27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

Application to helicopter engine fuel system

Requirements engineering for radical innovation

Who are we?

Adrien MONSIMER
Ph D. Student

Jean-Charles MARE
Professor and
Researcher

Pierre SICAIRE
Fuel System Engineer

Ph. D. thesis carried out in France since 2015 on the
Design of radically innovative fuel system architectures

Outline

1 Context and specificites of the case studied

2 Problematics of RE for radical innovation

3 Process proposed

4 Return of experience

5 Conclusion and perspectives

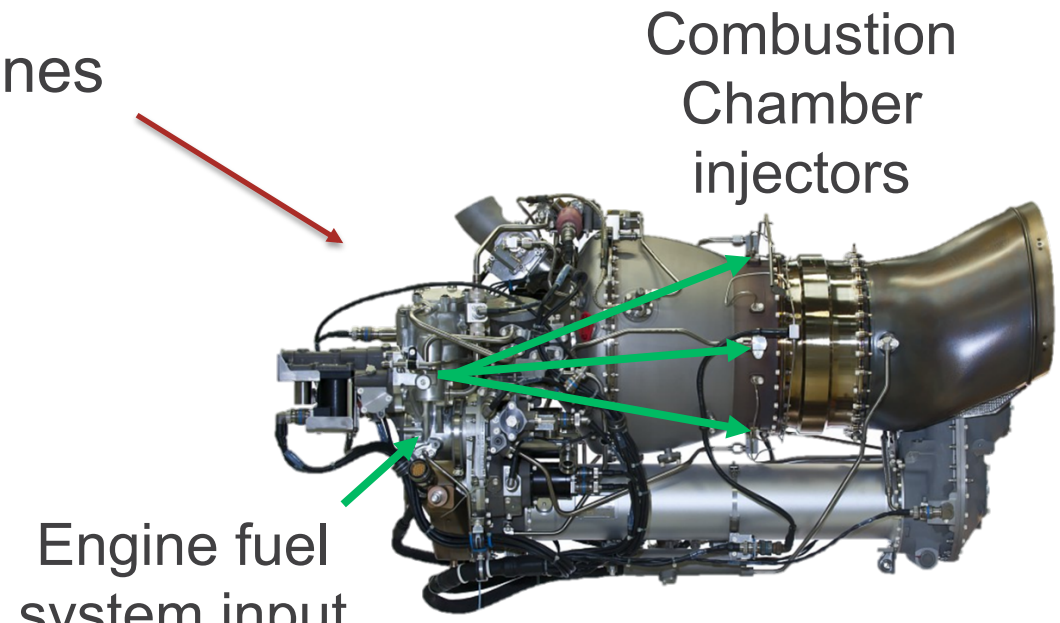
Context

Considered system: Helicopter engine's fuel system

Engines

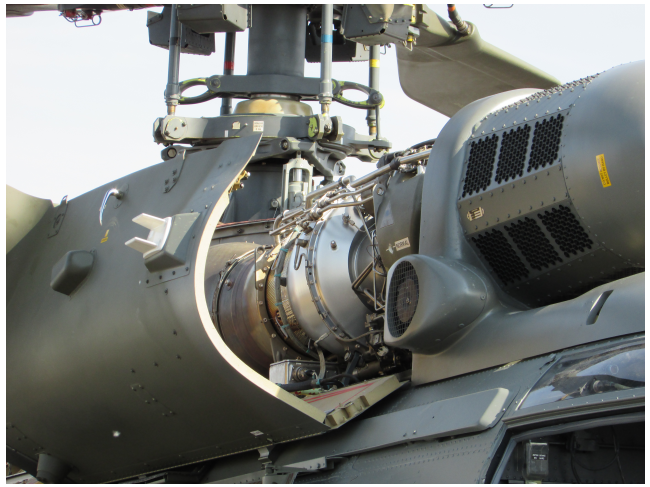
Context

Main Mission: Feed the engine combustion chamber injectors with fuel in good quantity at any time



