DAY 1

THALES
Building a future we can all trust

Advanced Model-Based Systems Engineering

Model-based Architecting to cope with growing complexity

www.thalesgroup.com

Introduction & Way of Working

Trainer: Juan Navas

> Academy

- Electronics & Electrical Engineer
- MsC Computer Science and Automation – MINES ParisTech
- PhD in Software Engineering for Embedded Systems – UBO

> Industry

- 20 years experience in Engineering: Finance, Oil & Gaz, Communications, Nuclear, Defense
- In charge of MBSE evaluation and deployment program in Nuclear Engineering (2014 – 2016)
- Leader of Thales MBSE Corporate Expertise and Coaching Team (2019 – 2023)
- Systems of Systems Architect at the Protection Systems Business Line in Thales SIX

https://www.linkedin.com/in/junavas

At the end of this course you should be able to

- Identify the distinguishing characteristics of complex systems engineering and use the proper tools to address this complexity
- Demonstrate the characteristics of Systems of Systems (SoS) types of systems and apply SoS-specific engineering techniques
- Comprehend the Product Line Engineering (PLE) approach, identify the situations where this approach delivers the most value, and apply the PLE techniques
- Apply Model-Based Systems Engineering approaches in complex systems engineering contexts, adopt new Arcadia concepts and apply advanced features of the MBSE Capella tool

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Syllabus

SoS focus

PLE focus

> DAY 1 (3h30)

- Course introduction and way of working (20')
- What is complexity? (30')
- Understanding the Problem space - Context analyses (30')
- Stakeholders, value and benefits (30')
- Capella (20'): Operational Scenarios, OEB, HTML (20')
- Case Study – Exercise 1(1h20)

> DAY 2 (3h30)

- Restitution of Case Study – Exercise 1, Key Critical Topics (1h)
- System Boundaries, Systems of Systems (30')
- Case Study: Initial state (15')
- Capabilities, MOE/MOP, Mission Threads, Capability Roadmaps (30')
- Capella (15'): Context diagram, Capabilities (15')
- Case Study – Exercise 2 (1h)

> DAY 3 (3h30)

- Restitution of Case Study – Exercise 2 (1h)
- Case Study: Concept (15')
- Architecture Views and SoS Boundaries (20')
- Functional Chains (15')
- Emerging constraints and -ities (20')
- Architecture evaluation and alternatives (20')
- Case Study - Exercise 3 (1h15)

> DAY 4 (3h30)

- Restitution of Case Study – Exercise 3 (1h)
- Architecture Evaluation Brainstorming (15')
- Product Line Engineering and Feature Models (25')
- Variability analysis at Product Capability level (35')
- Capella Filtering (15')
- Case Study - Exercise 4 (1h)

Syllabus

SoS focus

PLE focus

Both

> DAY 5 (3h30)

- Restitution of Case Study – Exercise 4 (1h)
- Variability at Functions and Functional Exchanges (20')
- Variability at Components (10')
- Product Configurations and Derivation (15')
- System Integration into the SoS (20')
- Capella Libraries and REC/RPL (15')
- Case Study - Exercise 5 (1h10)

> DAY 6 (3h30)

- Restitution of Case Study – Exercise 5 (1h)
- Effective communication: A3A0 (30')
- Case Study - Exercise 6 (1h30)
- Restitution of Case Study – Exercise 6 (25')
- Closure (5')

Relation with ROB308 (MBSE Basics)

- ROB308 allowed you to know the basic concepts of the Arcadia method and the most-commonly used features of the Capella MBSE tool, when used for systems engineering
- This course leverages on the knowledge acquired in ROB308 and goes beyond by addressing a more complex systems engineering context and presenting the techniques that will help you face the kind of challenges you will often encounter in a Systems Architect professional path

Way of Working (1)

Only for taking notes
and during Exercises

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Way of Working (2)

> Active learning

> (Hopefully) no homework

> Exercises and presentations

- Use HTML exports of models

> Final report

- 2 slides in « A3AO » format
- Models developed during the courses

> Evaluation

- Based on restitution of exercises – each day
- And on your involvement

Complexity

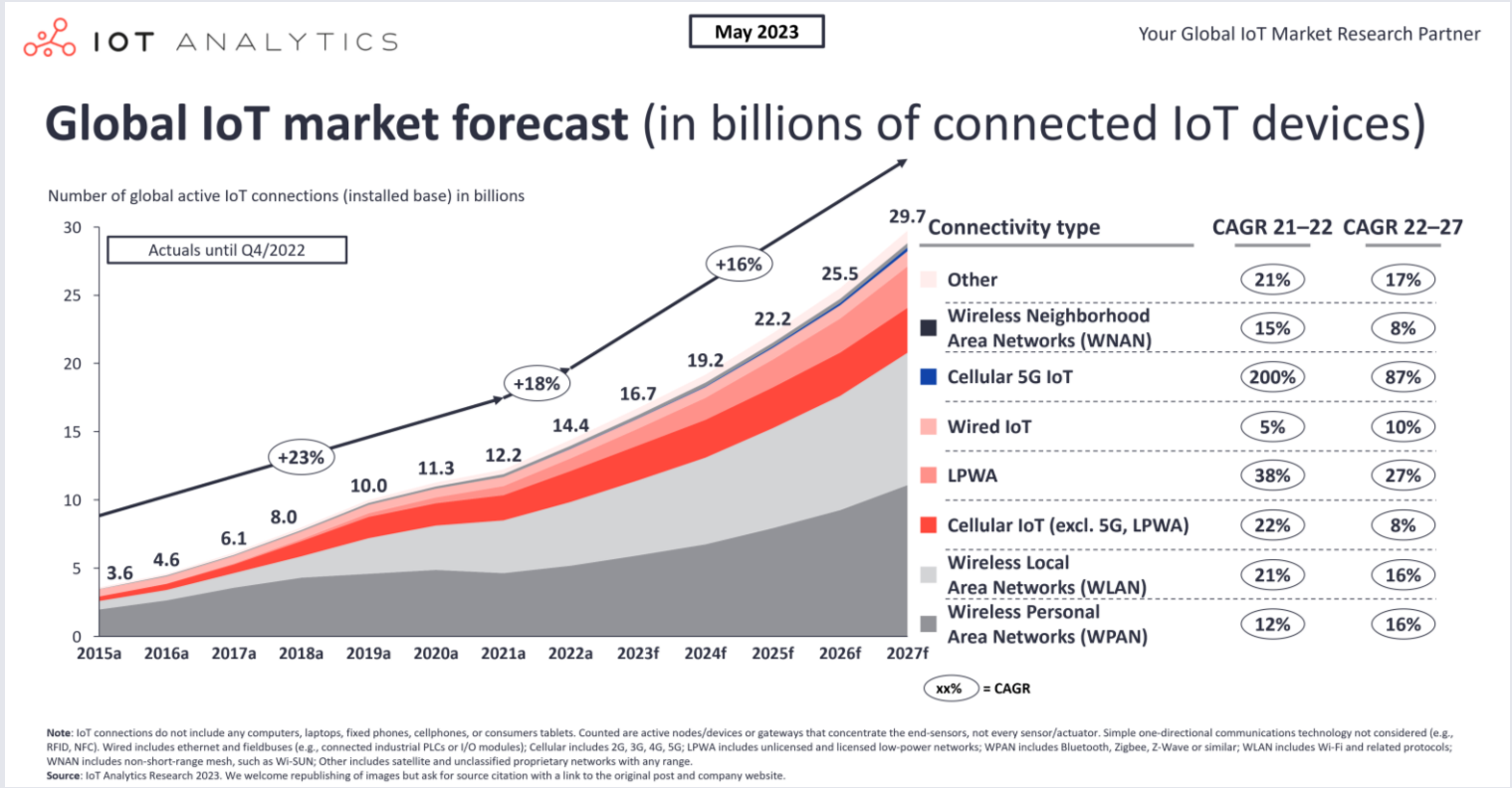
Internet of Things (IoT)

18%

2022 grow rate of number of global IoT connections

×2

Number of IoT connections will double between 2022 and 2027



The ever increasing number of connected devices makes emerge an exponential number of opportunities to arrange them on innovative ways and to provide new services

The ever increasing number of connected devices makes emerge an exponential number of concerns to be taken into account when providing new services

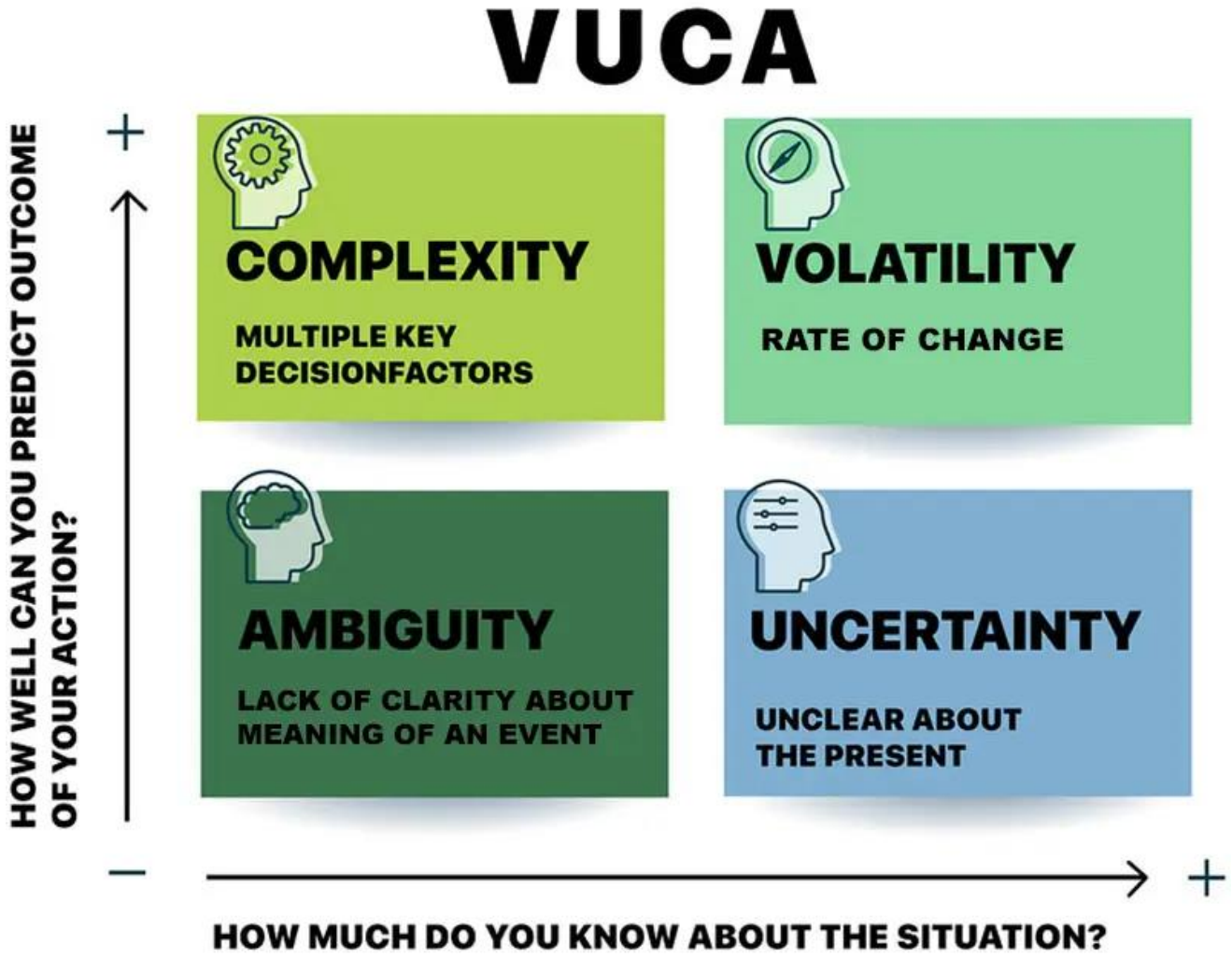
How to orchestrate assets to produce the desired effects?

