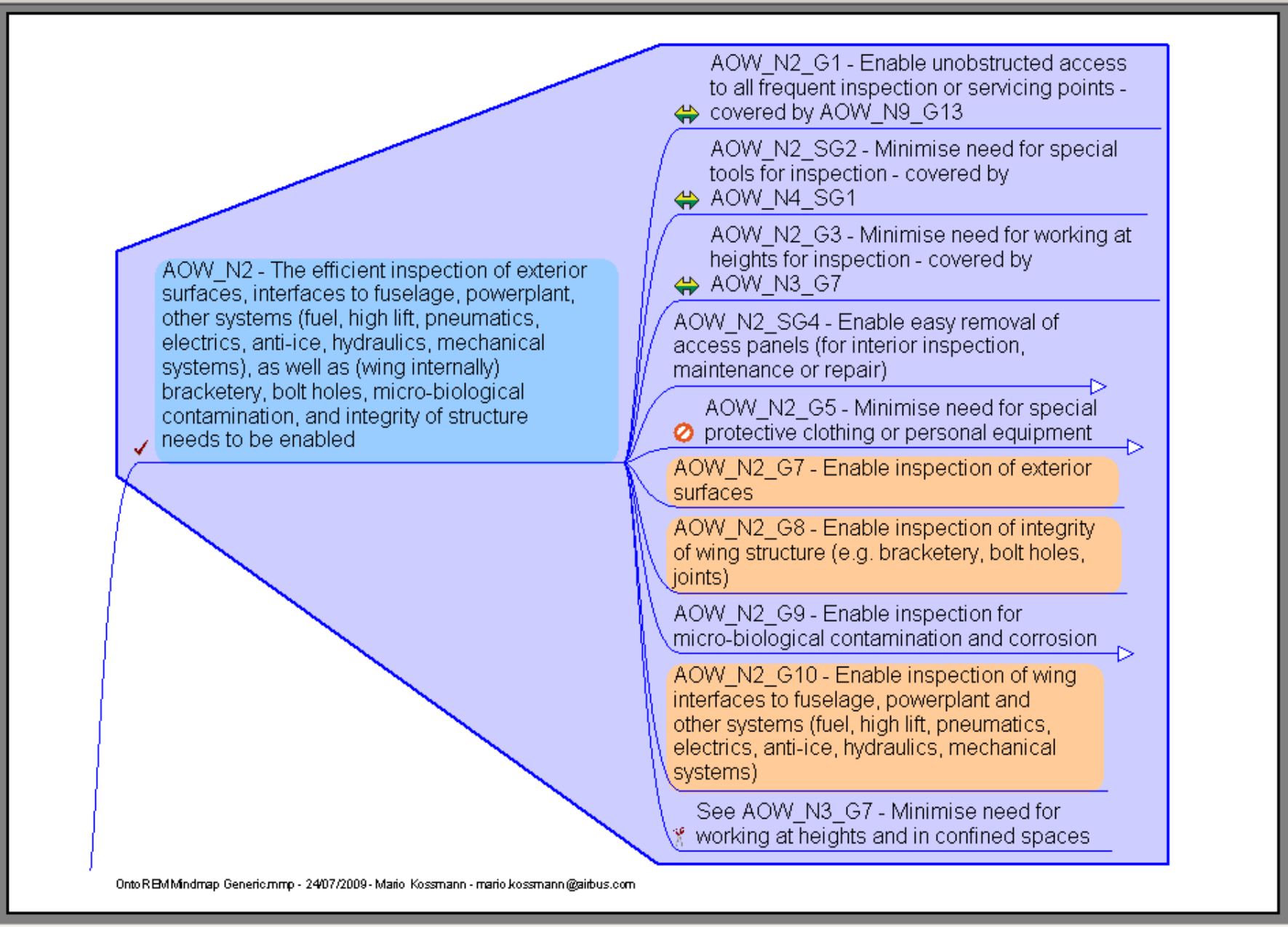
Problem space domain ontology

Solution space domain ontology

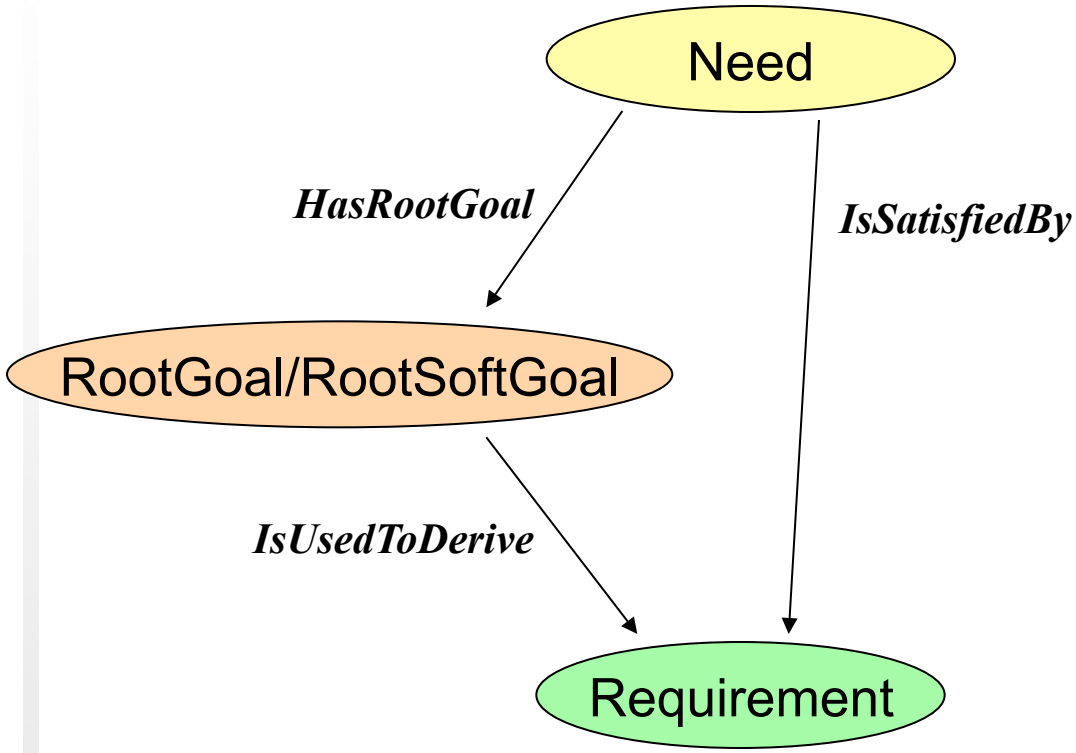


Enhancement of programme management





Reasoning at both goal and requirement levels



Analysis

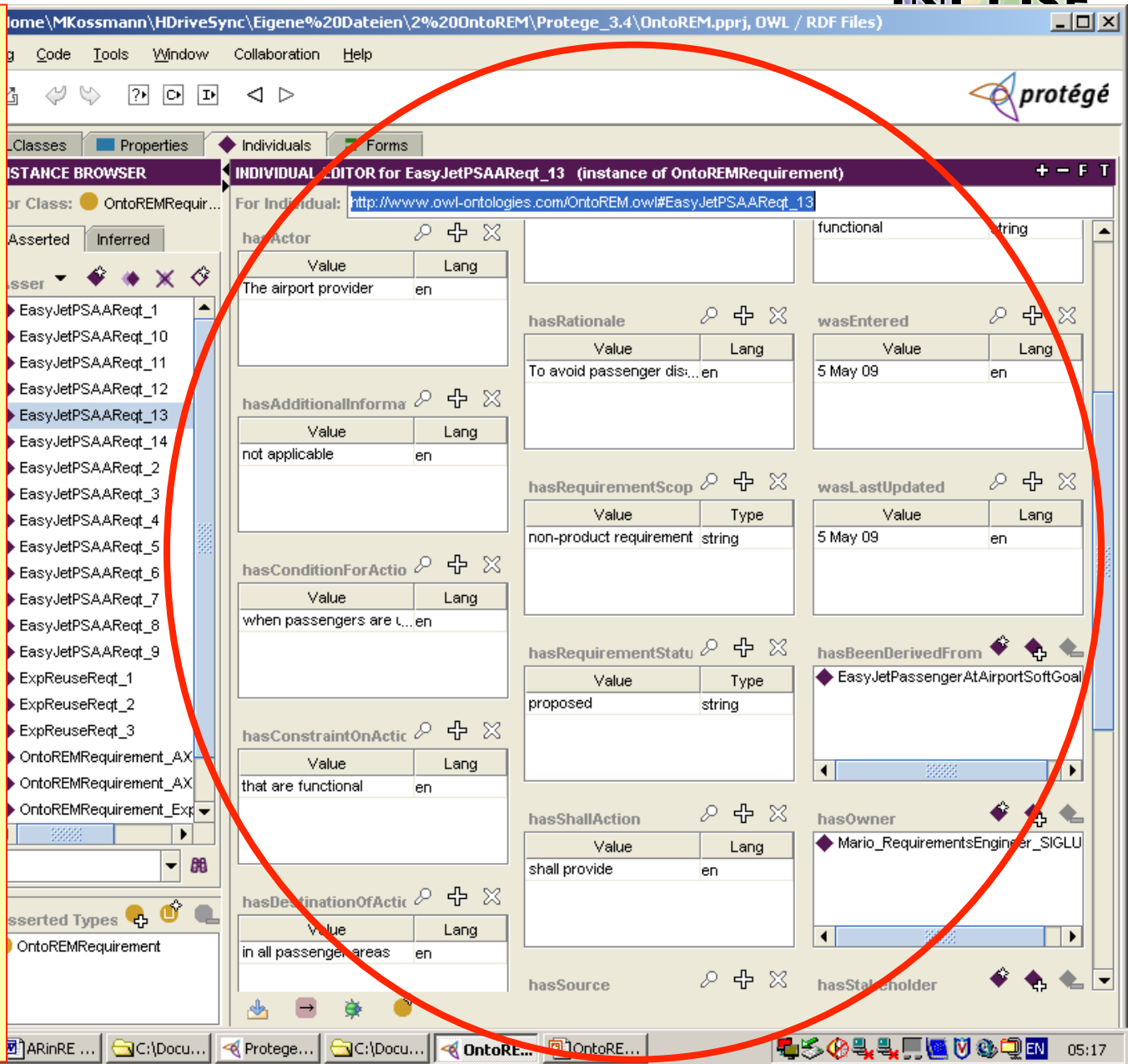
- Goal conflicts?
- Goal duplications?
-Missing goals/soft goals?
(based on available information)

- Requirement conflicts?
-Requirement duplications?
-Missing components?
-Missing requirements?
(based on the available information)

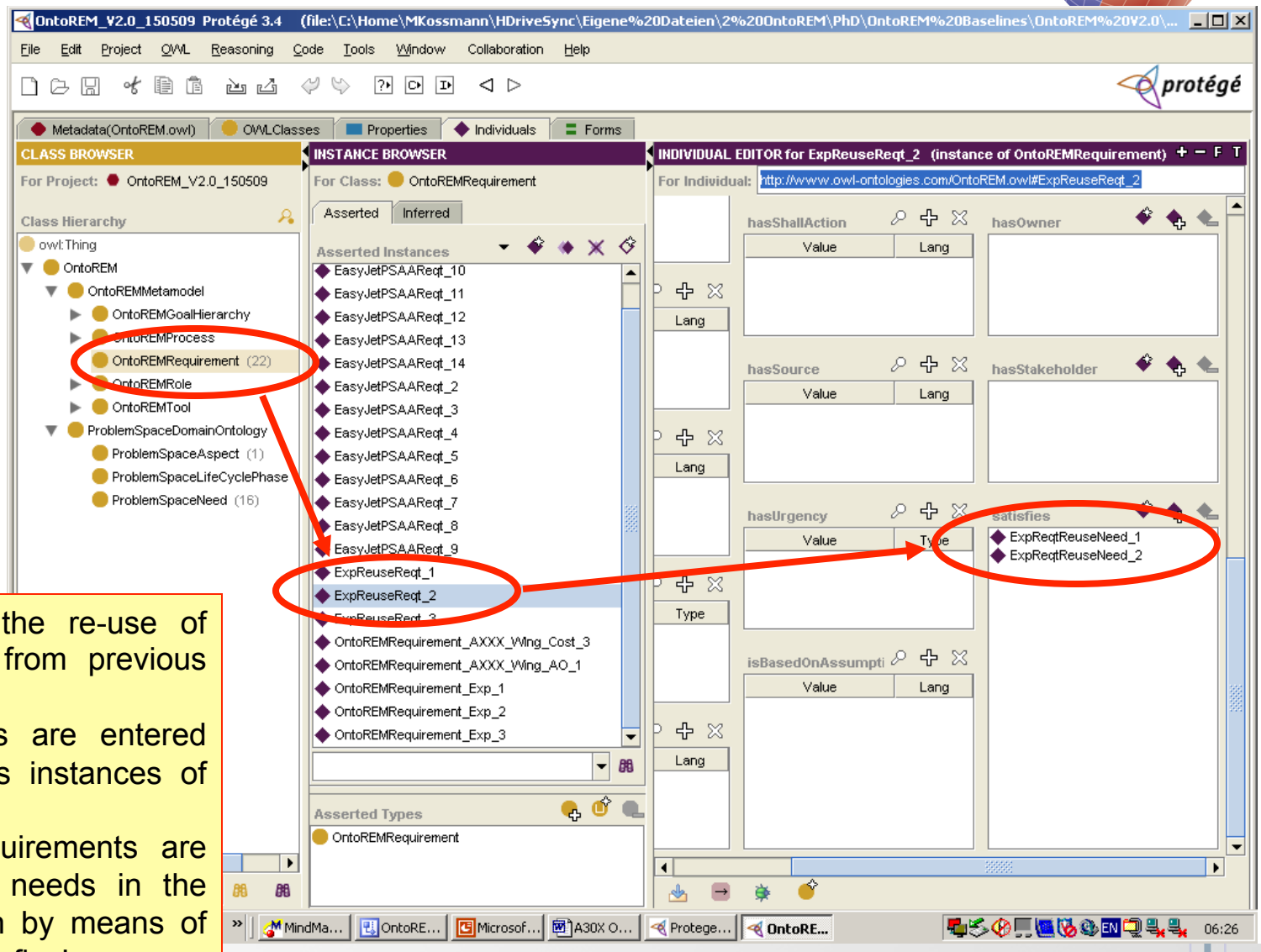
Analysis at both goal level and requirements level saves time (and therefore cost), as well as improves requirements consistency.

Creating quality in requirements (up front)

1. For each instance of a requirement, widgets based on the specified properties in the 'requirements template' of the Metamodel are made available.
2. Authors of requirements are 'forced' to provide the necessary inputs into the requirement statement itself (sub-components), as well as attributes and link information.
3. Requirement statements are automatically compiled from the available sub-component information.
4. This supports writing good quality requirements upfront as opposed to checking requirements quality once they have been written. However, no libraries of allowed words or writing rules (as used by quality checking tools) are currently behind this approach.