Case specificities

Highly integrated



Source: http://gallery.airbushelicopters.com/

Lightweight

The studied system is…

1 Embedded

Case specificities

Source: http://gallery.airbushelicopters.com/

Hostile environment

Source: http://gallery.airbushelicopters.com/

Dense urban areas

Source: http://gallery.airbushelicopters.com/

The studied system is…

1. Embedded
2. Critical

Must be reliable and safe

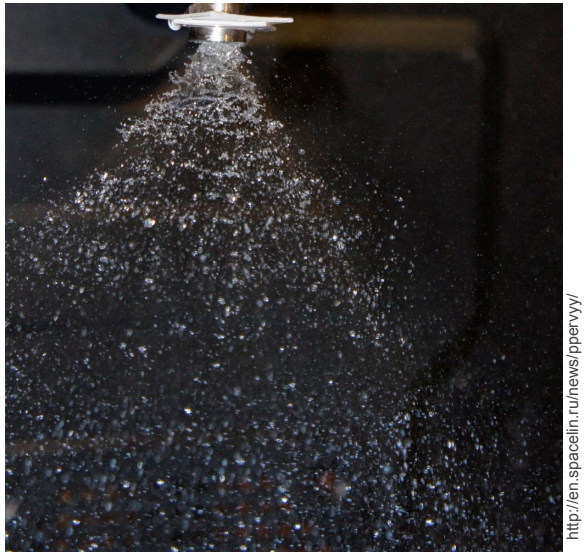
Case specificities

Transfer the fuel from tanks to the engines combustion chamber

https://www.flickr.com/photos/neuwieser/

Fluid Power System

Pressurise fuel for better pulverisation



http://en.spacelin.ru/news/ppervyy/

The studied system is…

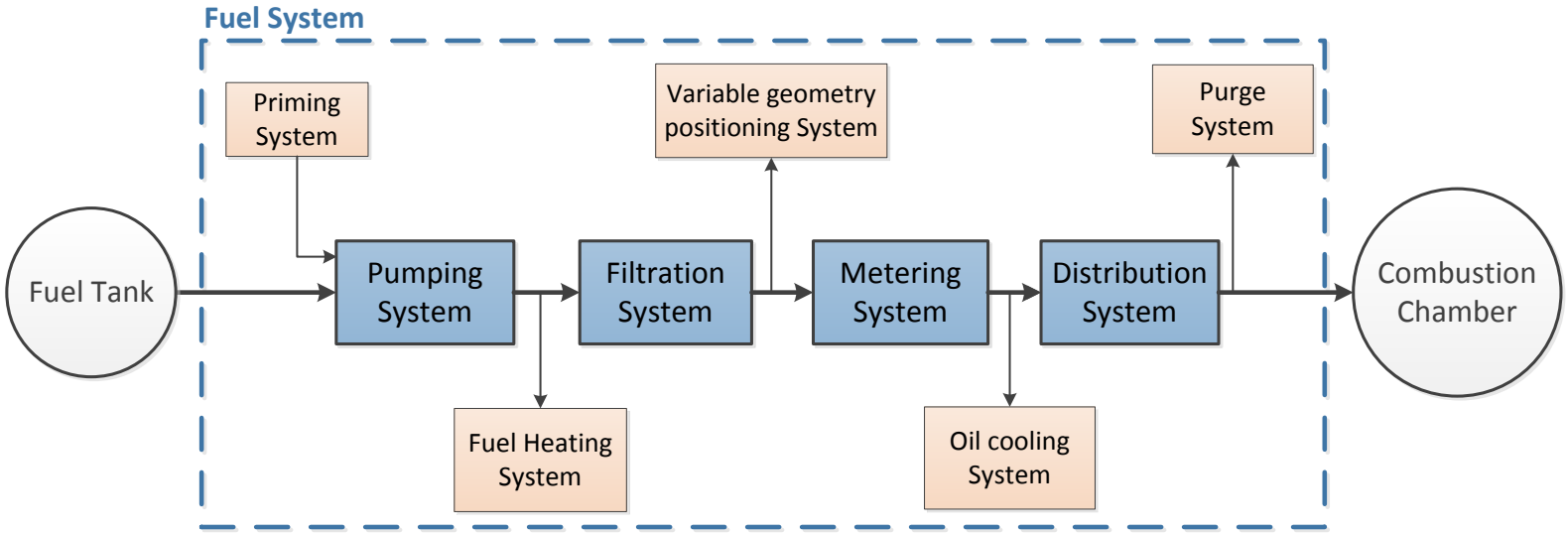
1. Embedded
2. Critical
3. Power Transforming

Current Situation

Similar helicopter engine fuel system architecture at:

- Safran Helicopter Engines
- Competitors

→ Obtained from Baseline Architecture after 50 years of continuous improvement



Incremental innovation of a given system architecture

Problematics

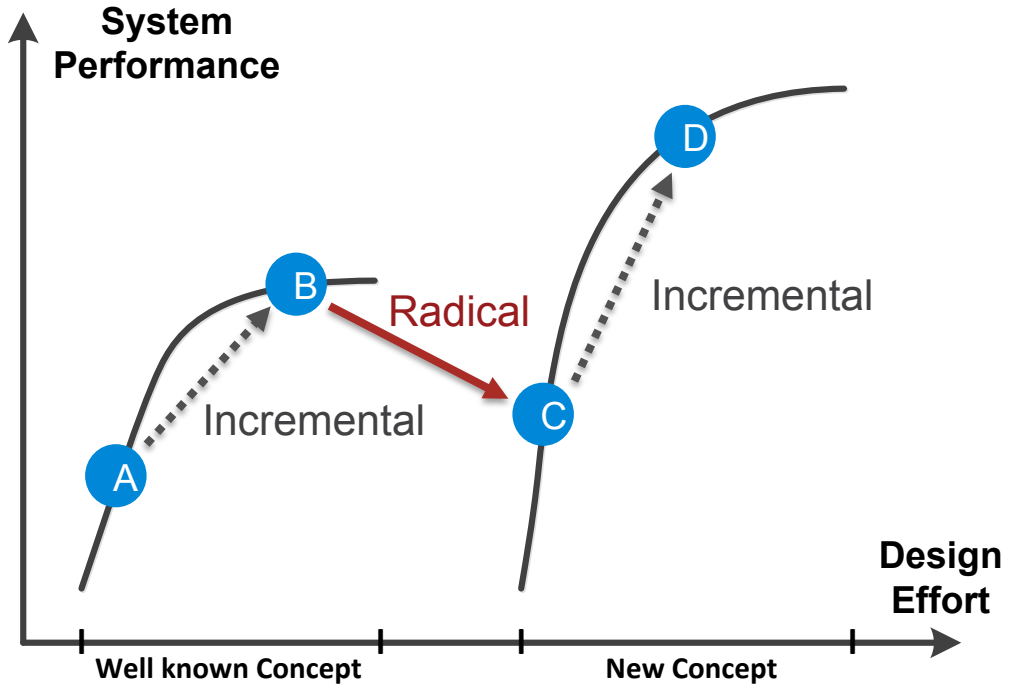
Radical innovation means betting on the future

Until today, incremental innovation has been efficient.

Radical innovation needs to be investigated in order to overcome incremental limitations.

- A 50 years ago
- B Today

- \+ Short/Medium term benefits
- \+ Low risks on development
- \- Decreasing ability to improve



- C Radically new architecture [Unmature]
- D Radically new architecture [Mature]

- \+ High potential of improvement
- \- High development risks
- \- Low short/medium term benefits

Problematics

Radical innovation means betting on the future - The Airbus Fly by Wire example

Radical innovation implies taking risks

Technology may not be mature when introduced by radical innovation

A 320 *(1988)*

Maturation

19 years

A 380 *(2007)*

Source: http://www.aircharterservice.com/aircraft-guide/group/airbus-europe/airbusa380

Radically new architecture introduction

Normal mode: Electrical (6 channels)

Backup mode: Mechanical (2 channels)

Radically new architecture is mature

No mechanical mode

Pilots training

Maintenance

Flights safety

Problematics

How is RE related to radical innovation ?