An example of « emergence » in SoS

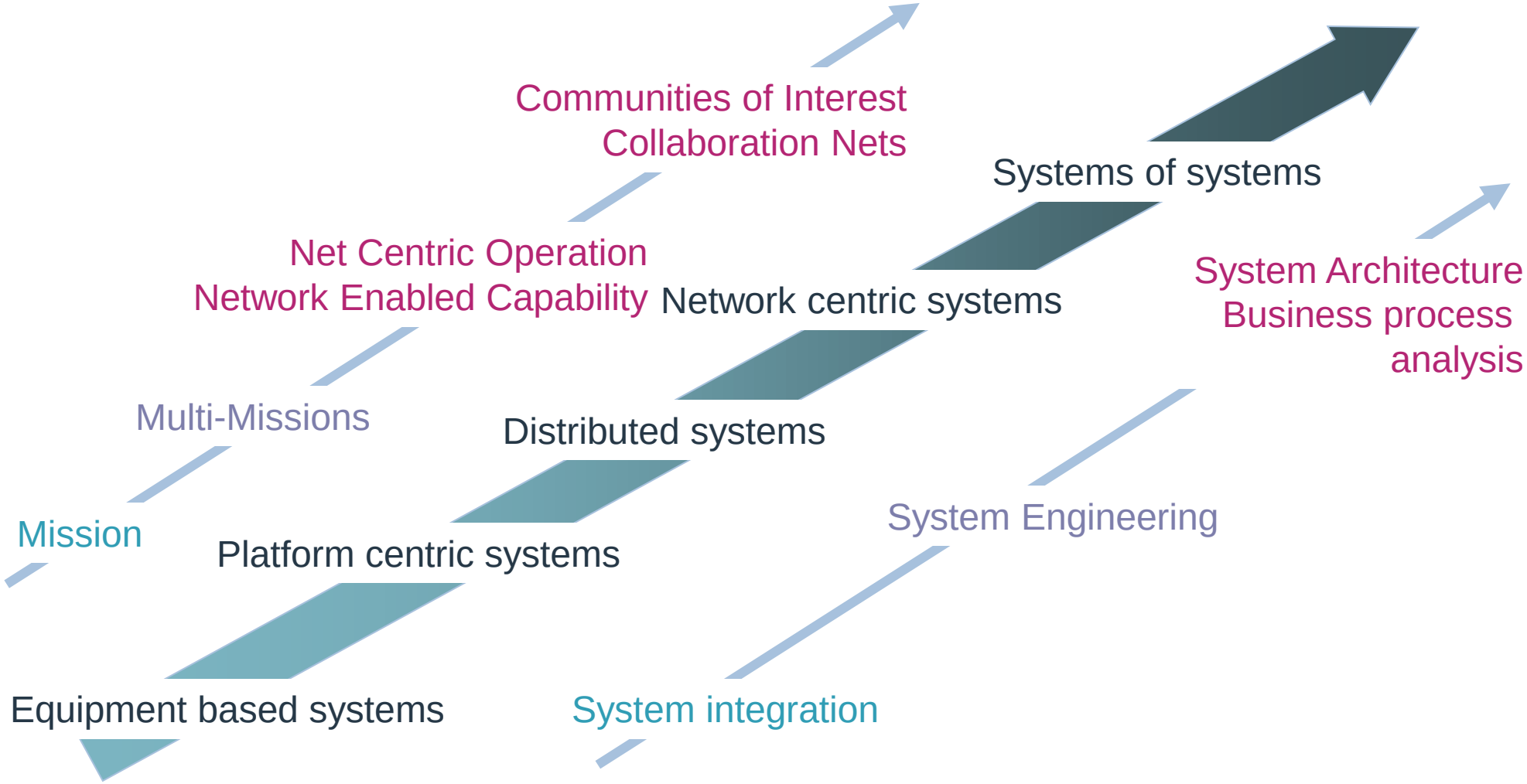
- In the Netherlands alone, consumer and business solar panels generate a power output equivalent to at least 25 medium sized nuclear power plants
- If one solar panel goes down… nothing happens.
- But if these cloud-based management platforms are, by accident, after a hack, or intentionally, simultaneously shut down all their millions of solar panels, the entire European electricity grid would collapse
  - Note: these cloud-based management platforms are most often hosted in non-European countries

Taken from: Bert Hubert, 2024. The gigantic and unregulated power plants in the cloud

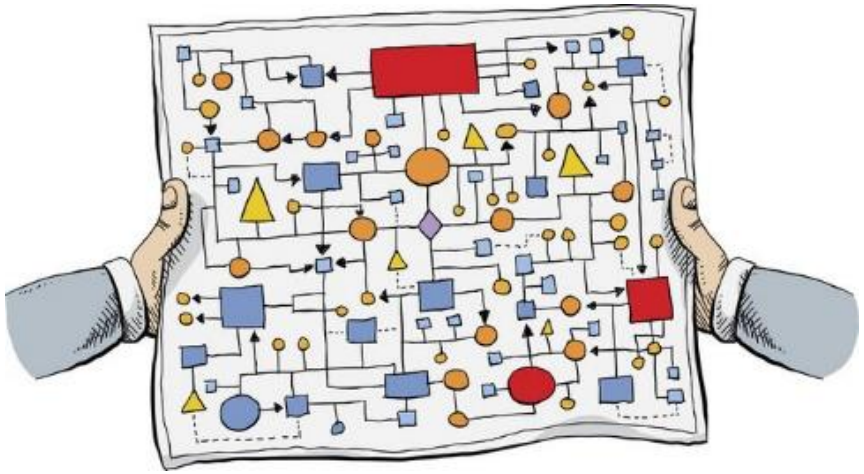
Beyond complexity - VUCA



Systems are More & More Complex



Complicated vs. Complex

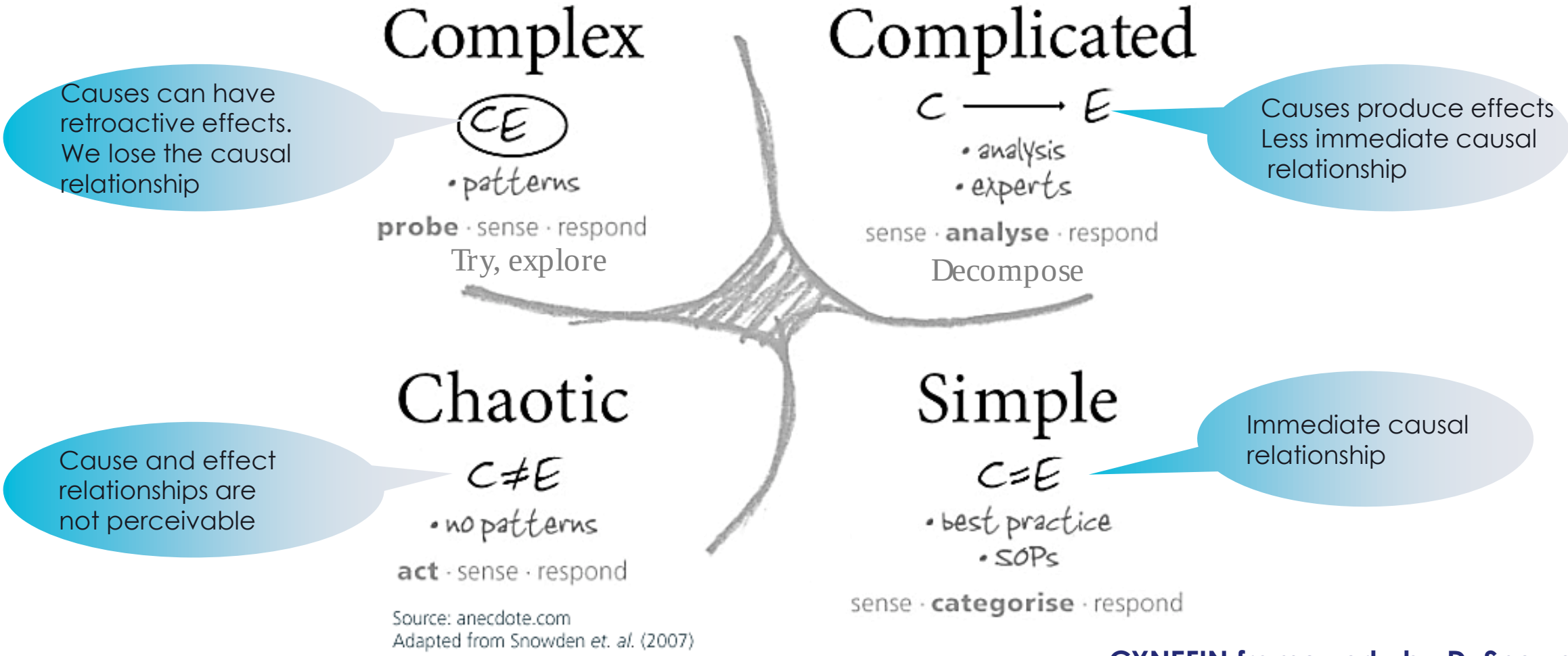


Complicated

≠

Complex

Simple, Complicated, Complex … and beyond



CYNEFIN framework, by D. Snowden

4EX FRAMEWORK

Uncertainties, key architectural decisions yet to be made

I don't know

Explore

Fairly good vision/orientation, need to refine and clarify, tackle remaining architecture decisions

I know

Explain

?