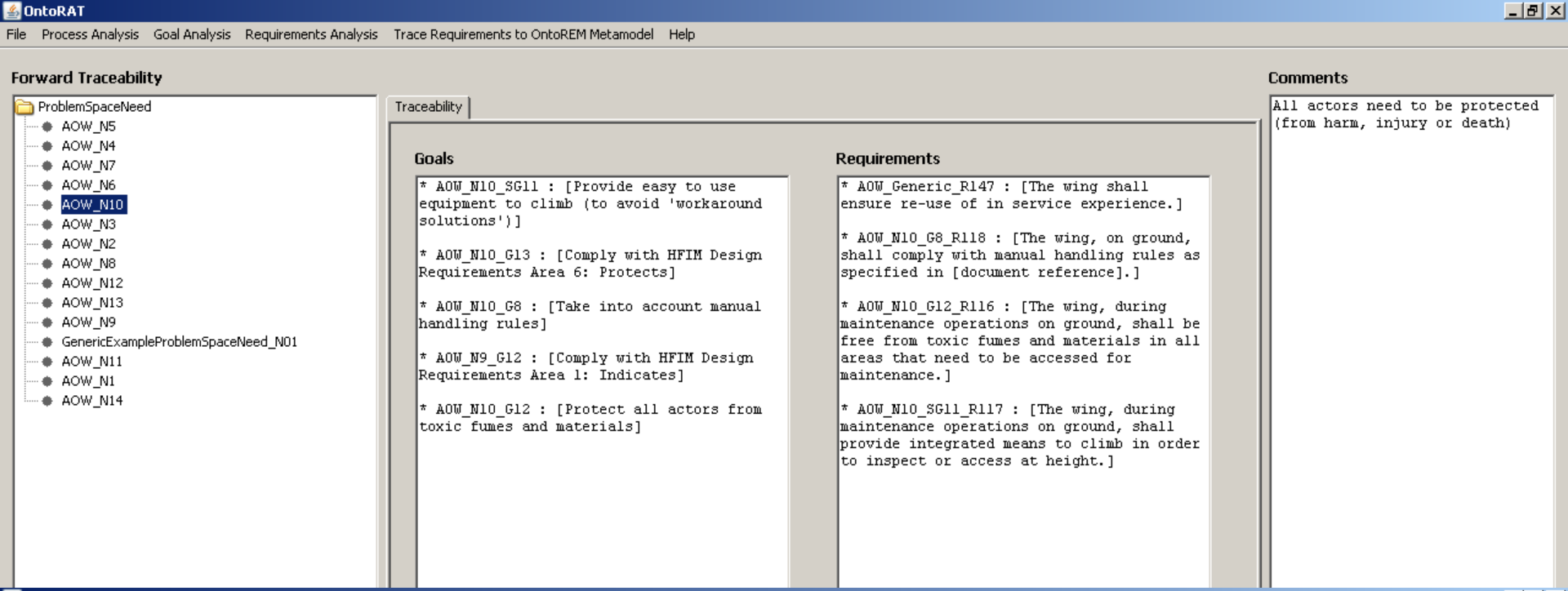
Re-use of requirements

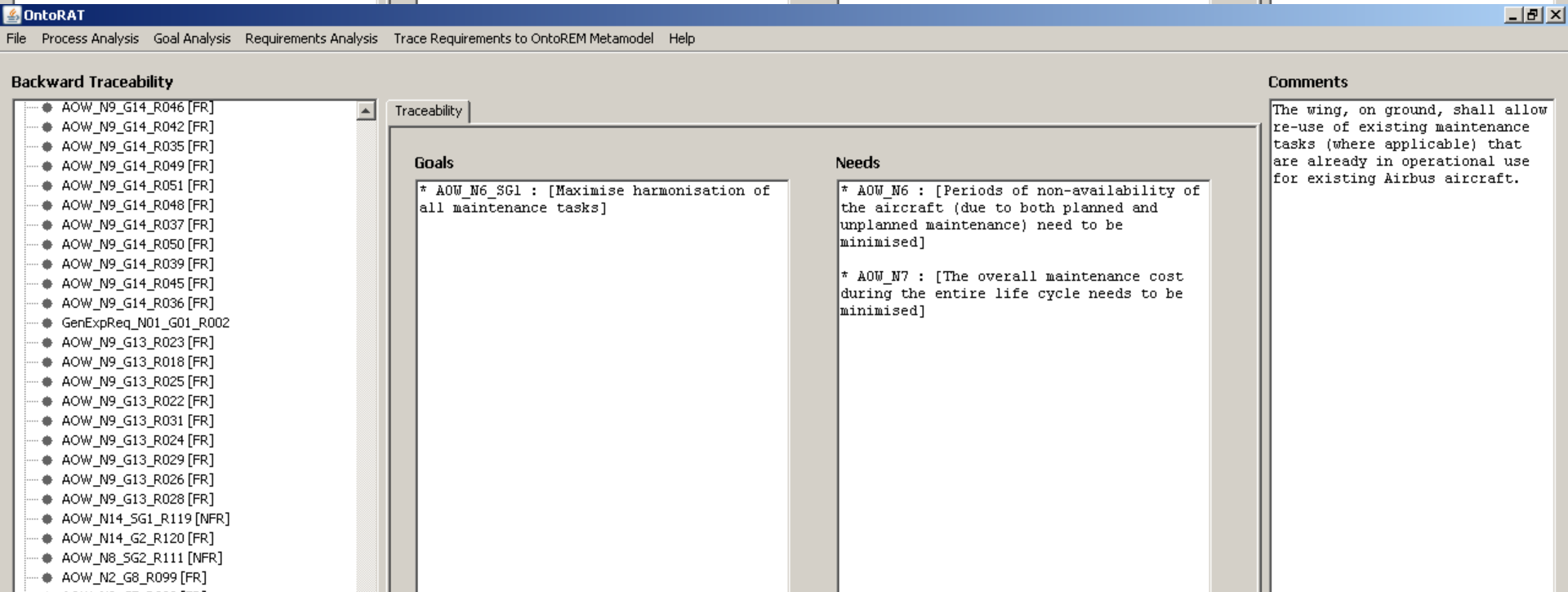


OntoREM addresses the re-use of existing requirements from previous programmes/projects:

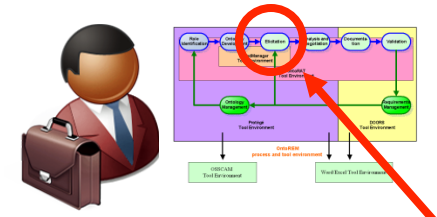
-Re-used requirements are entered into the Metamodel as instances of OntoREMRequirement.

-Entered, re-used requirements are then linked to actual needs in the problem space domain by means of the object property ‘satisfies’.