Our studied system is mature and optimized (50 years of incremental innovation)
→ Starting with the same specification will lead to the current best concept

Conventional Vehicle

http://o.aolcdn.com/commerce/autodata/images/CAB00TOC021A0101.jpg

\+

New requirements

Fuel price $

=

Hybrid Vehicle

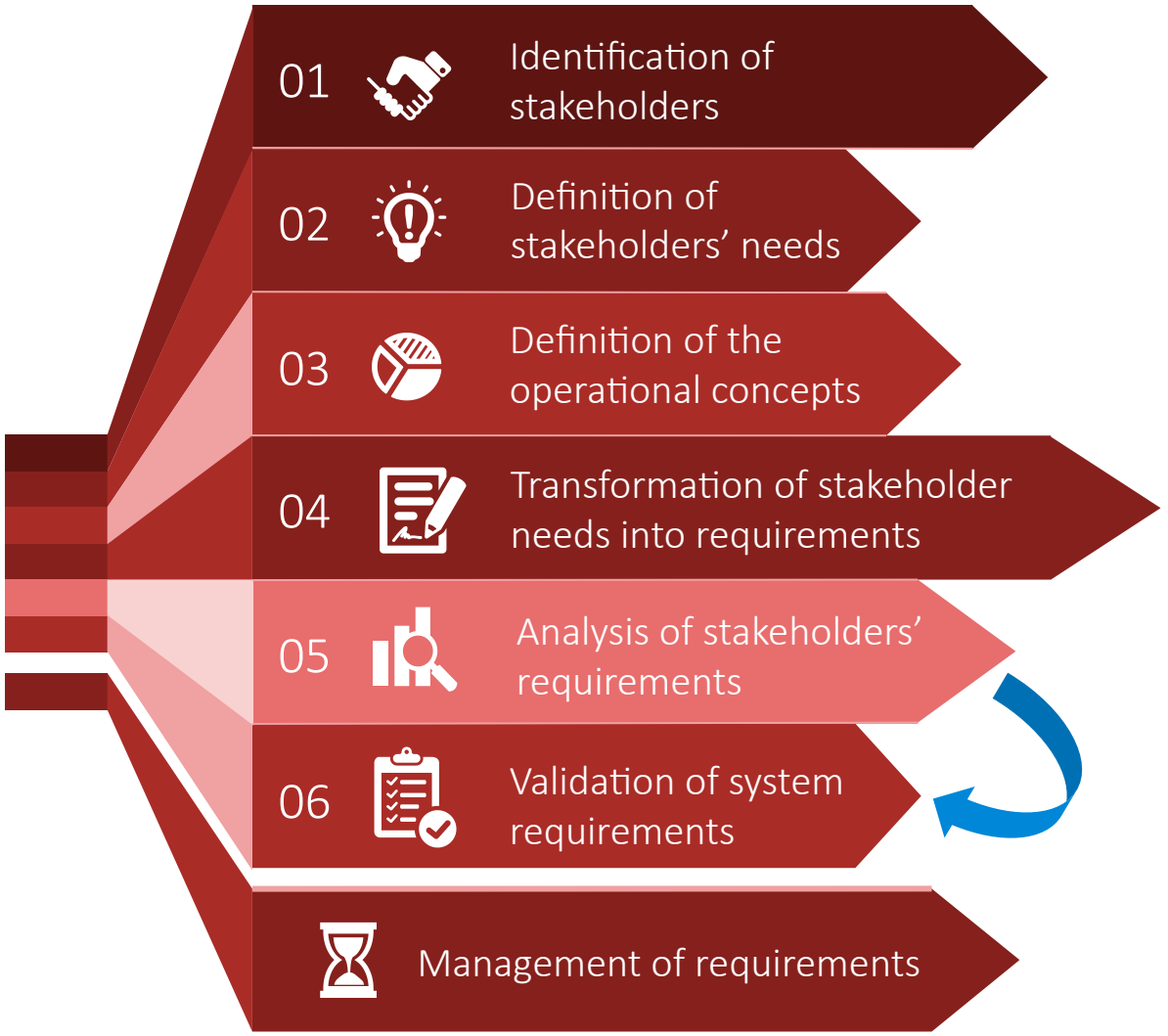
http://www.toyota-global.com/innovation/environmental_technology/hybrid/