Exploit

I observe, I collect

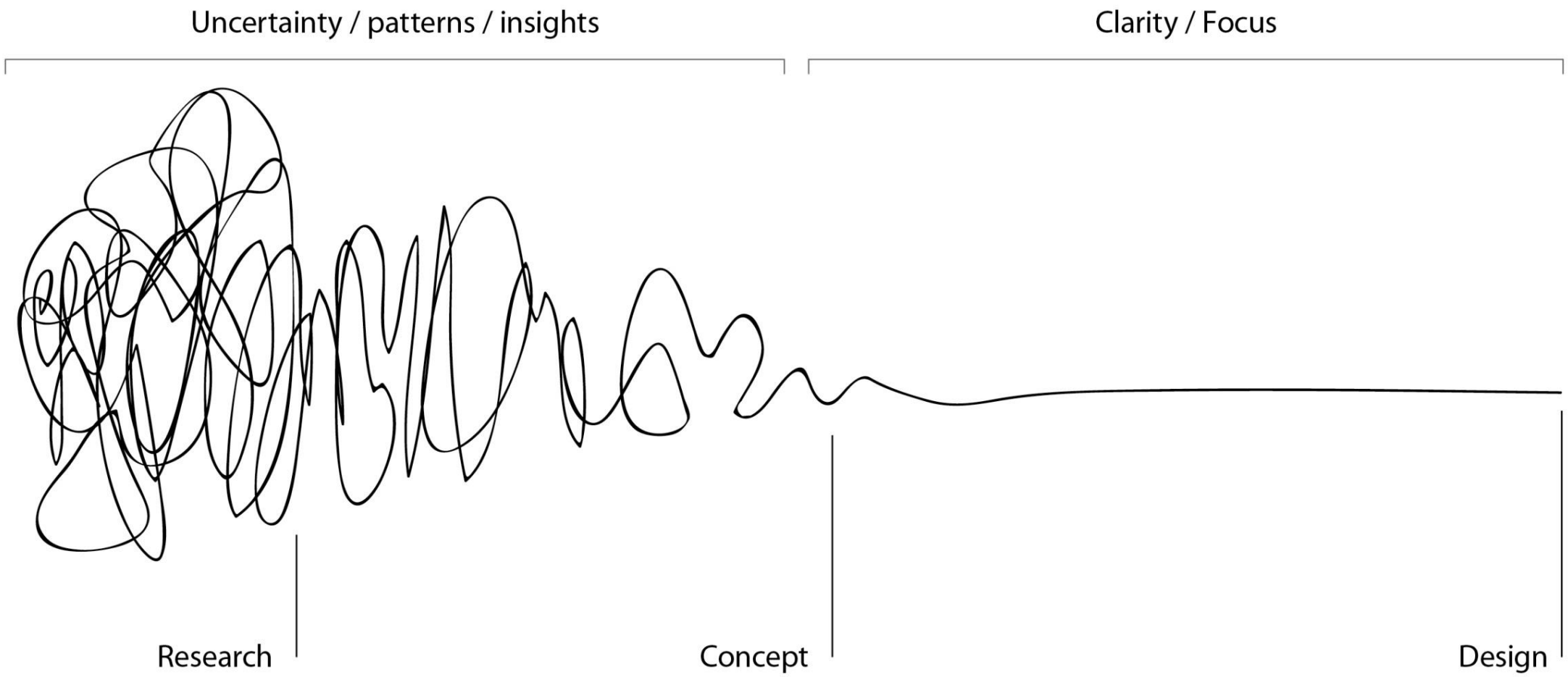
Users utilize a working solution

Execute

I have a plan

Move forward in a rigorous, monitored, coordinated, paced way. Take deviations into account, compensate

Architecting Process



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Complexity Profiler

> Objectives

- Evaluate the complexity of systems & the operational environment as soon as possible and all throughout the engineering projects, in support to technical governance actions
- Guiding key activities to manage **potential risk** areas

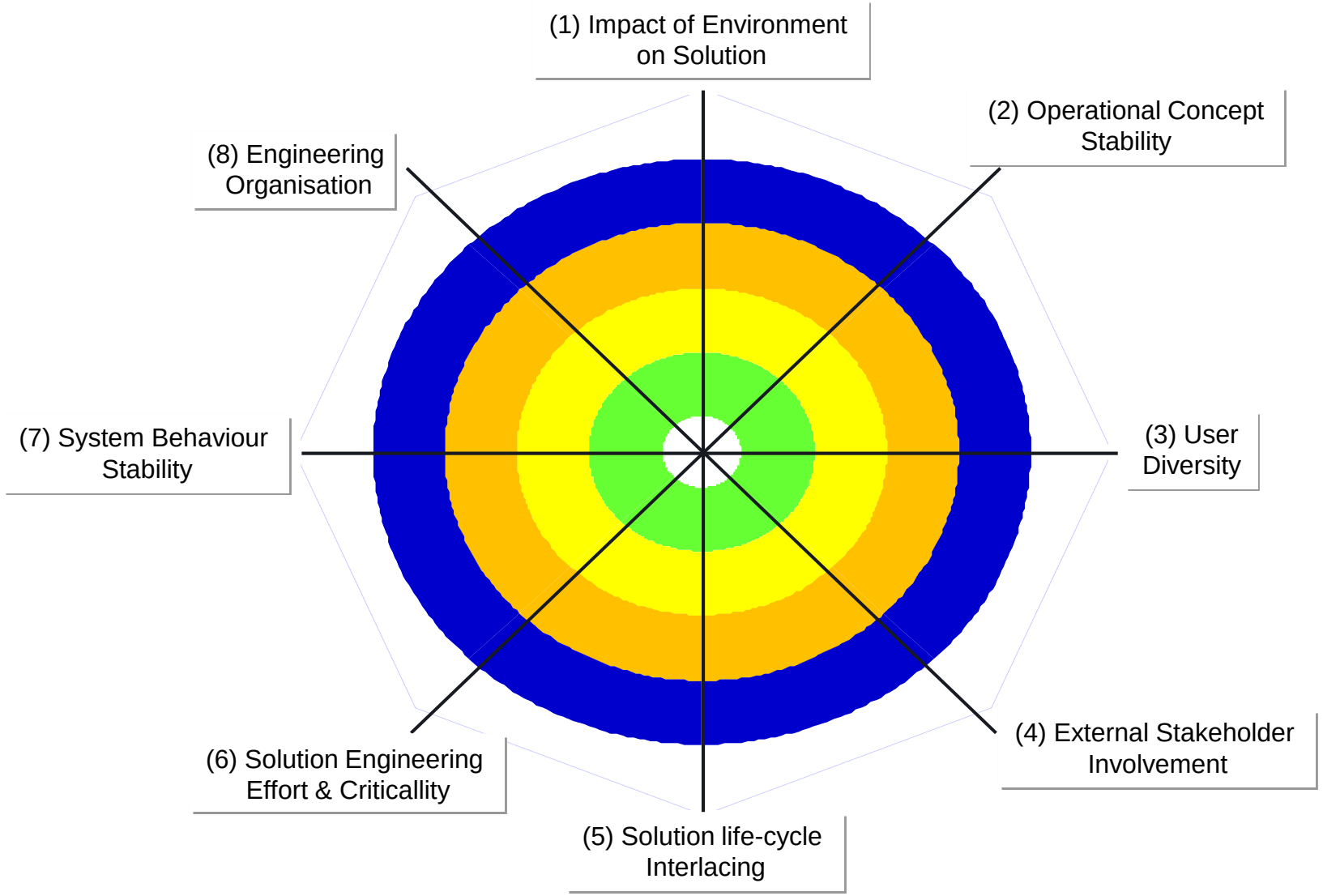
> At stake

- Identify & communicate organizational, operational & system complexity, to establish an action plan to manage this
- Ensure the balance between domain maturity & solution complexity

> Added value is to

- Carry team collaborative architecting process
- Reduce non-quality costs
- Foster & disseminate best practices

Complexity Profiler



Complexity Factors

(1) Impact of environment on solution	Impact of physical environment on the properties of the solution (which includes operational processes)
(2) Operational concept stability	Operational concept includes concept of operation, concept of use, & concept of employment. This factor is meant to evaluate the stability & the predictability of each concept (purpose, goals, mission, activity objectives), along the solution life cycle (from solution conception to disposal).
(3) User diversity	Expected number of users & their role diversity
(4) External stakeholder involvement	Level of confidence regarding their support during the execution of the contract
(5) Life-cycle interlacing	Number of systems/solution life-cycles possibly interlaced in a global Programme shared between several contractors
(6) Solution Engineering effort & criticality	Level of innovation & critically of engineered parts
(7) System behaviour stability	Determinism. The ability to define system modes, system functions, system states & system performances, & to predict their evolution according to well-defined mathematical laws
(8) Engineering Organisation	Level of cooperation & subcontracting due to team size & number of organisation units

Complexity Factors

Complexity Factors	Value	Low (1)	Medium (2)
(1) Impact of Environment on Solution	1	Not significant	Minor physical constraints
(2) Operational Concept Stability	2	Mission well defined	Minor evolution
(3) User Diversity	3	Single User	Several similar users
(4) External Stakeholder Involvement	4	High confidence in data	Common understanding with minor risks
(5) Solution life-cycle Interlacing	2	Single life-cycle	Several simple life-cycles
(6) Solution Engineering Effort and Criticallity	4	Limited dev. and no critical technology	Medium development and no critical technology
(7) System Behaviour Stability	3	Behaviour well defined	Minor evolution
(8) Engineering Organisation	4	Small size	Medium (size and # of organisation units)

Complexity Factors	Value	High (3)	Critical (4)
(1) Impact of Environment on Solution	1	Major physical constraints or operational impact	Major physical constraints and operational impact
(2) Operational Concept Stability	2	Major evolution	Unpredictable major evolution
(3) User Diversity	3	**Few dissimilar users**	Multiple Dissimilar users
(4) External Stakeholder Involvement	4	Common understanding with major risks	**Low confidence in stakeholders**
(5) Solution life-cycle Interlacing	2	Several interlaced life-cycles with medium interactions	Several interlaced life-cycles with high interactions
(6) Solution Engineering Effort and Criticallity	4	Large development and no critical technologies	**New development with critical technologies**
(7) System Behaviour Stability	3	**Major evolution**	Unpredictable major evolution
(8) Engineering Organisation	4	Large engineering population (internal)	**Large engineering population (external and possibly interna**