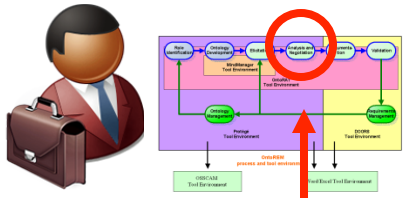

OntoRAT
File
Process Analysis
Goal Analysis
Requirements Analysis
Trace Requirements to OntoREM Metamodel
Help
Forward Traceability
ProblemSpaceNeed
AOW_N5
AOW_N4
AOW_N7
AOW_N6
AOW_N10
AOW_N3
AOW_N2
AOW_N8
AOW_N12
AOW_N13
AOW_N9
GenericExampleProblemSpaceNeed_N01
AOW_N11
AOW_N1
AOW_N14
Traceability
Goals
* AOW_N10_SG11 : [Provide easy to use equipment to climb (to avoid 'workaround solutions')]
* AOW_N10_G13 : [Comply with HFIM Design Requirements Area 6: Protects]
* AOW_N10_G8 : [Take into account manual handling rules]
* AOW_N9_G12 : [Comply with HFIM Design Requirements Area 1: Indicates]
* AOW_N10_G12 : [Protect all actors from toxic fumes and materials]
Requirements
* AOW_Generic_R147 : [The wing shall ensure re-use of in service experience.]
* AOW_N10_G8_R118 : [The wing, on ground, shall comply with manual handling rules as specified in [document reference].]
* AOW_N10_G12_R116 : [The wing, during maintenance operations on ground, shall be free from toxic fumes and materials in all areas that need to be accessed for maintenance.]
* AOW_N10_SG11_R117 : [The wing, during maintenance operations on ground, shall provide integrated means to climb in order to inspect or access at height.]
Comments
All actors need to be protected (from harm, injury or death)


OntoRAT
File
Process Analysis
Goal Analysis
Requirements Analysis
Trace Requirements to OntoREM Metamodel
Help
Backward Traceability
AOW_N9_G14_R046 [FR]
AOW_N9_G14_R042 [FR]
AOW_N9_G14_R035 [FR]
AOW_N9_G14_R049 [FR]
AOW_N9_G14_R051 [FR]
AOW_N9_G14_R048 [FR]
AOW_N9_G14_R037 [FR]
AOW_N9_G14_R050 [FR]
AOW_N9_G14_R039 [FR]
AOW_N9_G14_R045 [FR]
AOW_N9_G14_R036 [FR]
GenExpReq_N01_G01_R002
AOW_N9_G13_R023 [FR]
AOW_N9_G13_R018 [FR]
AOW_N9_G13_R025 [FR]
AOW_N9_G13_R022 [FR]
AOW_N9_G13_R031 [FR]
AOW_N9_G13_R024 [FR]
AOW_N9_G13_R029 [FR]
AOW_N9_G13_R026 [FR]
AOW_N9_G13_R028 [FR]
AOW_N14_SG1_R119 [NFR]
AOW_N14_G2_R120 [FR]
AOW_N8_SG2_R111 [NFR]
AOW_N2_G8_R099 [FR]
Traceability
Goals
* AOW_N6_SG1 : [Maximise harmonisation of all maintenance tasks]
Needs
* AOW_N6 : [Periods of non-availability of the aircraft (due to both planned and unplanned maintenance) need to be minimised]
* AOW_N7 : [The overall maintenance cost during the entire life cycle needs to be minimised]
Comments
The wing, on ground, shall allow re-use of existing maintenance tasks (where applicable) that are already in operational use for existing Airbus aircraft.

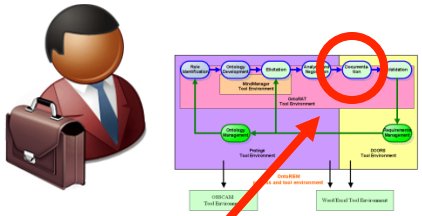
Concurrent work with different stakeholders



Stakeholder 2



Stakeholder 1



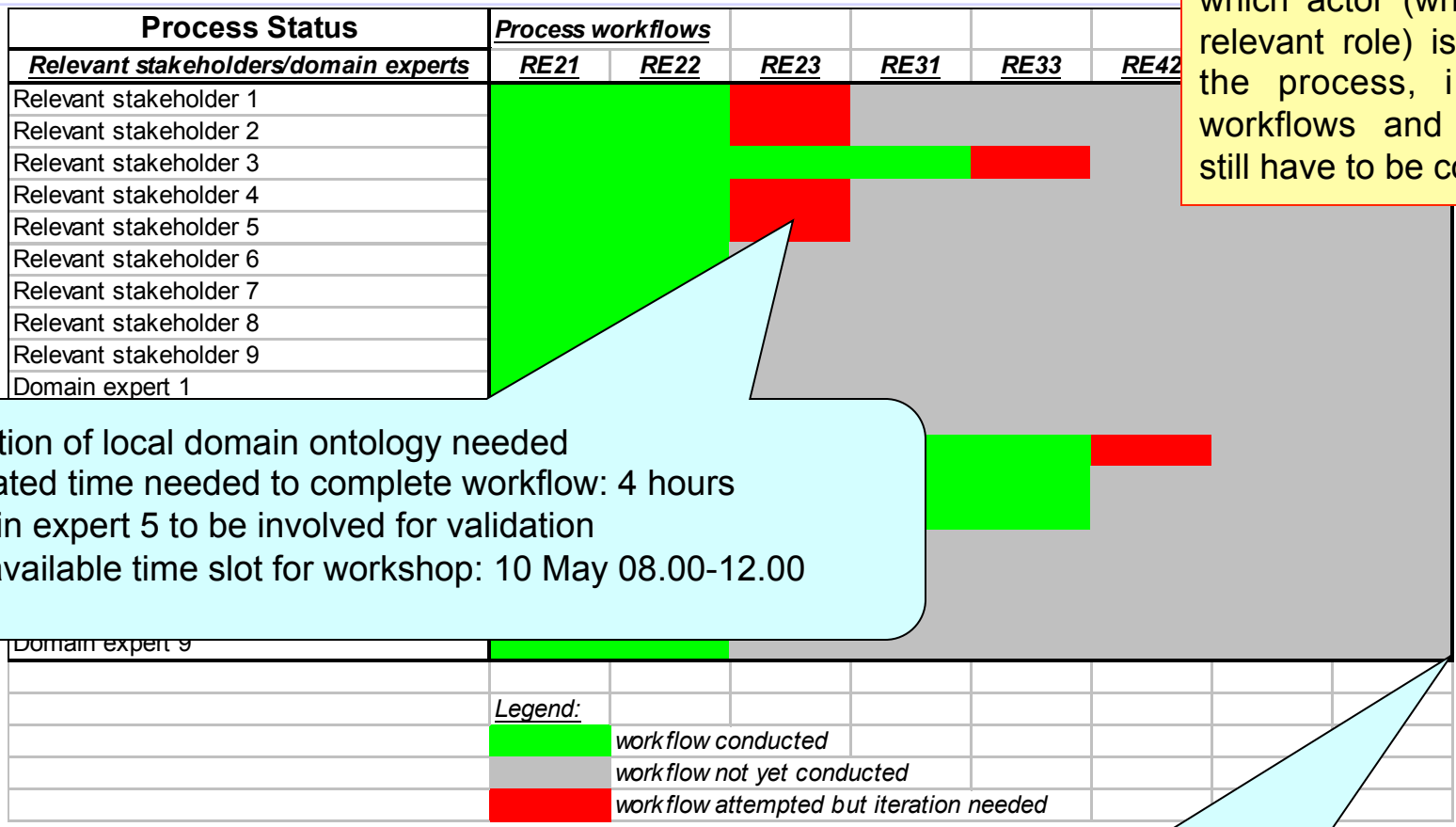
Stakeholder 3

Requirements Engineer

High flexibility to adapt the requirements process as conducted to the scarce availability of individual stakeholders or domain experts.