It is crucial to anticipate new needs to trigger radical innovation

RE process for Radical Innovation

Proposed RE process

Based on INCOSE 2015



Jump from Stakeholder Requirements to System Requirements

Process construction

01 Identification of stakeholders

System requirements = Σ Stakeholders requirements

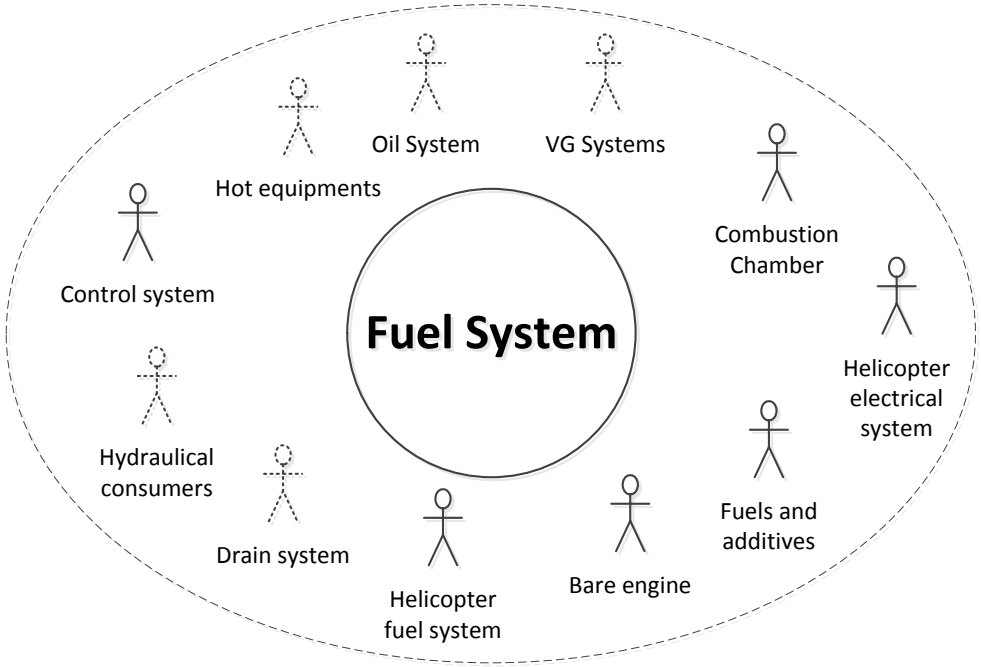
INCOSE 2015

Owner builder
Stakeholders requirements

General contractor
System requirements

Strong customer supplier relashionship

Safran Helicopter Engines

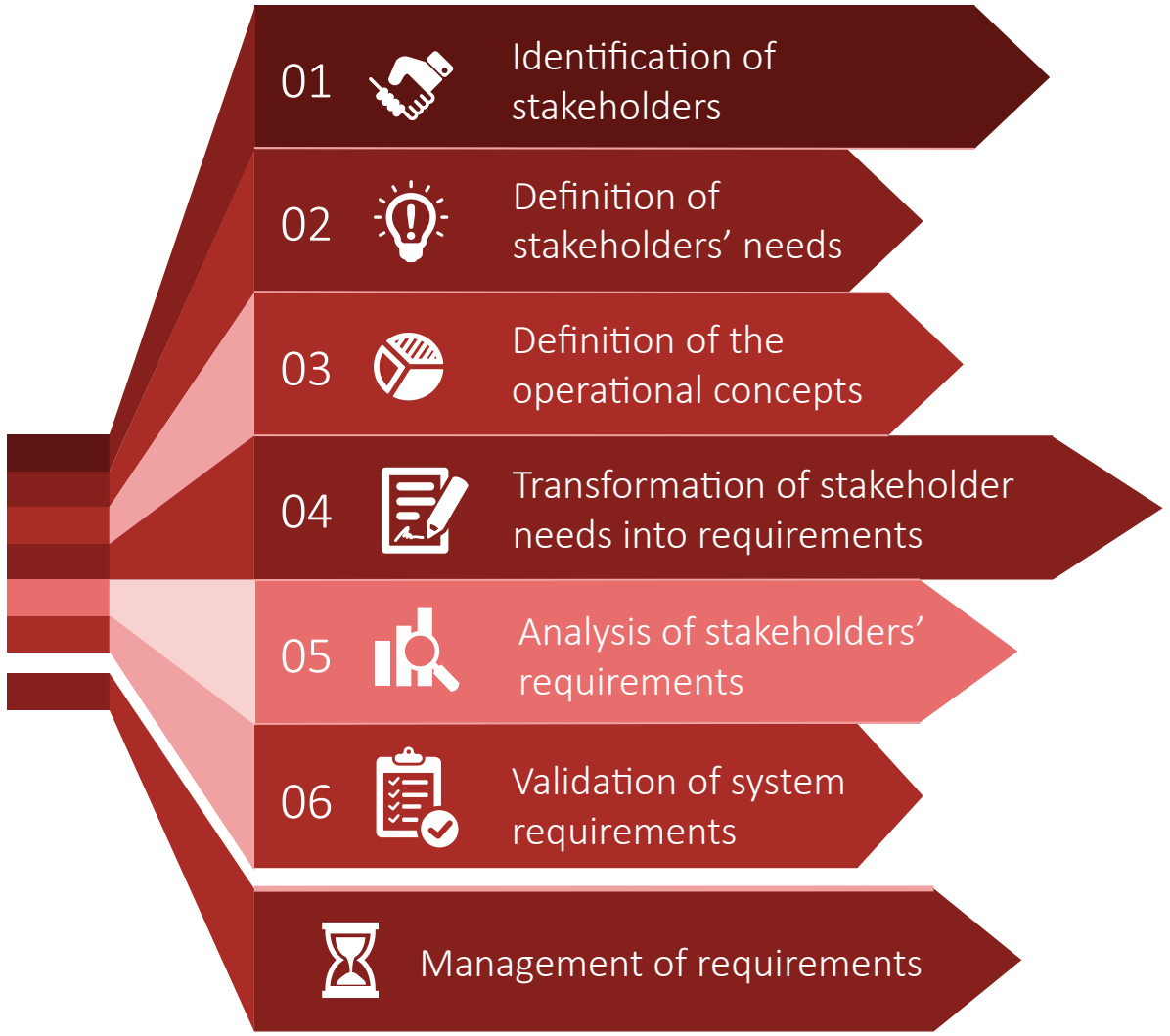


Stakeholders from the same company with the same culture and vocabulary

RE process for Radical Innovation