Life-cycle and defects costs vs. time

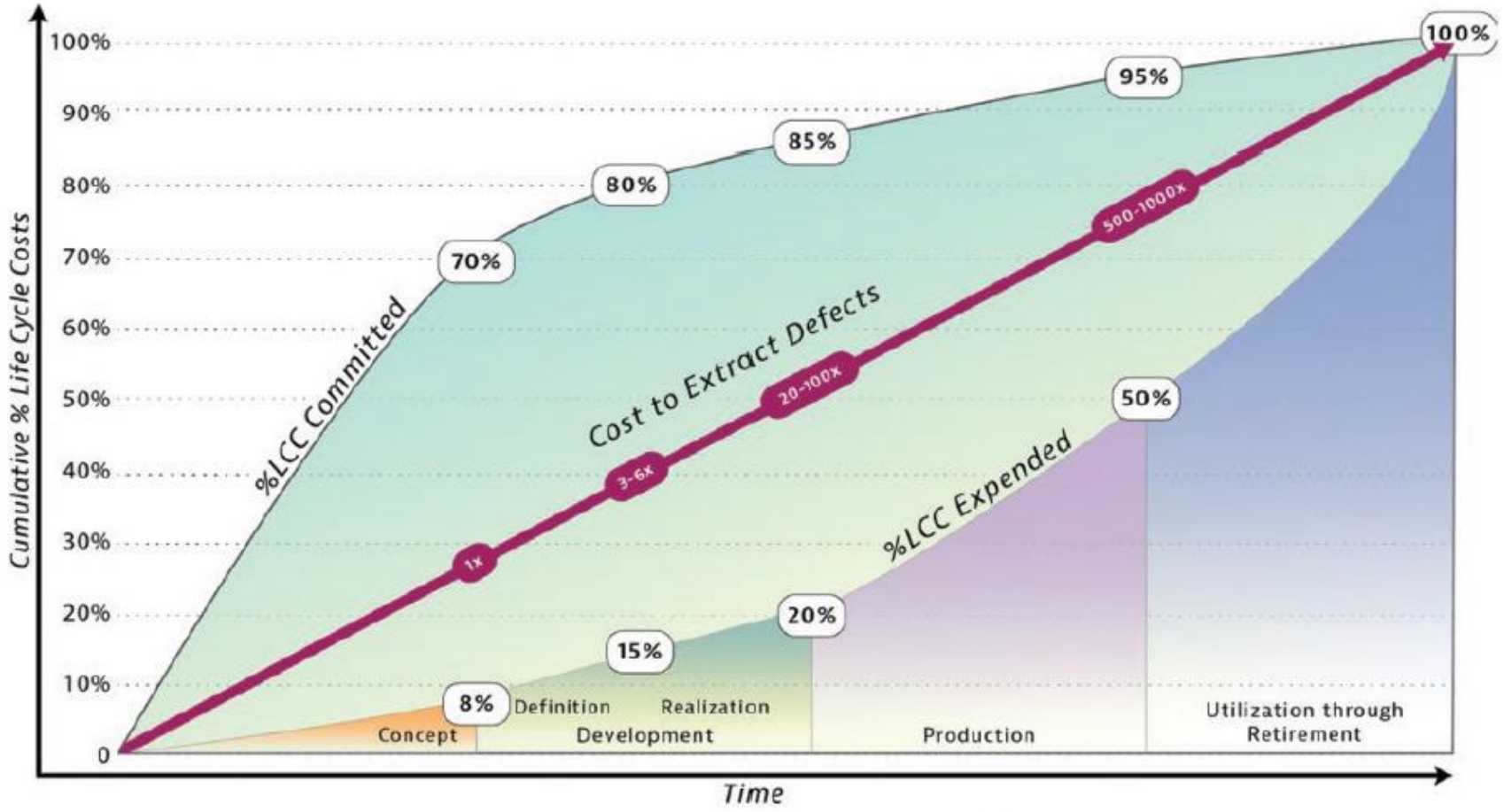


FIGURE 1.4 Life cycle costs and defect costs against time. INCOSE SEH original figure created by Walden derived from DAU (1993). Usage per the INCOSE Notices page. All other rights reserved.

Understanding the Problem space

"We fail more often
because we solve the wrong problem
than because we get the wrong
solution to the right problem"

Russell Ackoff (1974)

Understand the opportunity space within the problem scope

> Define the problem or opportunity space (cf. ISO 15288)

Review identified gaps in the organization strategy with respect to desired organization goals or objectives.

Analyze the gaps across the trade space

Describe the problems or opportunities underlying the gaps

Obtain agreement on the problem or opportunity descriptions.

A solution includes more than just the equipment or technology

Logistics

Technology

Interoperability

Training

Legal

Maintenance

Equipment

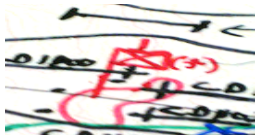
Personnel

Leadership

Political

Social

Facilities



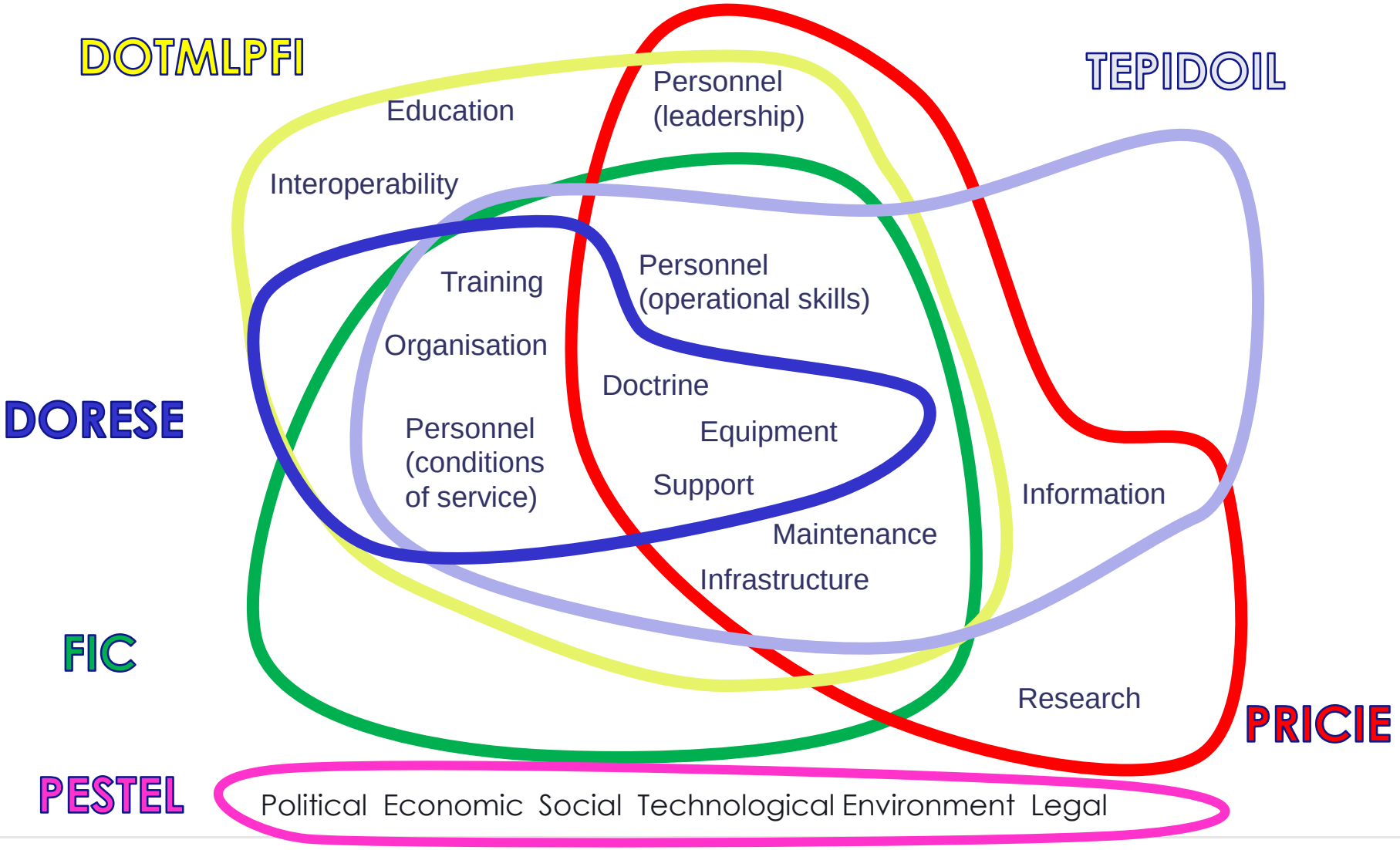
Doctrine (Procedures)

Environmental

Financial

Organisation

Main topics used to scope the problem space in Defense domains



Understanding the Problem Space with the canvas

Facilities

Do we need property / installations / industrial facilities? If so, what for?

Organisation

What organisation is needed to operate?

What organisation (s) do we need to work with?

Leadership

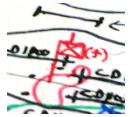
What leadership roles are needed?

Training


Do we provide training? If not who does?

Personnel

Do we provide (qualified) people?
If so who
(operators, maintainers…)?
If not, who does?

Doctrine

Is there an impact on stakeholders' Doctrine?

Do we need our own doctrine? If so what is it?

Support

How is equipment maintained, supplies replenished etc.?
Do we provide this? If not, who does?

Hardware

What equipment is needed ?
Do we provide it? If not, who does?

Interoperability

Do we need to interoperate with partners
If so, how?

Legal

Is there an impact from health /safety/discrimination/anti-trust /employment/consumer law?

Political

Is there support from government?
Do we need to lobby?

Technological

Is the required technology mature?
How rapidly is it changing?

Economic

Are economic conditions favourable

Social

Are we compatible with population, age distribution, culture ,values?

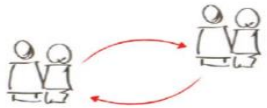
Environment

Are there geographic, ecological or climatic factors?

Example Methods used to explore Context and Needs

Serious Gaming

What? How? Why?



Story Share-and-Capture

Saturate and Group

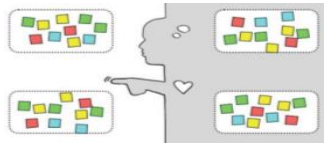
Internet / Big Data

Operational Analysis

User Camera Study

Beginner's Mindset

Analogous Empathy

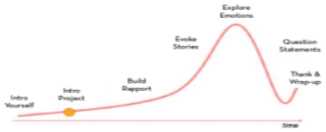


Empathy Map

Group Facilitation

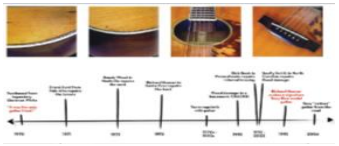
Conferences / Trade shows

Interview



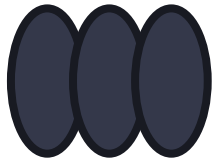
Interview for Empathy

Extreme Users



Journey Map

Composite Character Profile



… and many more

Storytelling: Stories and Scenarios

> Stories are one of the most ancient tools for transmitting values encoded in a memorable form

> A (System) Story:

- Describes the **interaction** that takes place with the system.
- Includes **references** (technical, cultural…) to relevant aspects of the interaction [except where it represents a design constraint].
- Informs, inspires, communicates **value**