Role-driven process guidance

The OntoREM process status per identified roles will be analysed, giving users a clear picture of which actor (who plays a relevant role) is where in the process, i.e. which workflows and iterations still have to be conducted.

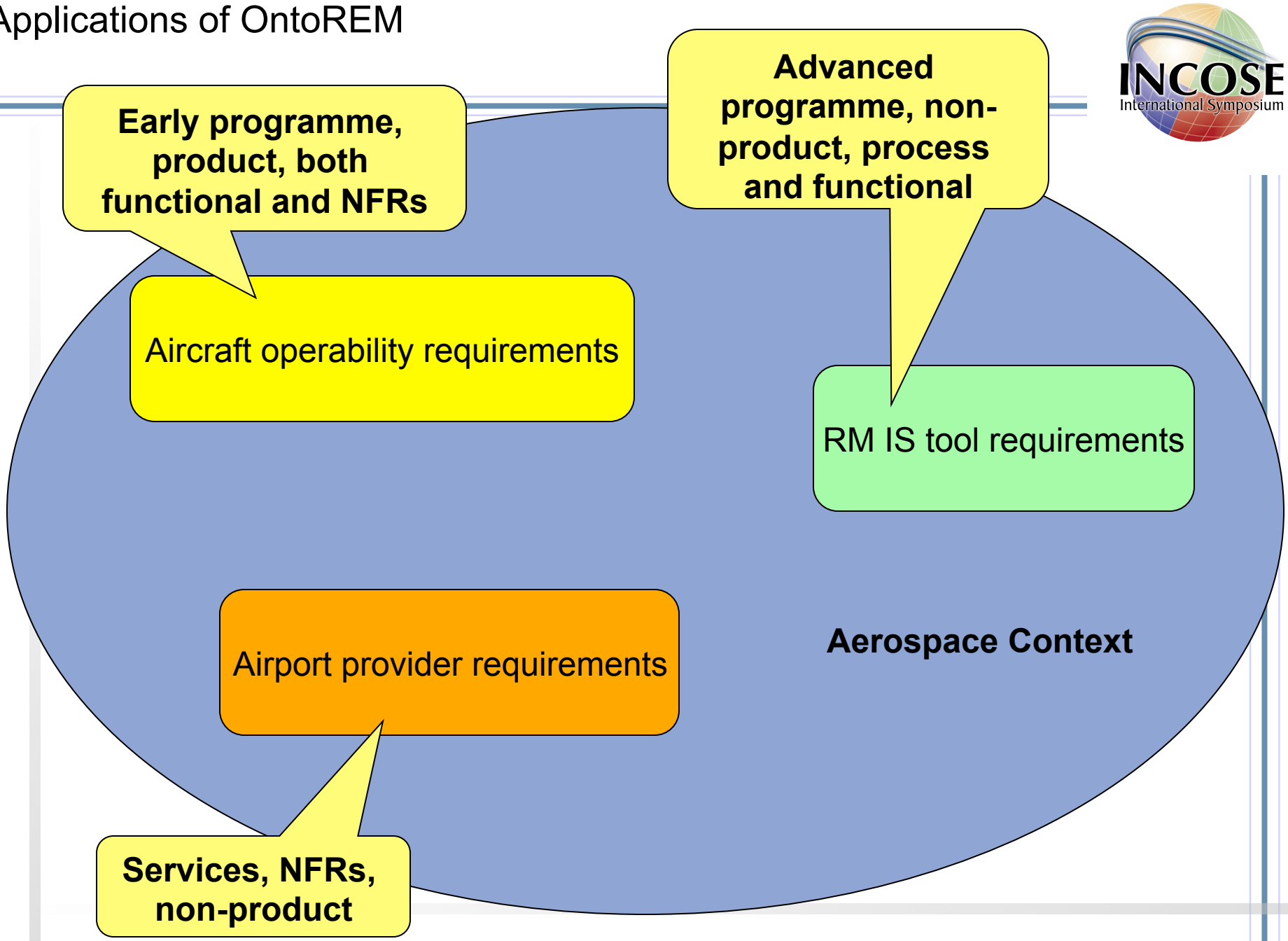


Validation of local domain ontology needed
Estimated time needed to complete workflow: 4 hours
Domain expert 5 to be involved for validation
Next available time slot for workshop: 10 May 08.00-12.00

Based on process status analysis, workflows to be conducted, gaps to be filled and roles to be involved can be identified, and the process will be guided (also allowing for time estimates for remaining workflows or iterations).

Estimated remaining time needed to complete all workflows: 185 hours
Time already spend: 105 hours
Expected total time needed: 290 hours

Applications of OntoREM



Aerospace context – some typical characteristics

- The actors in the RE process are potentially spread across many sites, cultures, countries, time zones and languages.

- There is a global, highly complex and multi-layered network of suppliers, risk sharing partners and sub-contractors.

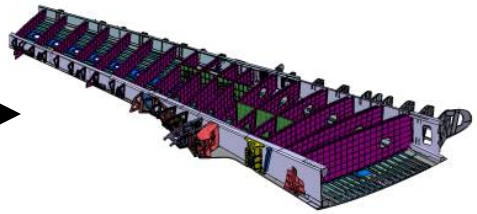
- The main development products are long-lead time, high-cost, highly complex products and have a very long life cycle.

- The products developed will be used all over the world within a highly complex system (aviation).

- Software engineering is crucial but within a systems context.

Context of the case study

Aircraft operability requirements for the wing design



Traditional RE process (RBE/DOORS): Contexts X and Y

Ontology-driven RE process (OntoREM): Context Z

Main assumptions:

1 Average quality measures $Q_{1\text{-}3}$ of the aircraft operability requirements for the wing design (AOW) of contexts X and Y to be compared with the equivalent quality measures of the newly developed AOW requirements (context Z).

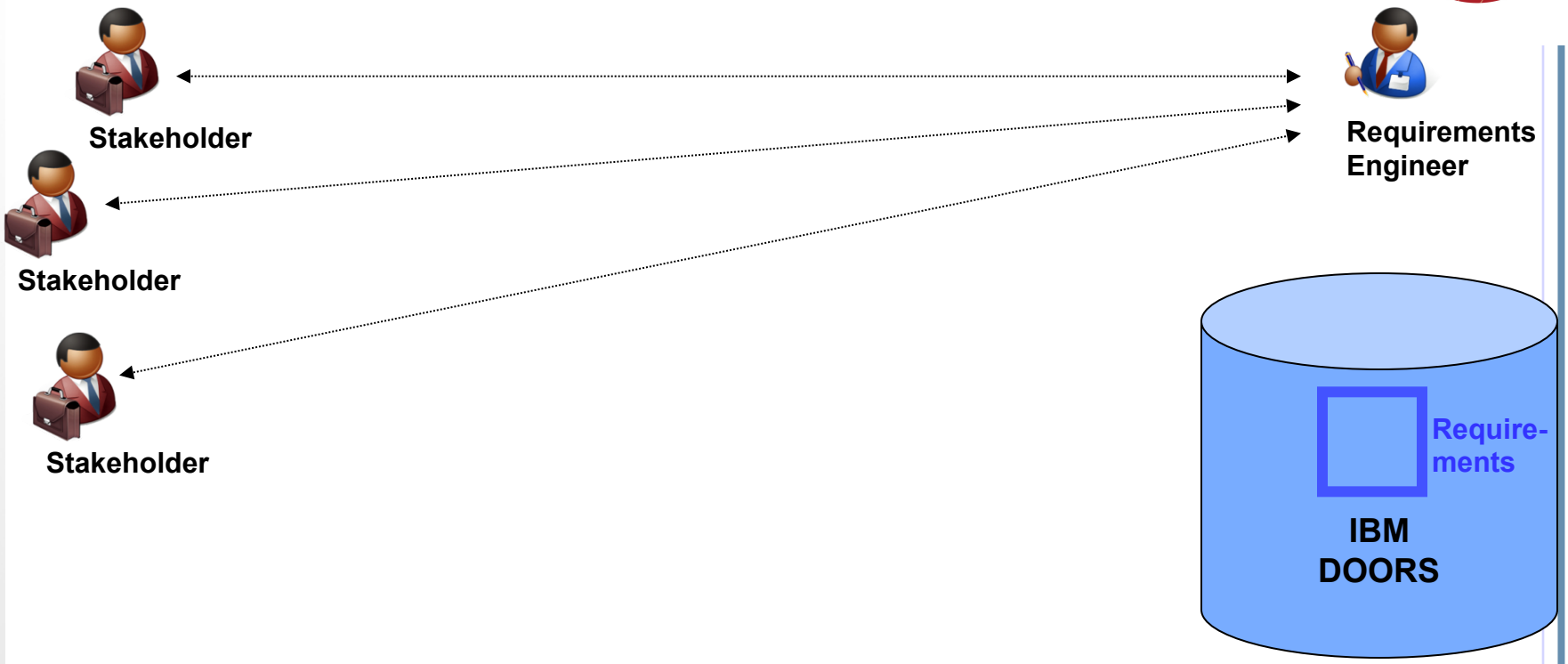
2 Dedicated Requirements Engineers were in place in all three cases that were comparable in terms of relevant knowledge and experience