Proposed RE process

Based on INCOSE 2015



We choose to focus on these

Mostly unchanged compared to usual RE practices

Return of experience

02 Definition of stakeholders' needs

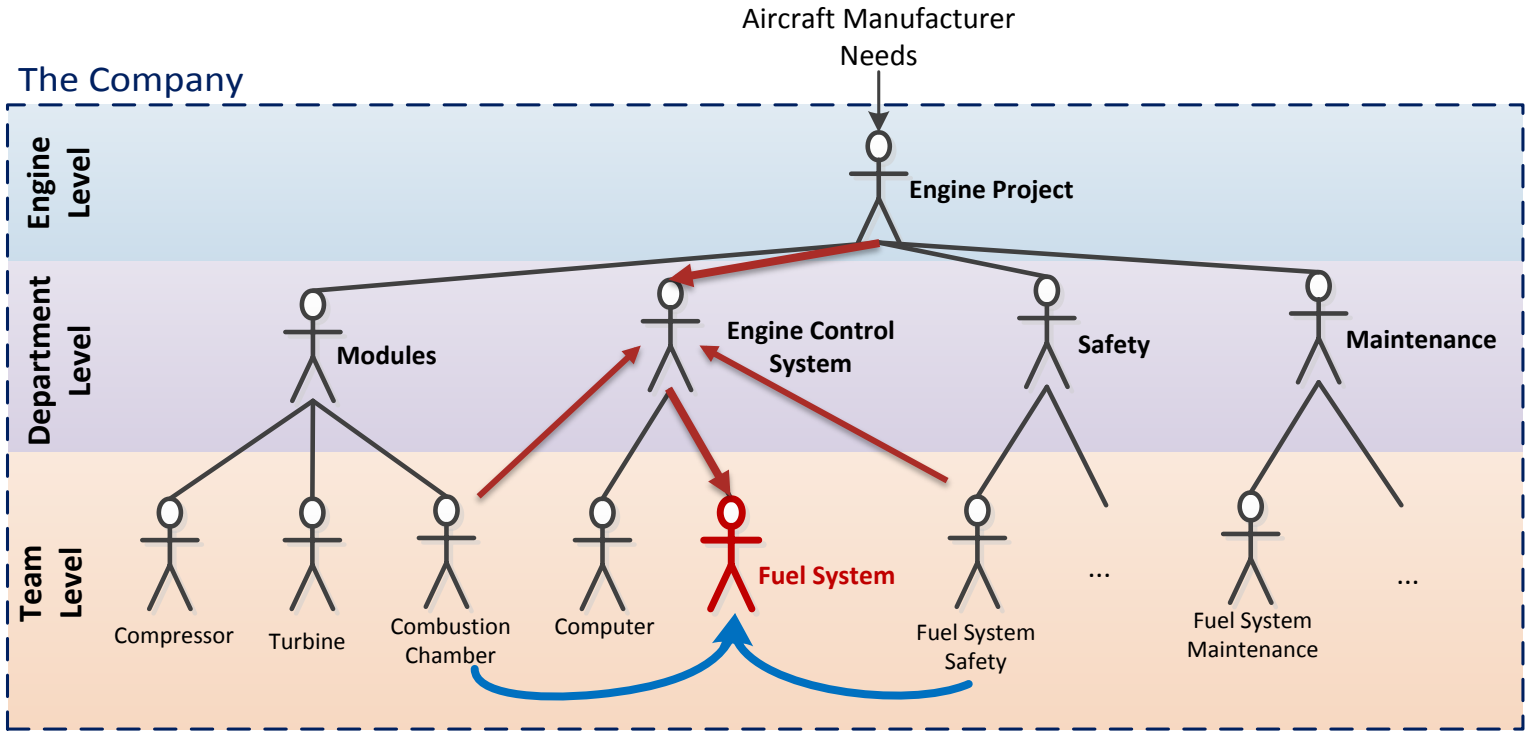
1- Hierarchical organization of the company

2- Cognitive effects

Return of experience

02 Definition of stakeholders' needs

1- Hierarchical organization of the company



In industrial engine projects, top-down declension of needs

\+ Formal and well structured

\- Risk of low communication

In radical innovation projects, transversal declension of needs

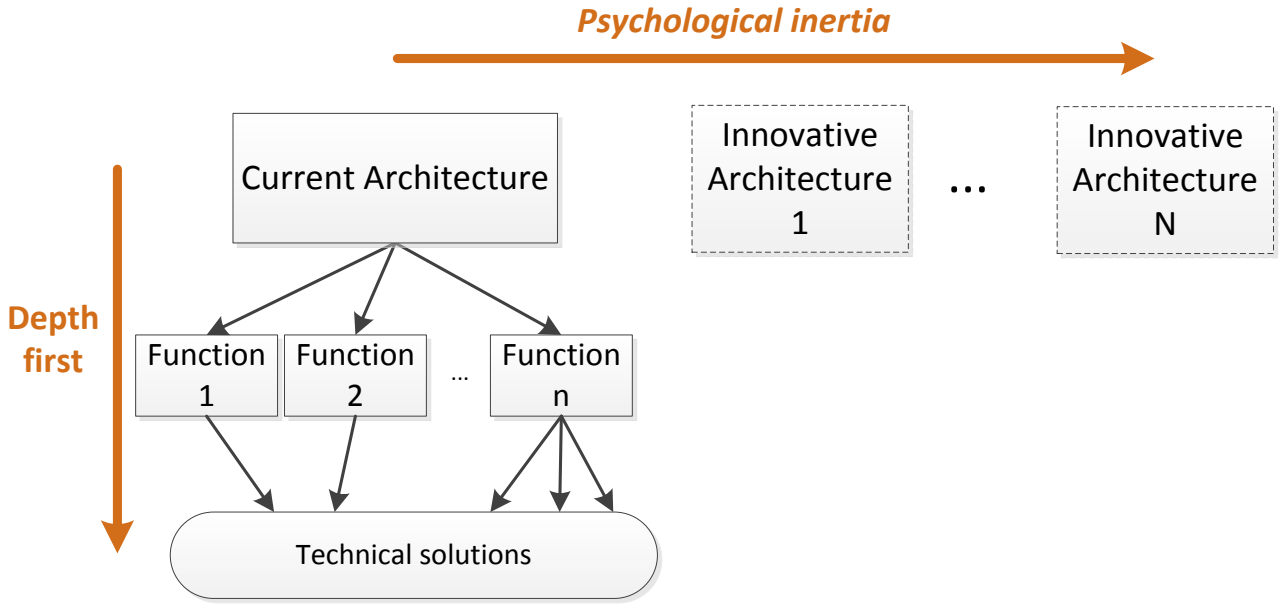
\+ Enable expert to exchange directly on future needs