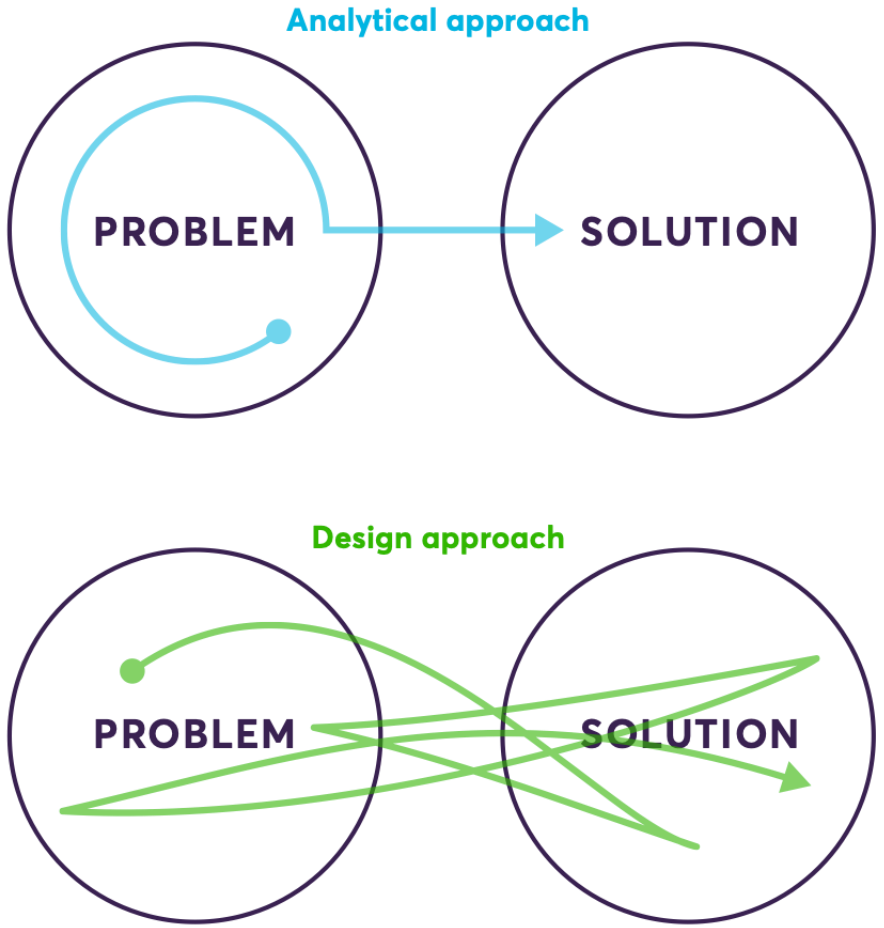
> Characteristics of a scenario:

- **Descriptive** (setting: environment, objectives, actors with roles and responsibilities).
- **Narrative** (characters, intrigue, desired result of good execution).
- **Sequential** (beginning, middle, end; events mapping)

• Scenario description

1. **Context**: In what situation? Where and when ? What are the "characters"?
2. **Scenes** 1, 2, … : Indicate who does what, who says what
3. **Final situation** at the end of the scenario

Real-life



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Stakeholders, value and benefits

Stakeholders

Individuals or Organisations having a right, share, claim or interest in a system or in its possession of characteristics thet meet their needs and expectations (SE Handbook v5)

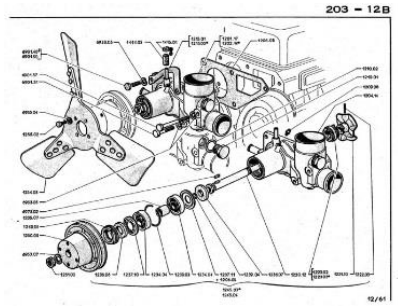
Know them thoroughly …

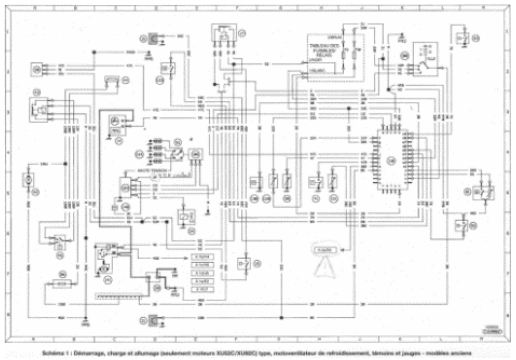
All stakeholders

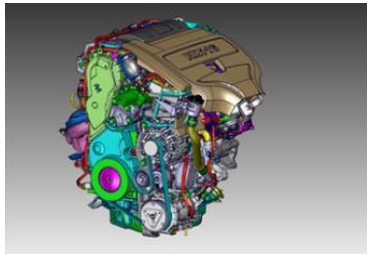
Their relationships

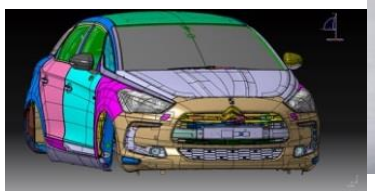
Their motivations, stakes …

Stakeholders and Lifecycle









Time

T0 2 years 5 years 30 years 35 years

Design	Manufacturing	Utilization	Dismantling

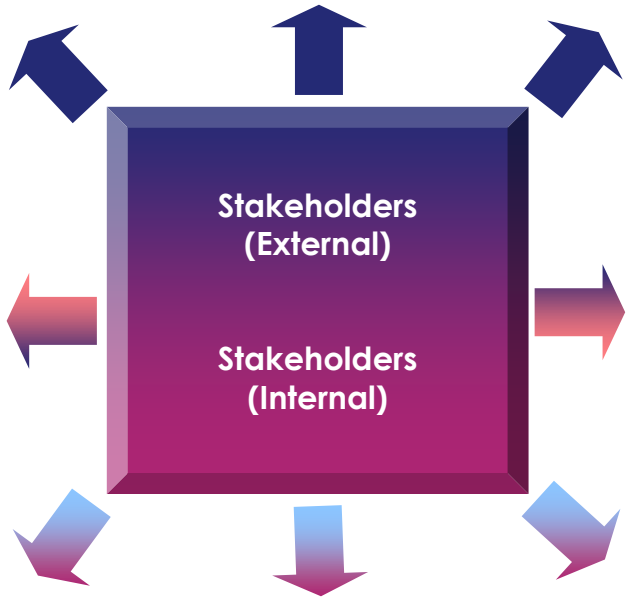
Including “the end” of the Lifecycle….

Typical Stakeholders

Customer, Users
Installers, Maintainers
Logistics Managers
Asset Managers
Finance

Environmental, ecological, economic, social, political, legal, regulatory bodies

Those concerned with other systems interfacing directly or indirectly both NOW & in the FUTURE



External suppliers directly or indirectly interfacing both NOW & in the FUTURE

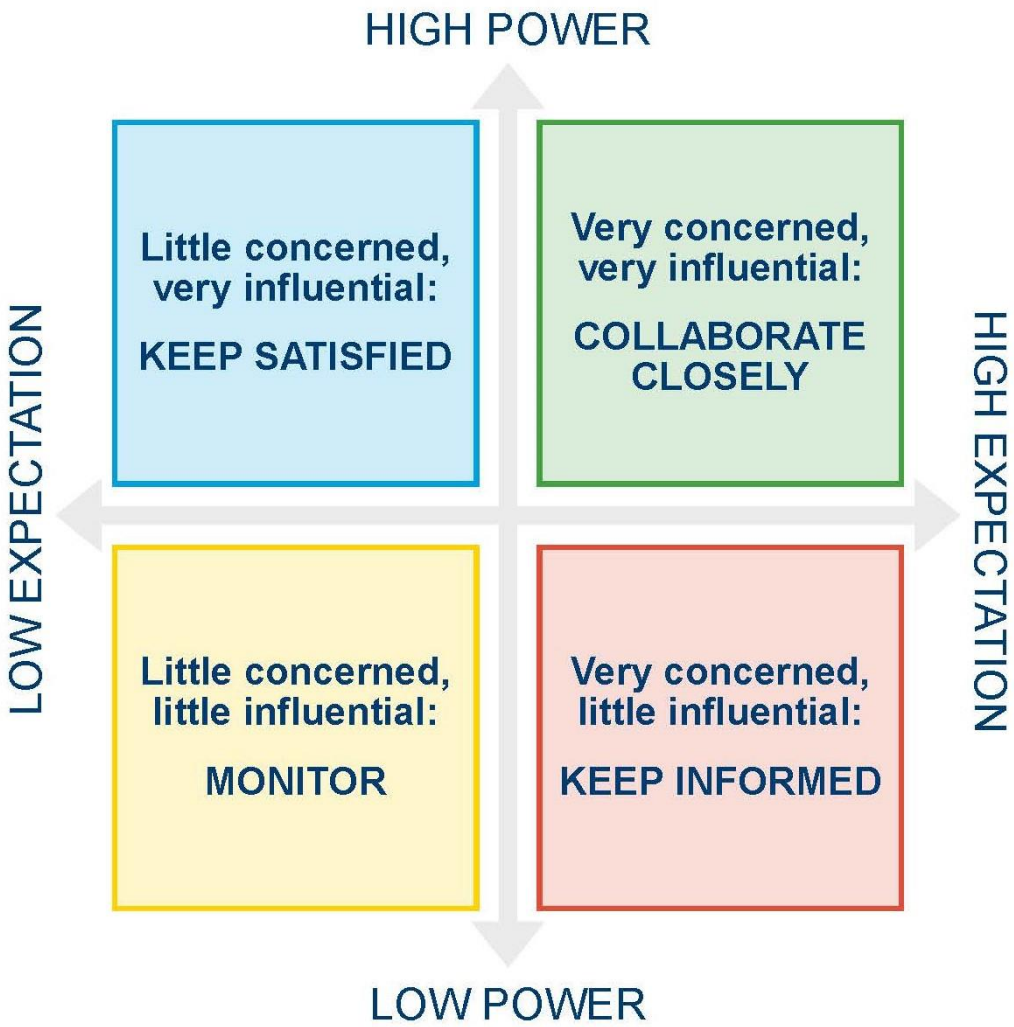
Internal "suppliers" directly or indirectly interfacing both NOW & in the FUTURE

Business Development
Product Line Managers

Business & Domain
Technical Specialists,
Specialty Engineering

Project Manager
Project Team Members
Finance, Commercial, Legal,
Procurement, Manufacturing
HR, Resource Management