3 The average process times per AOW requirement to be compared (as measured for OntoREM and estimated for RBE/DOORS)

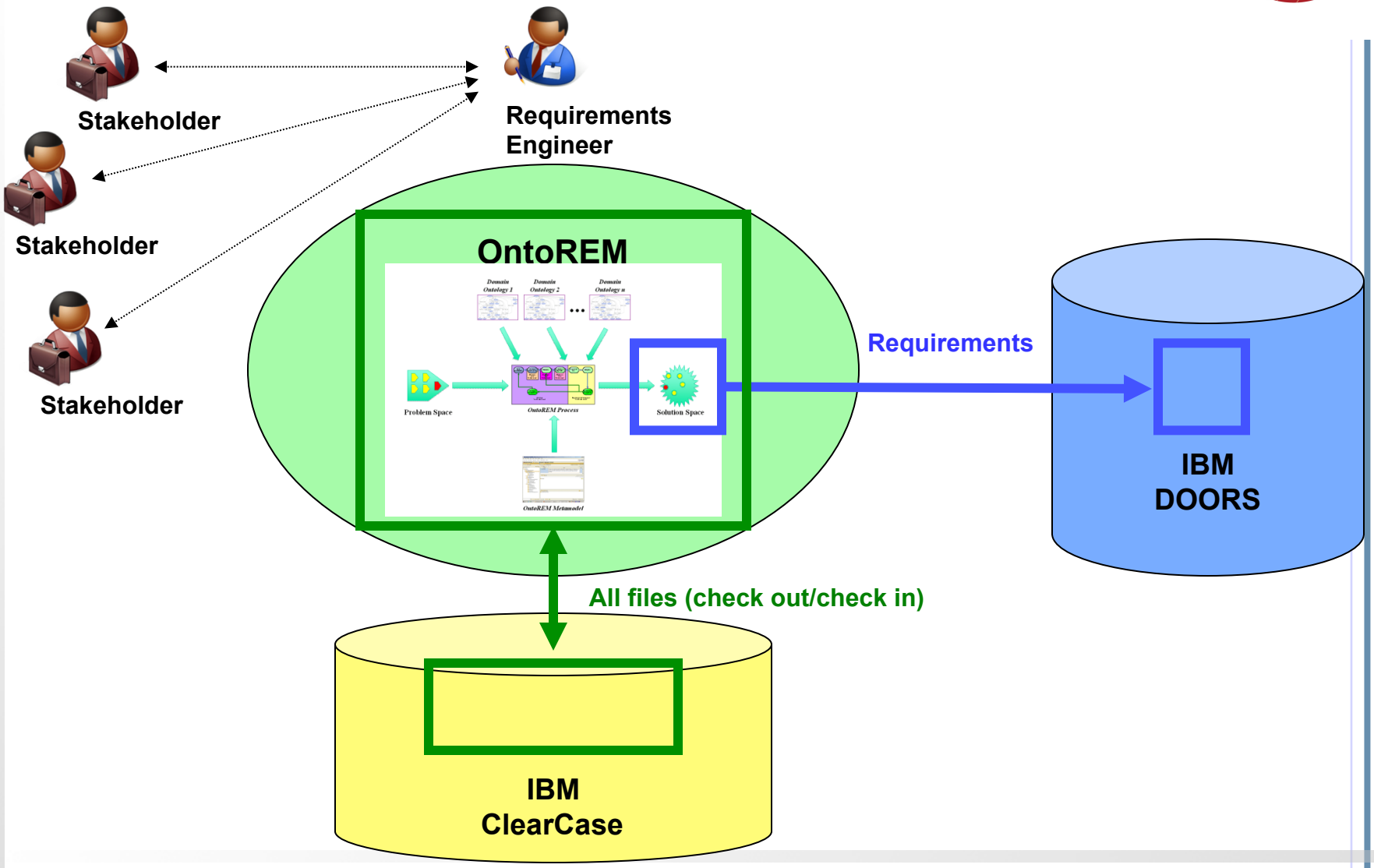
4 Cost in line with process time (directly proportional)

5 Relevant hourly rate [Euro/h]

‘As is’ situation (RBE/DOORS): Contexts X and Y



‘As is’ situation (OntoREM): Context Z



Evaluation framework (example criteria)

Q_1 => Measuring the completeness of individual requirement statements

Q_2 => Measuring the completeness of individual requirements in terms of recorded attribute and traceability information

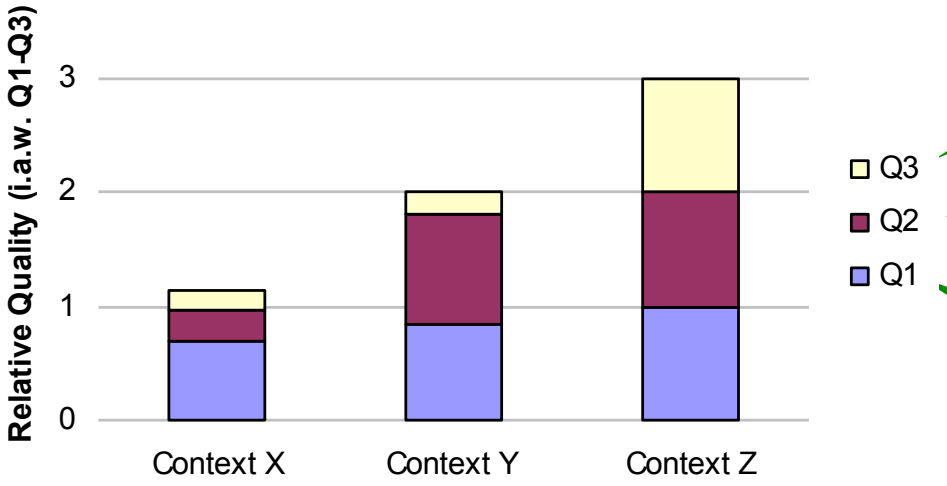
Q_3 => Measuring the degree of compliance of individual requirements with a harmonised structure of the requirement statements (important for the analysis and negotiation, and validation phases of the requirements process)