Need for transversal workshops with team experts

Return of experience

02 Definition of stakeholders' needs

2 – Cognitive Effects



Psychological inertia
→ Difficulty to think different

Depth first
→ Temptation to go into details

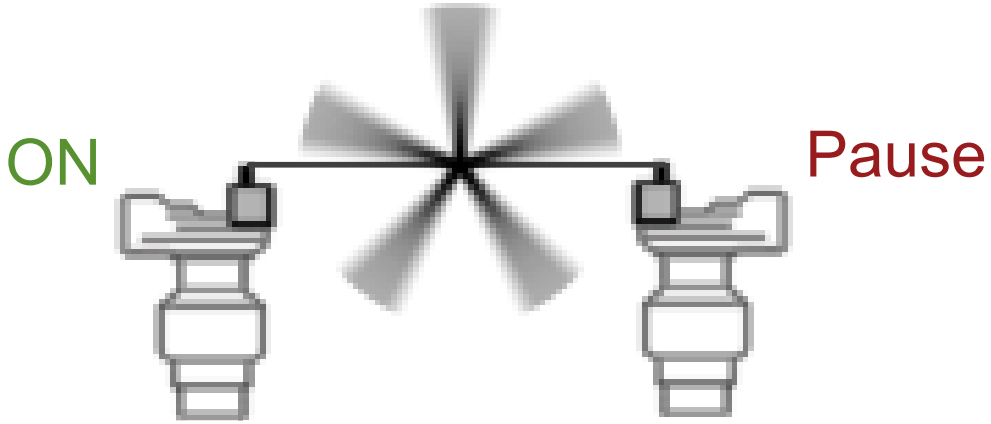
→ Have it in mind when animating workshops with experts

Return of experience

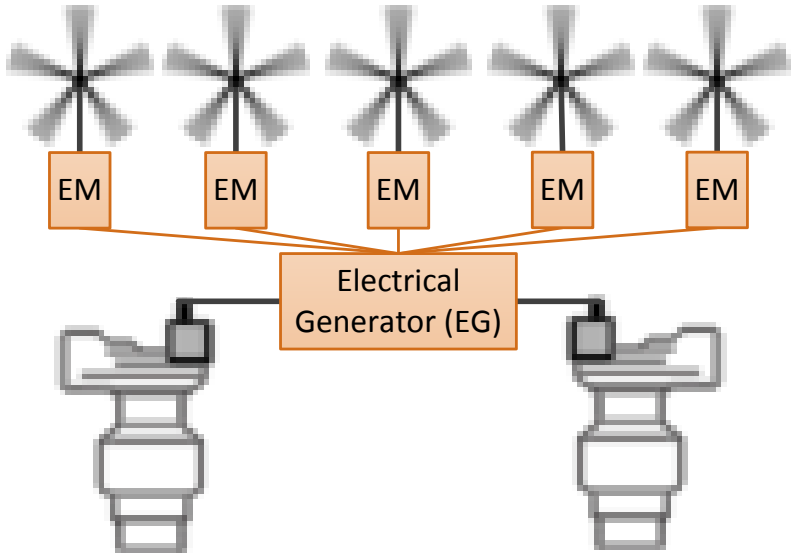
03 Definition of the operational concepts