Know your stakeholders: Influence and level of interest matrix



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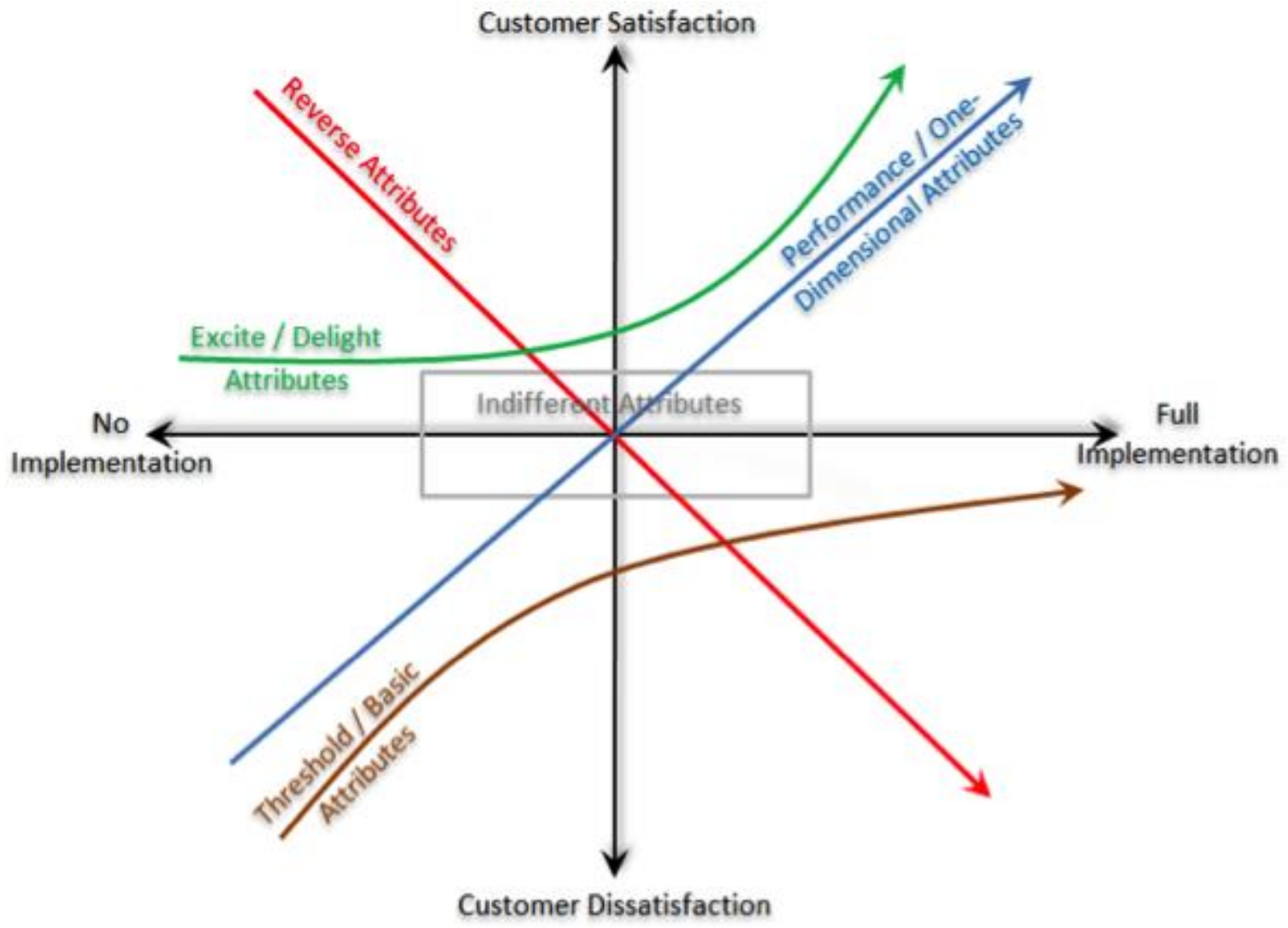
Engage your stakeholders

Tactics	Format
Engage (high priority)	Joint venture
	Partnership
	Research collaboration
	Summit
Communicate (medium priority)	Sponsorship
	Survey
	Mass email or newsletter
	Social media
	Conference
Inform (low priority)	Marketing campaign
	Sustainability report
	Publication
	News coverage

Categories of needs and their evolution: Kano Conceptual Model



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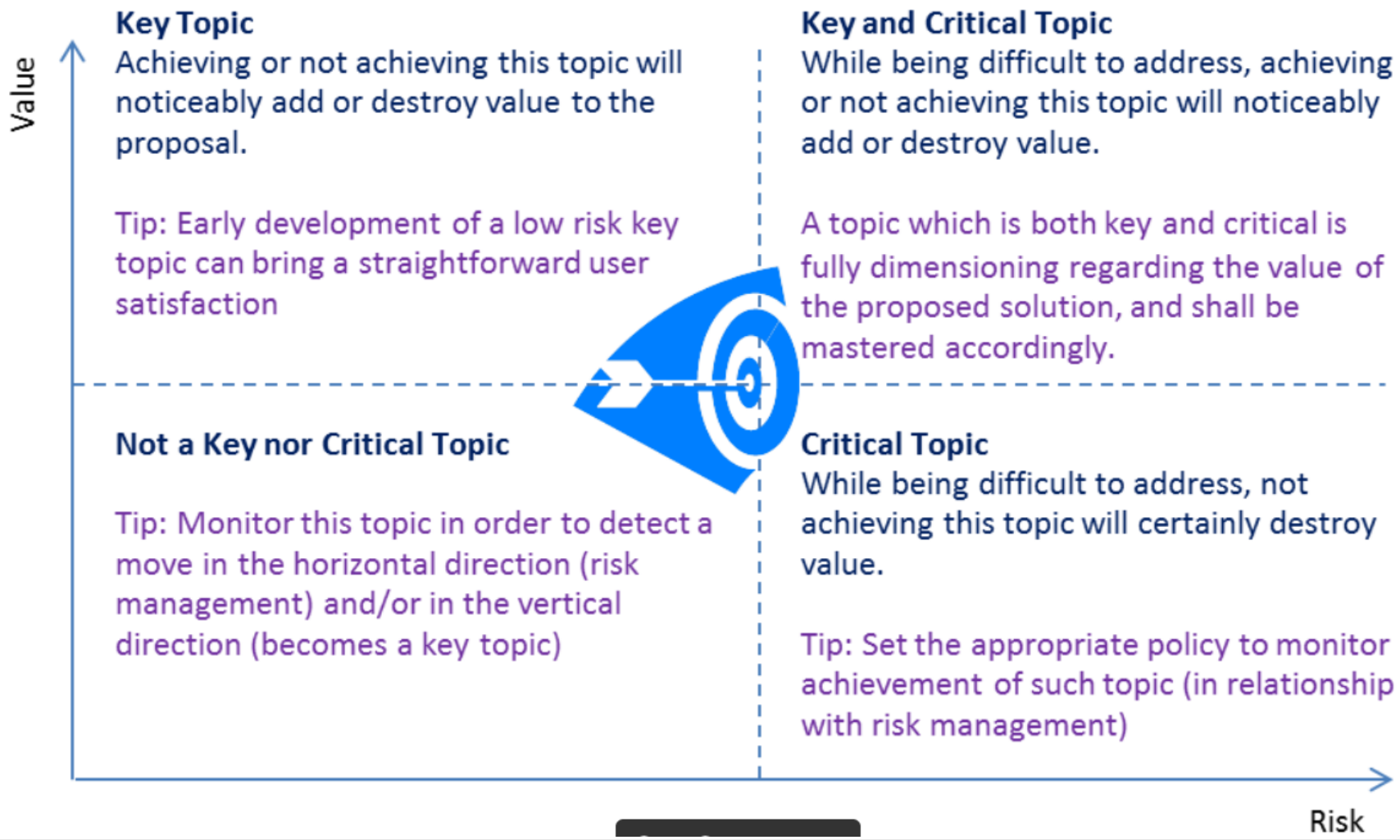
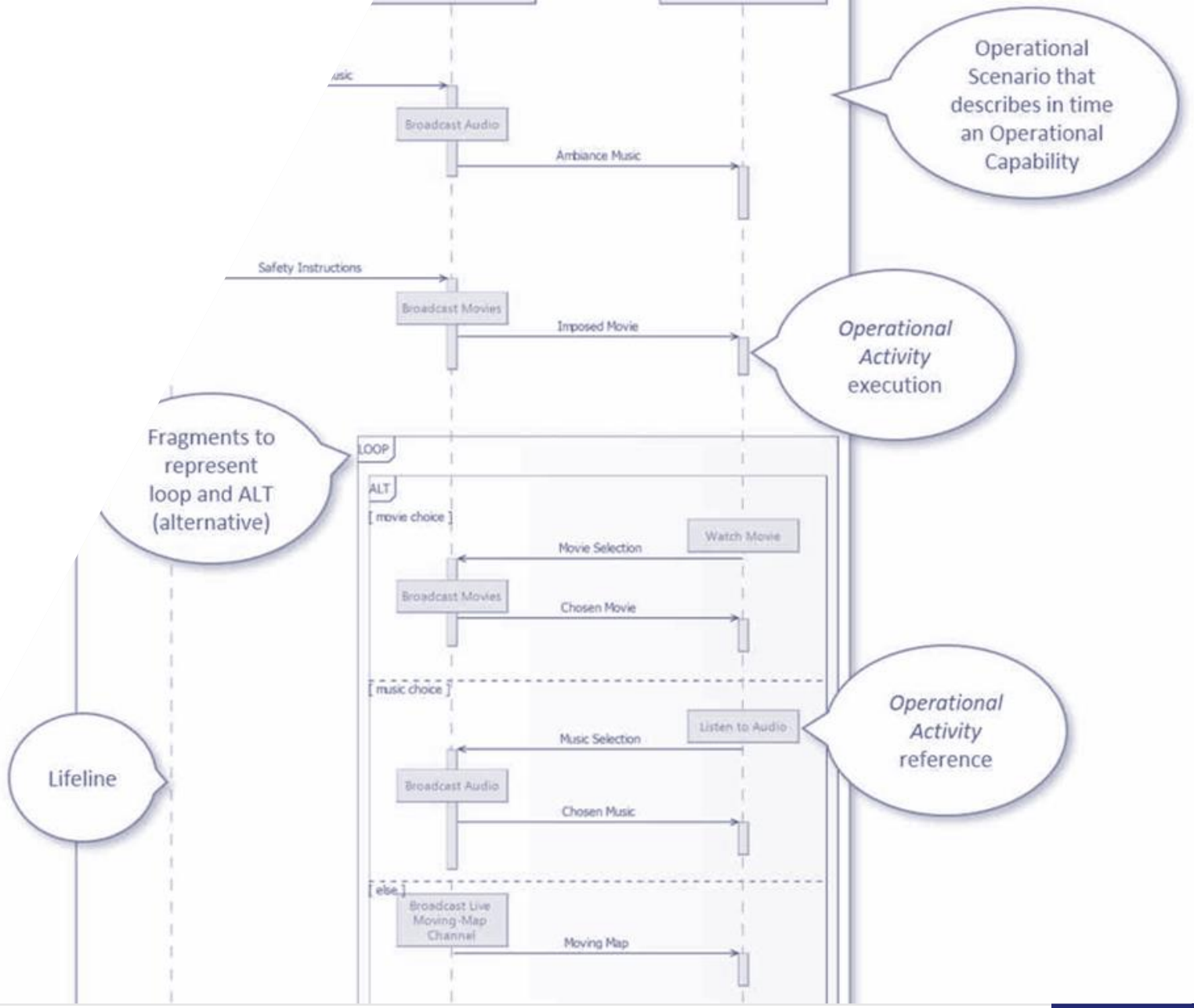
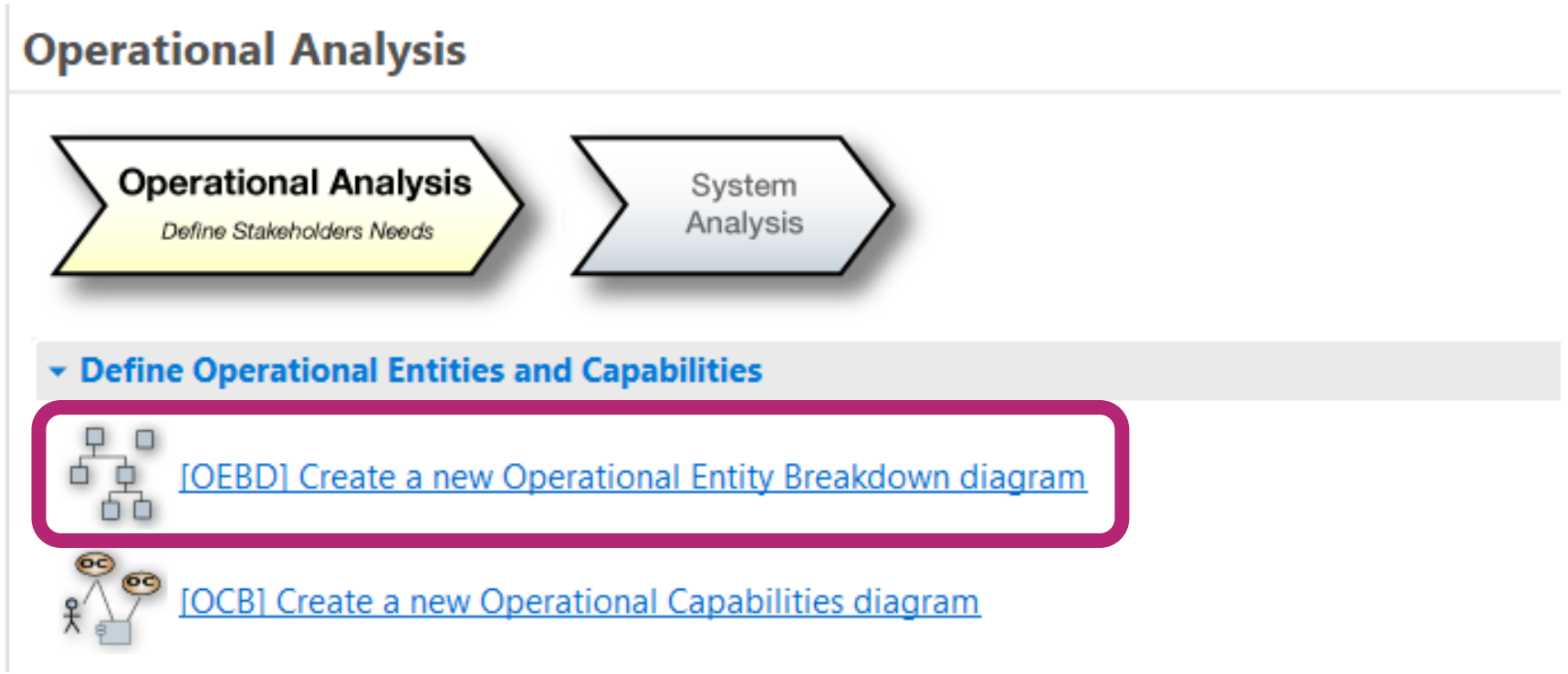
Key and Critical Topics