N_{AO} => Number of aircraft operability requirements

T_{AO} => Development time per requirement

C_{AO} => Development cost per requirement

Findings and analysis – quality



Structure of requirement statements: Not yet in the focus of contexts X and Y

Completeness of requirements (use of mandatory attributes and link information): Context X not yet, context Y much better

Completeness of requirements statements (Halligan): Context X fair, context Y even better

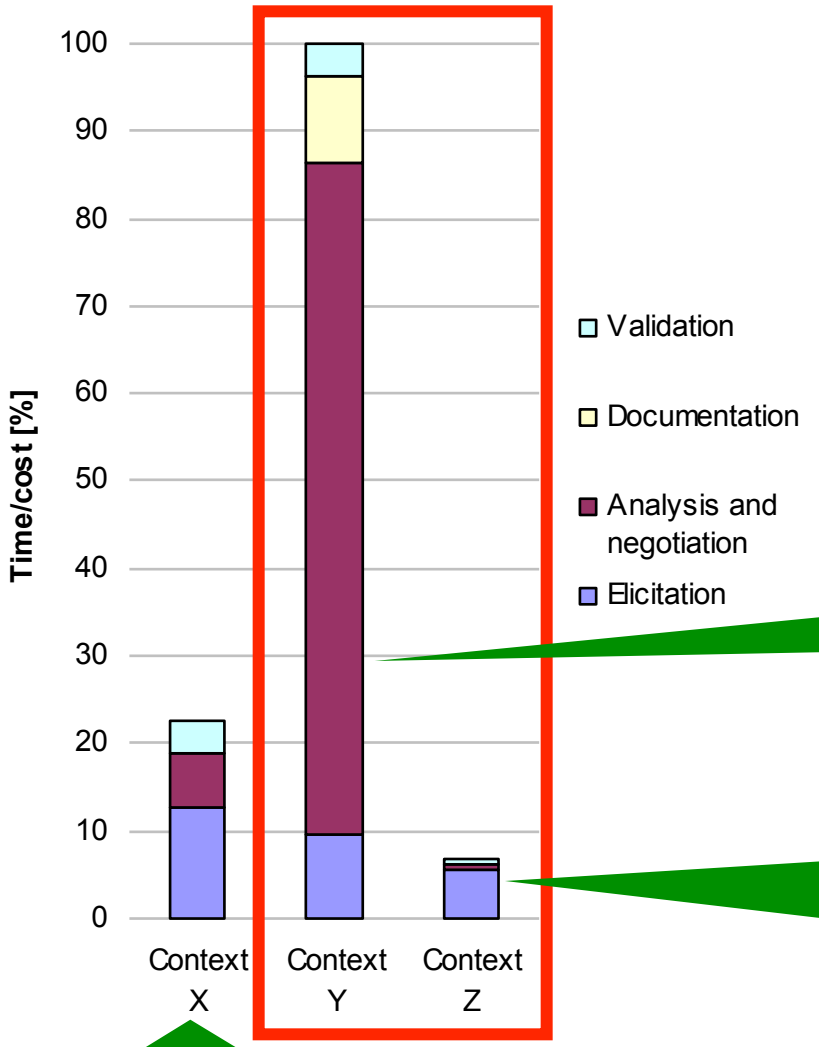
New requirements (OntoREM) 3 x 100% because:

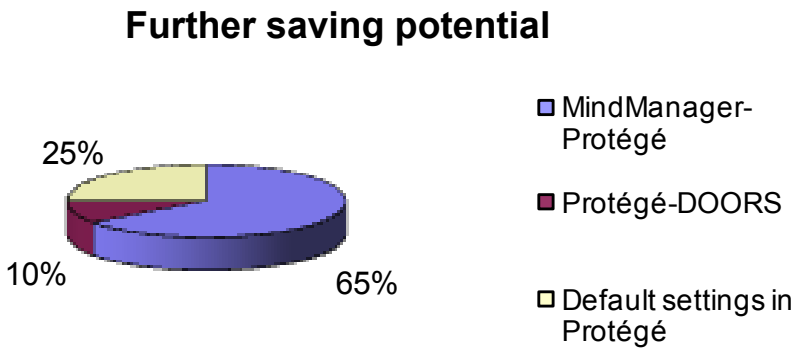
-Metamodel specifies the template (statement has to be complete) and mandatory attributes have to be populated/links established within the domain ontology

-Requirement statements are automatically compiled

Learning curve (from contexts X via Y to Z) with focus on the requirement statement itself first, via the increased use of associated information (attributes and links), to the structure of requirement statements in order to enhance requirements analysis and validation