Focus on new operational concepts

- **Eco mode** : pause one of the engines in cruise



- Engines used to **produce electrical power** to feed electrical motors



➡ Confidentiality can hamper transversal information sharing in the company

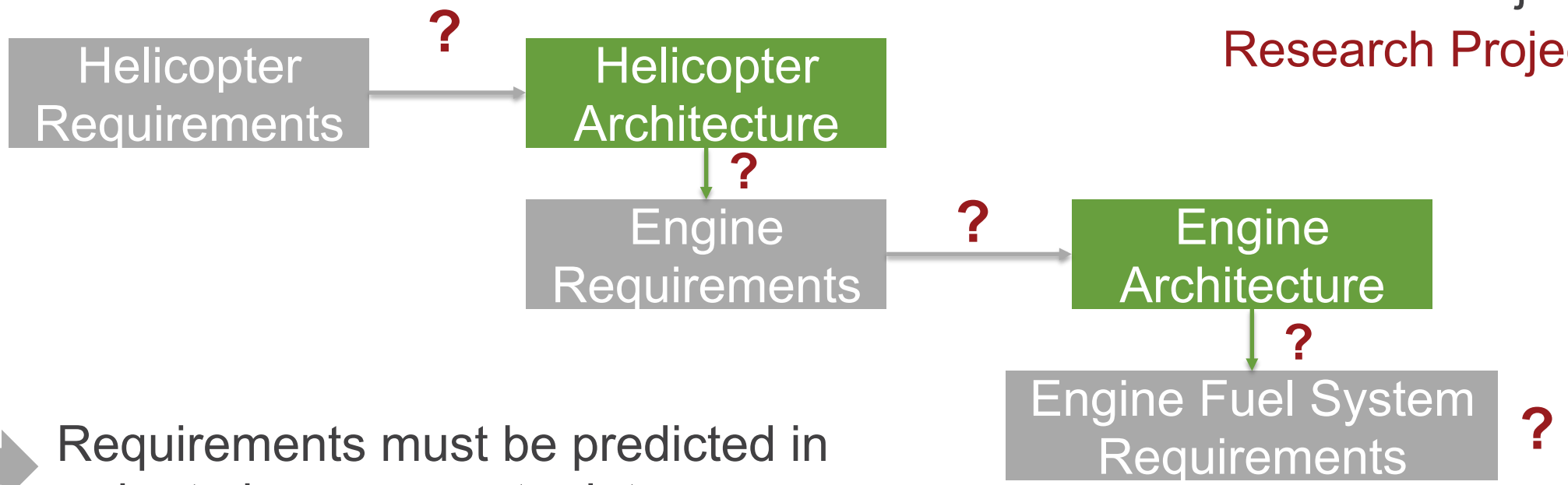
Return of experience

04 Transformation of stakeholder needs into requirements

Main difficulty: lack of confirmed informations

Industrial Project

Research Project



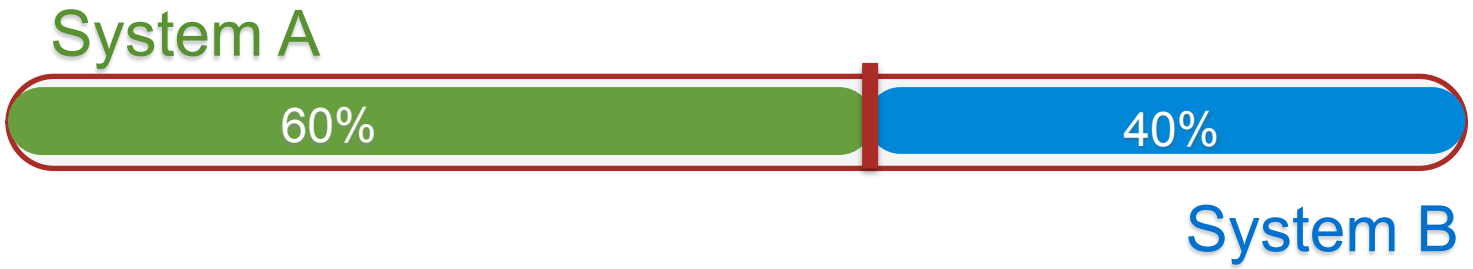
Requirements must be predicted in order to have concrete data

Return of experience

04 Transformation of stakeholder needs into requirements

Interfaces need particular interest

Interface: A system that belongs to several systems



Return of experience

04 Transformation of stakeholder needs into requirements

Interfaces need particular interest

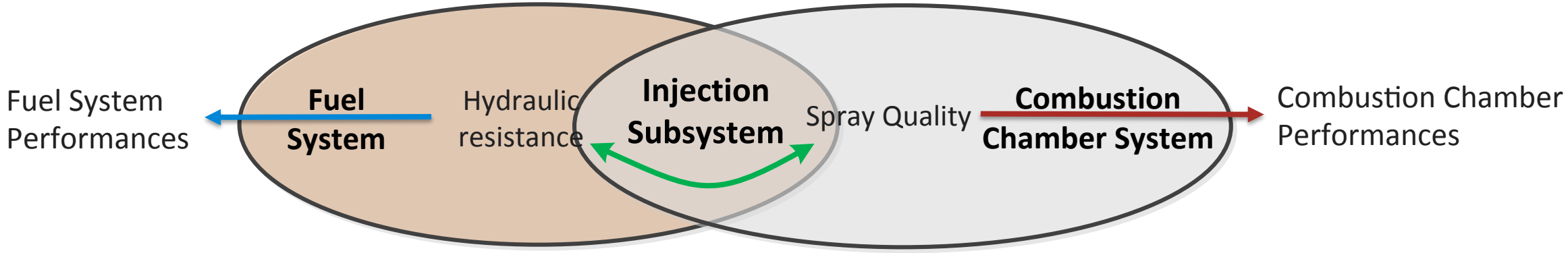
Interface: A system that belongs to several systems

➡ Change in the interface → Both systems are changed

Return of experience

04 Transformation of stakeholder needs into requirements

The example of the injection subsystem



- Interface specification is always a compromise between teams
- Higher-level trade-off studies must be made to come to the best compromise

Opportunity for radical innovation

Conclusion

RE is decisive when performing radical innovation

Radical innovation relies on new needs anticipation

Transversal needs elicitation is mandatory

Confidentiality shall be managed effectively within the company

Cognitive effects shall be considered when animating technical workshops

Interfaces shall be subjected to higher level trade-off studies

Perspectives

Radical innovation relies on new needs anticipation

Transversal needs elicitation is mandatory

Confidentiality shall be managed effectively within the company

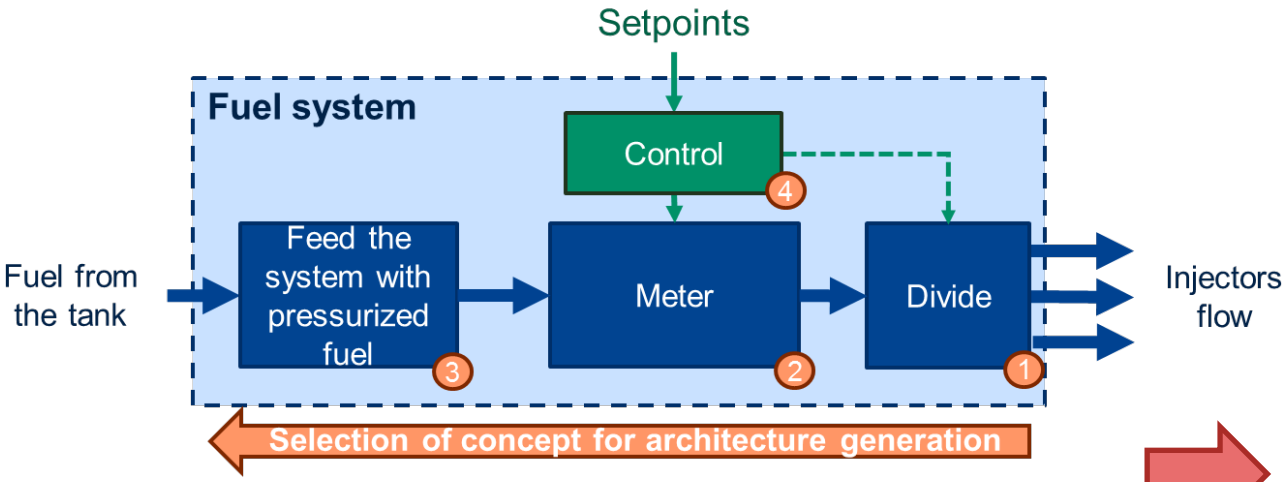
Cognitive effects shall be considered when animating technical workshops

Interfaces shall be subjected to higher level trade-off studies

Perspectives

Requirements Engineering → **Architecture Generation** → Architecture Evaluation

A) Generic functional decomposition



B) Systematic concept generation taking into account incompatibilities

Fonctions	Solutions			
	#1	#2	#3	#4
Feed pressuzized fuel				
Dose				
Divide				
Control				