Capella Advanced Operational Analysis



Operational Entities Breakdown



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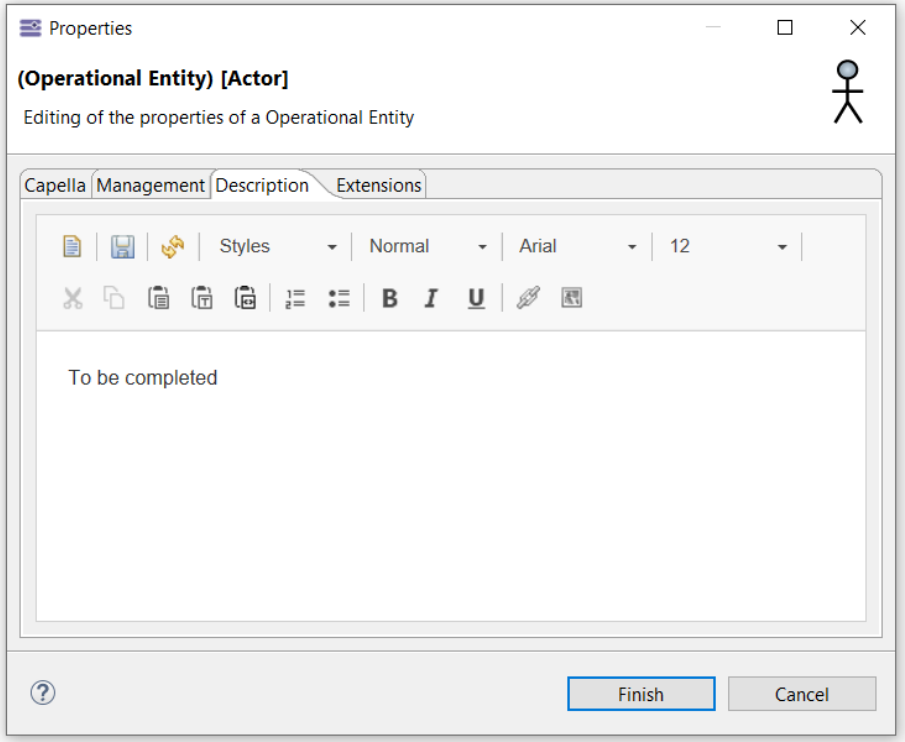
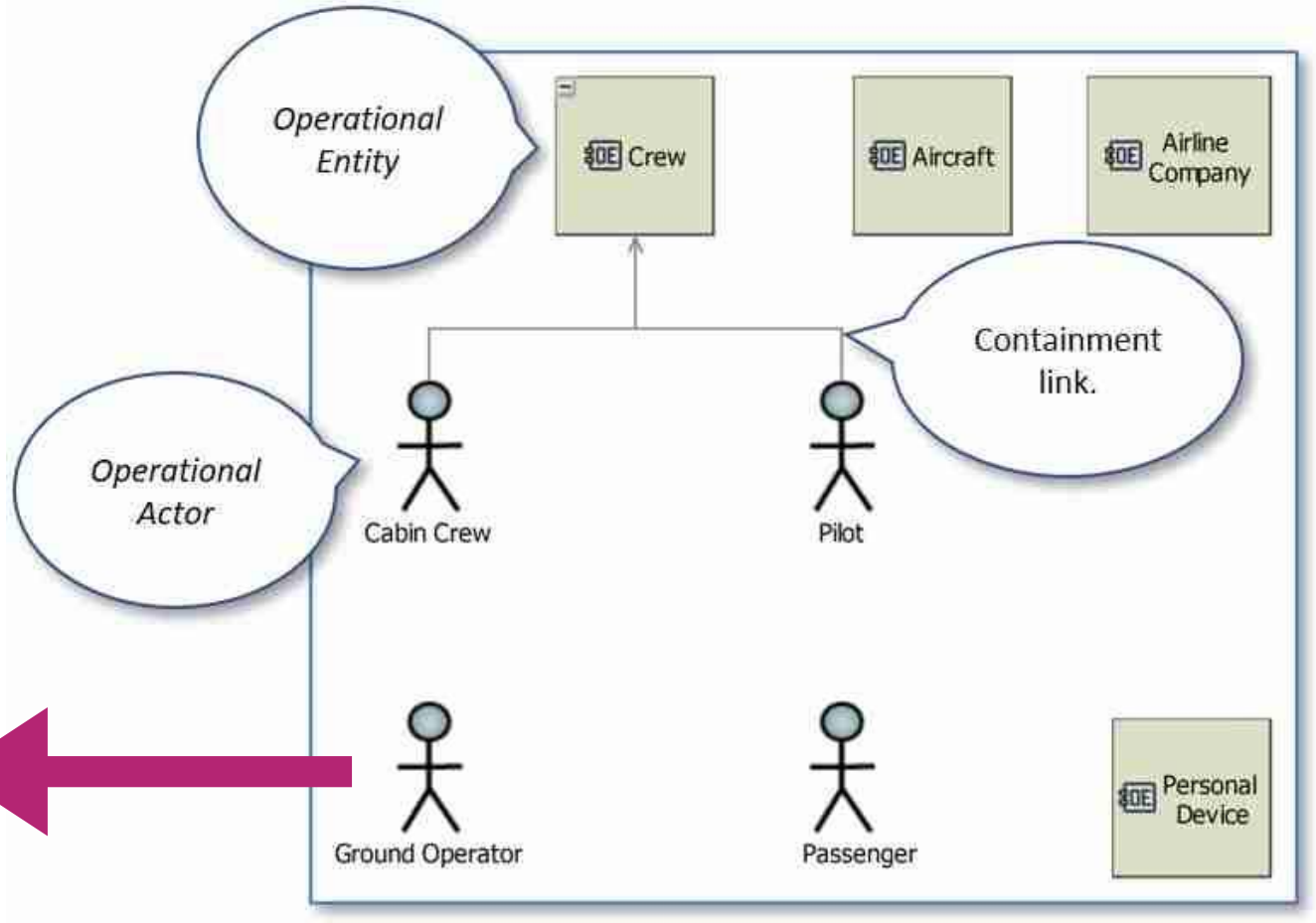
Operational Entities Breakdown





Extracted from: https://iexcelarc.com/operational-analysis-step-by-step/

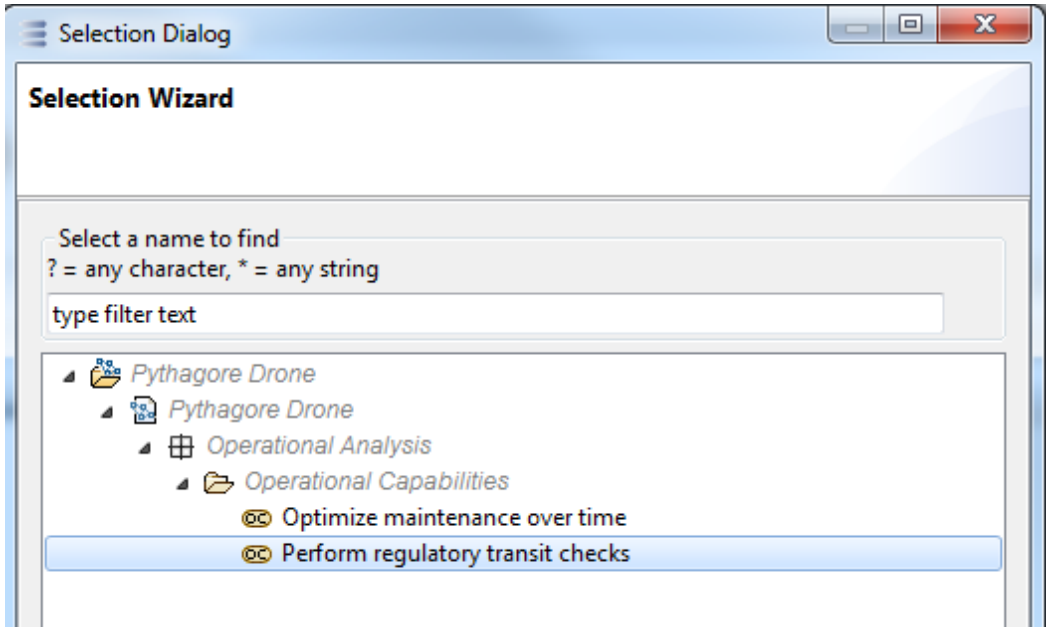
Operational Entity Scenario

- Define Operational Entities and Capabilities
- Define Operational Activities and describe Interactions
- Allocate Operational Activities to Operational Actors, Entities or Roles