Findings and analysis – time/cost



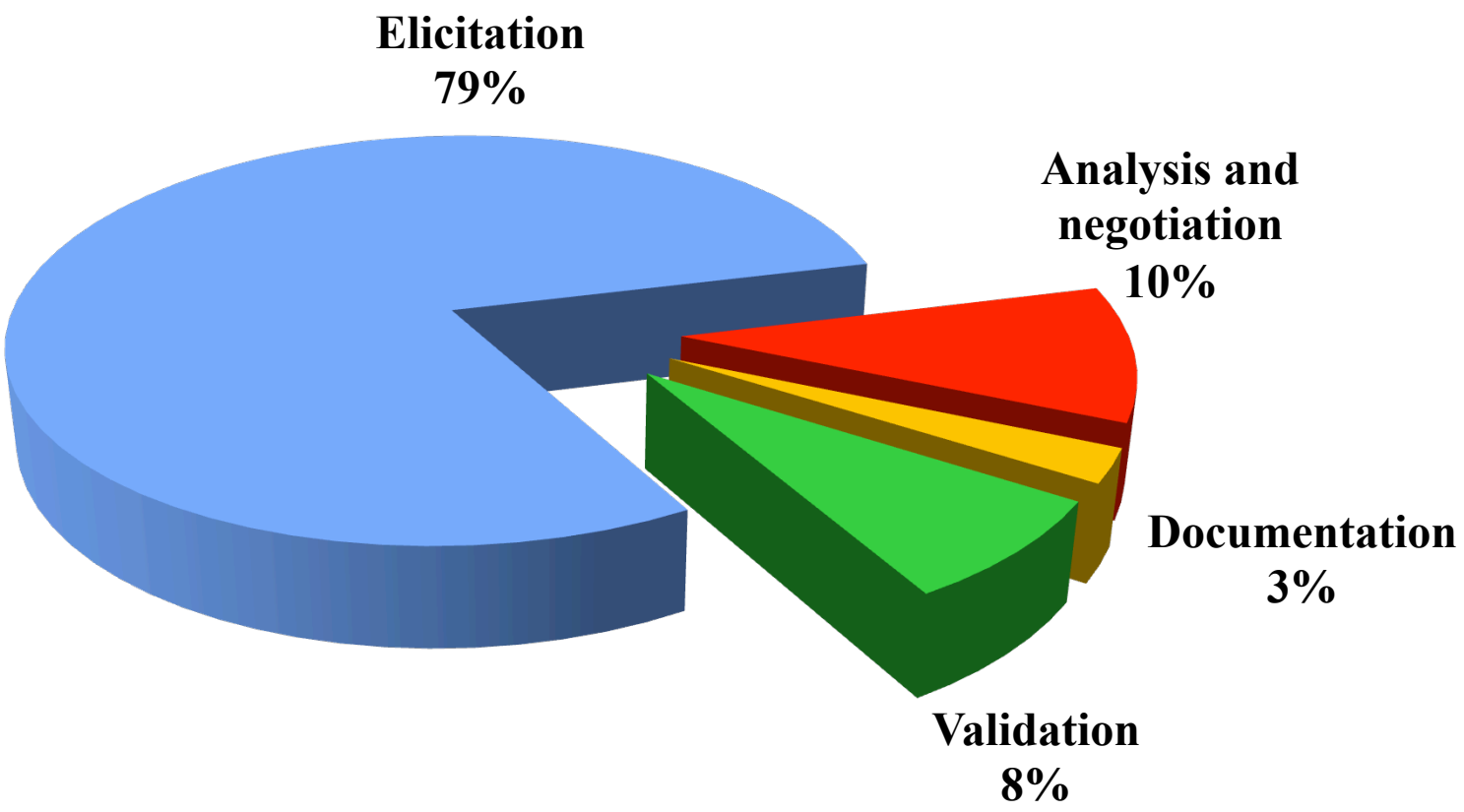


Focus on analysis and negotiation, more mature application of RBE/DOORS

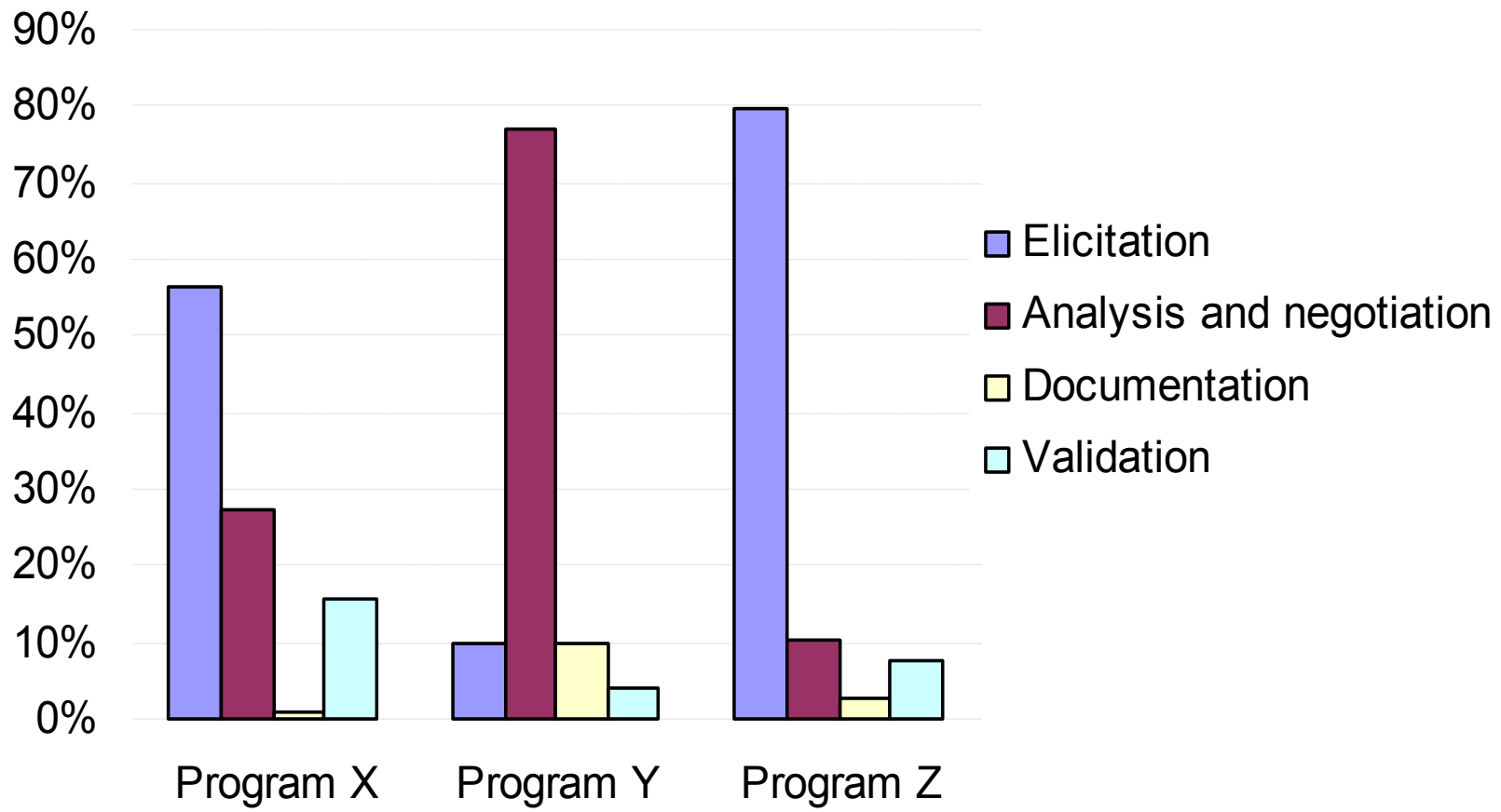
Focus on elicitation (creation of domain ontology), tool supported analysis at goal and requirement level, reduced involvement of domain experts and relevant stakeholder

High number of very detailed, contractual requirements

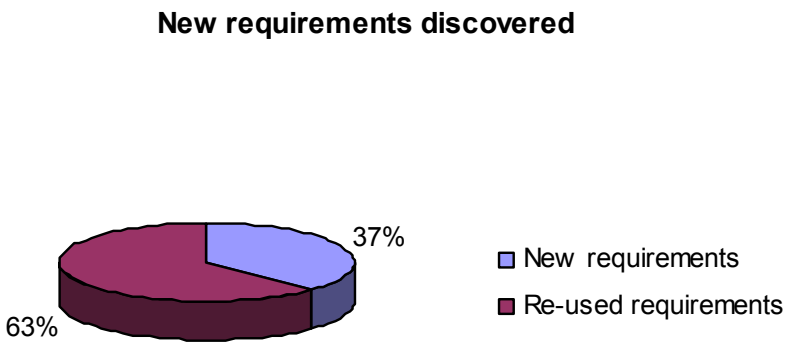
Findings and analysis – time/cost (context Z)



Findings and analysis – time/cost



Findings and analysis – additional advantages



HFIM design requirements (A/C level) were imported and linked into the developed domain ontology, and analysed (for non-applicability, conflicts, duplications)

+ Domain ontology (formal repository of validated domain knowledge)
+ Misunderstandings are reduced (harmonised domain terminology)
+ Re-use of knowledge (including generic domain requirements)
+ Newcomers/stakeholders can easily learn about the domain
+ Re-use requires little direct involvement of domain experts
+ Re-use less time-consuming (main focus: analysis and validation)
+ Feedback to programme management (for time and risk assessment)

Conclusion

✓Clear potential that ontology-driven RE leads to **better quality requirements** in **less time** at **less cost** with **further saving potential** through increased automation of OntoREM.

✓**Re-use of domain ontologies** including requirements in even less time (= at lower cost) in the future.

✓Explicit **domain knowledge capture and validation**.

✓OntoREM V5.0 is available (tested but limited **prototype**).

✓OntoREM ready for use but **not yet mature for industrial scale**:

- Partly new software or freeware
- Research IT infrastructure to be extended
- Transnational use to be tested
- Concurrent use at different development layers to be tested
- Missing aspects of requirements management and ontology management to be added

Thank you !!!