C) Automated architecture assembly

→ Generate a wide panel of architectures

Perspectives

Requirements Engineering → Architecture Generation → **Architecture Evaluation**

Challenges

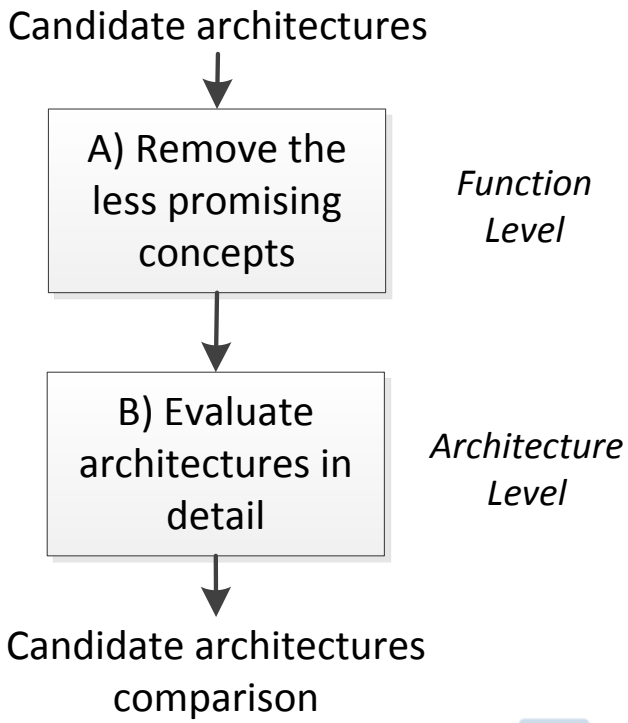
- **Deal with a large number and variety of architectures**
- **Keep all the promising architectures**

A) High level evaluation – Function level

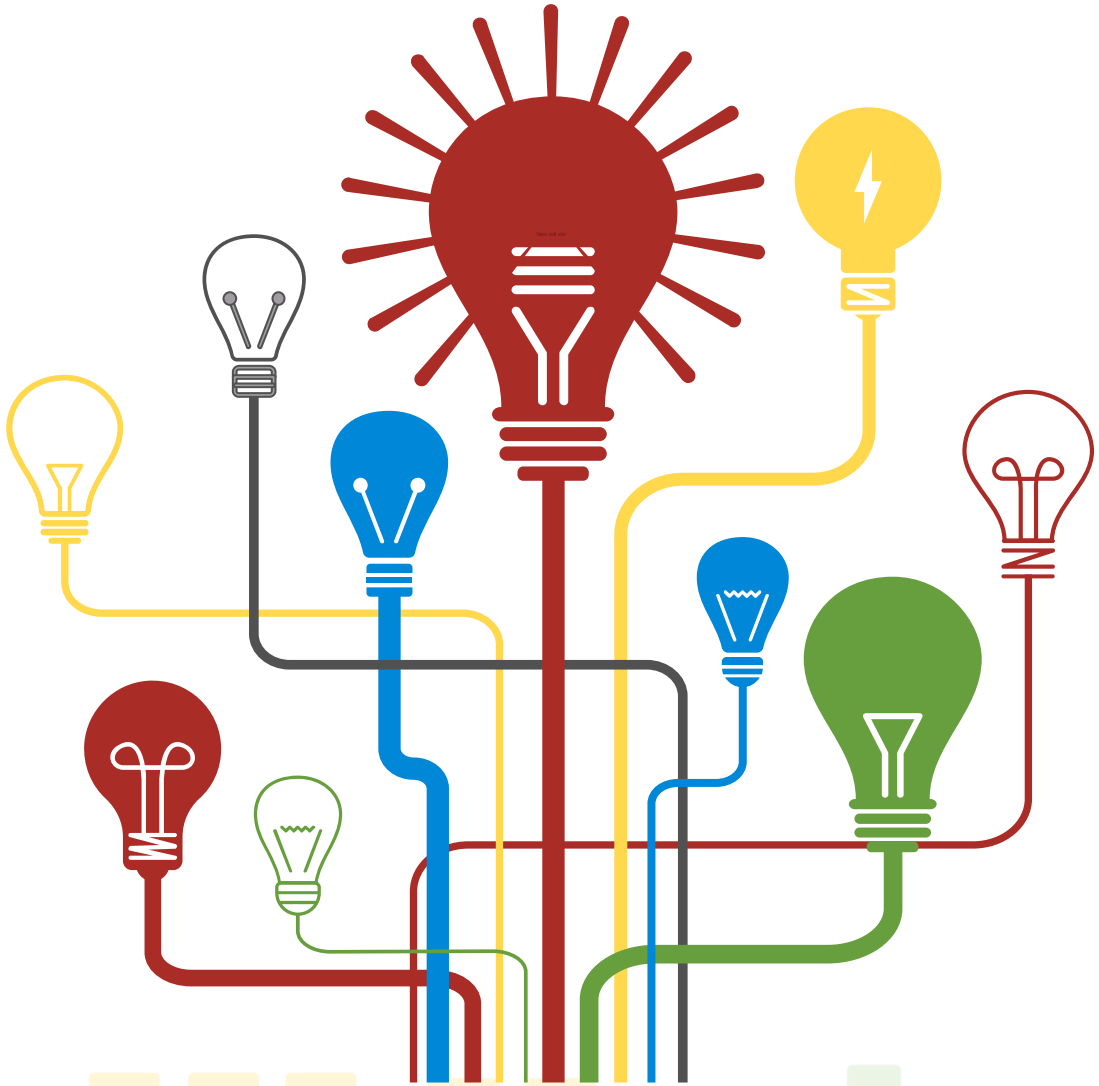
Risks and opportunities assessment for each concept regarding to key requirements

B) Detailed evaluation – Architecture level

Architecture sizing and evaluation regarding to all the requirements



Questions ?



27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

www.incose.org/symp2017