[OAB] Create a new Operational Architecture diagram

[ORB] Create a new Operational Role diagram

[OES] Create a new Operational Entity Scenario



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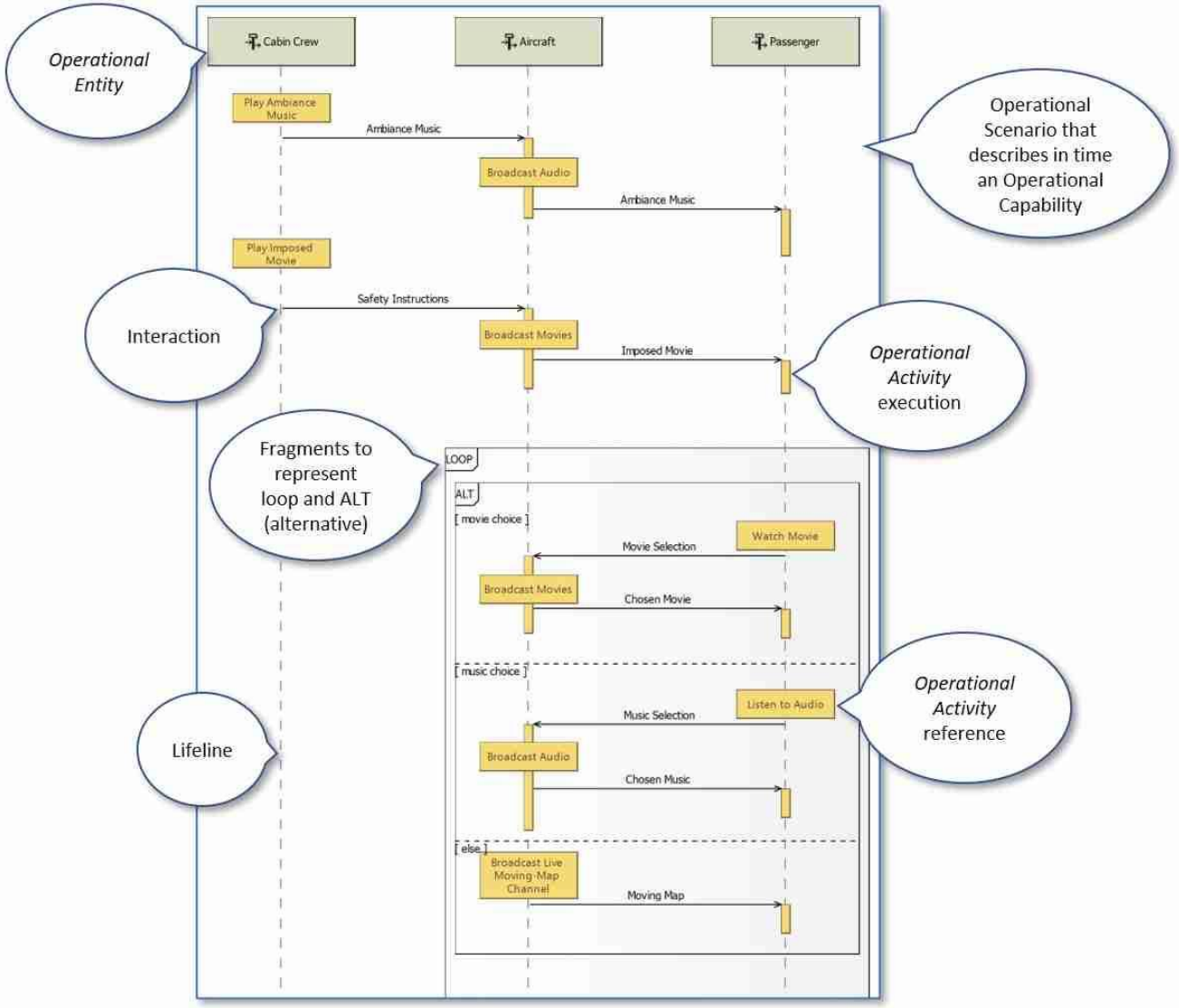
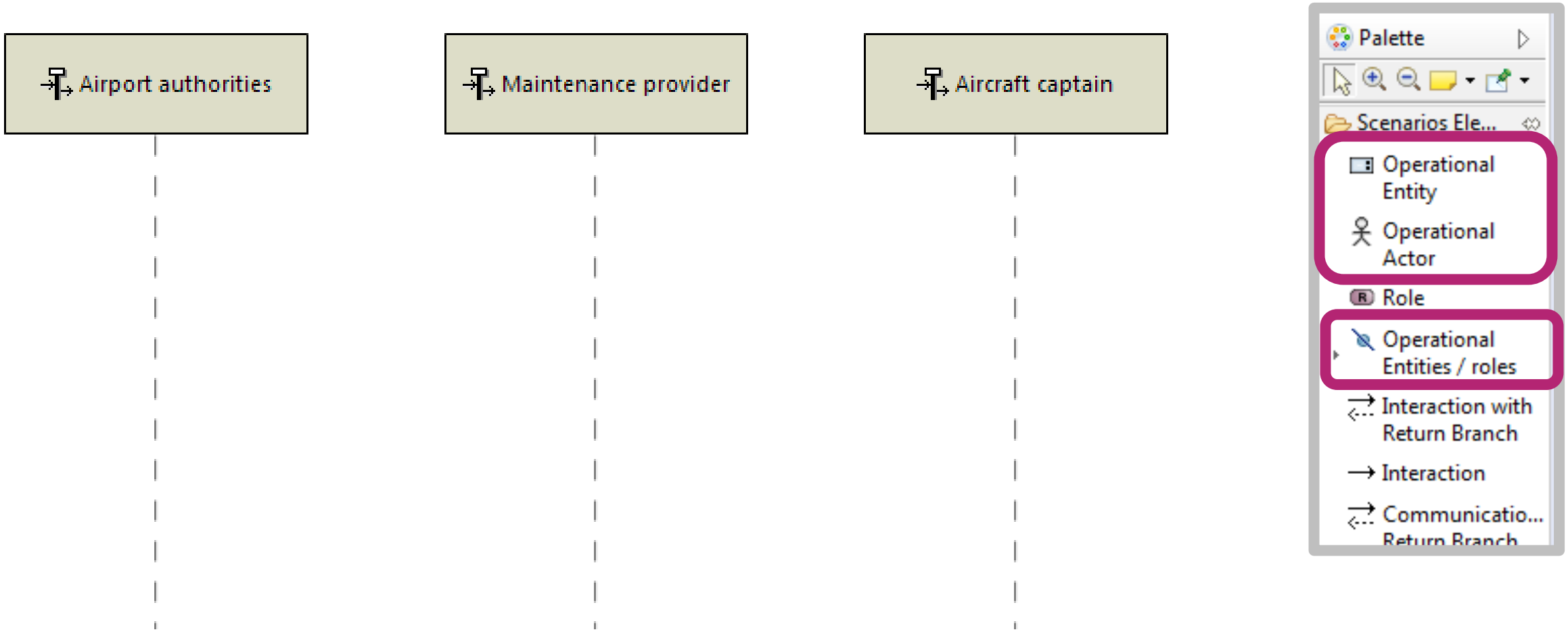
Operational Entity Scenario



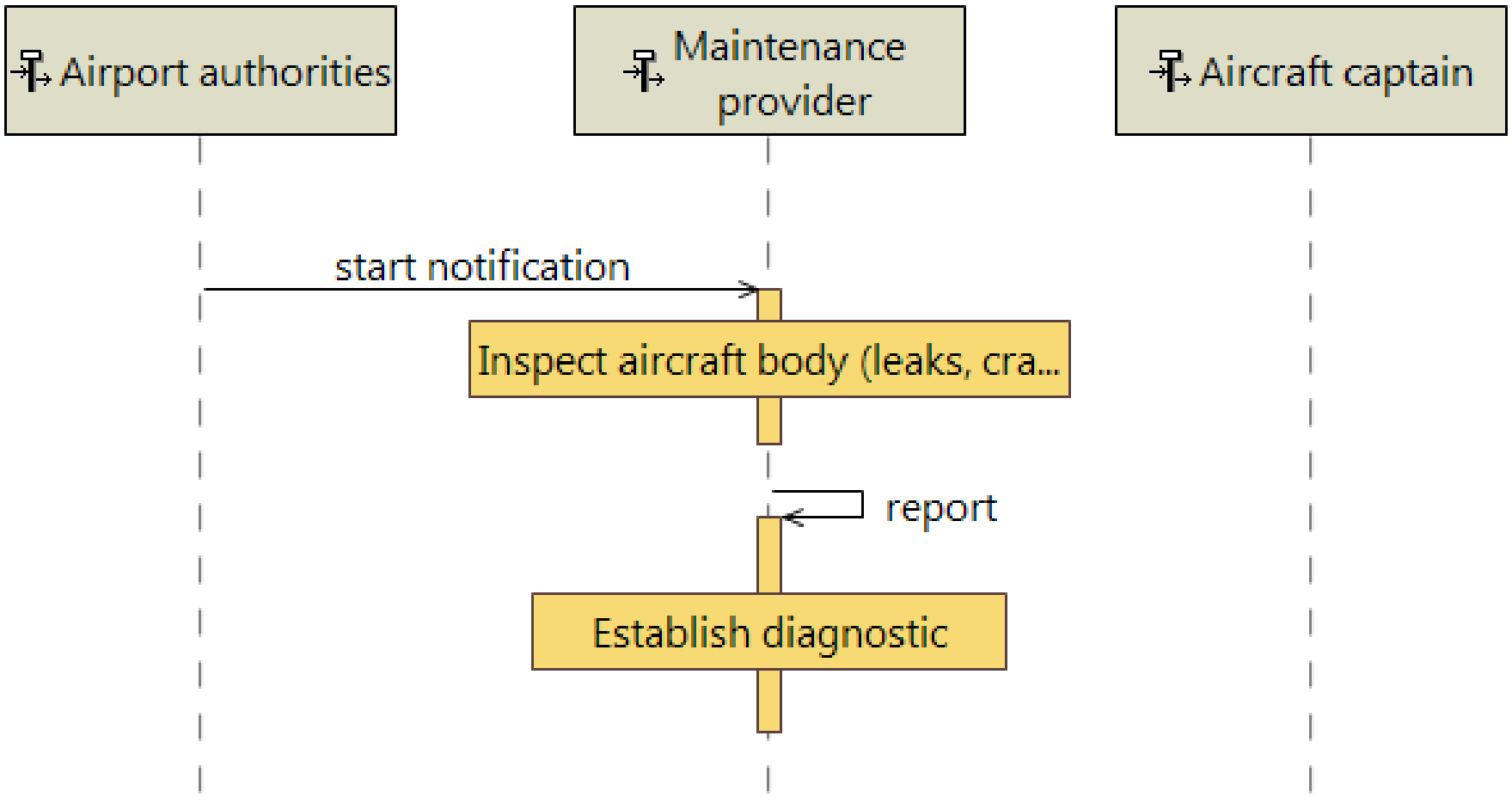
Extracted from: https://iexcelarc.com/operational-analysis-step-by-step/

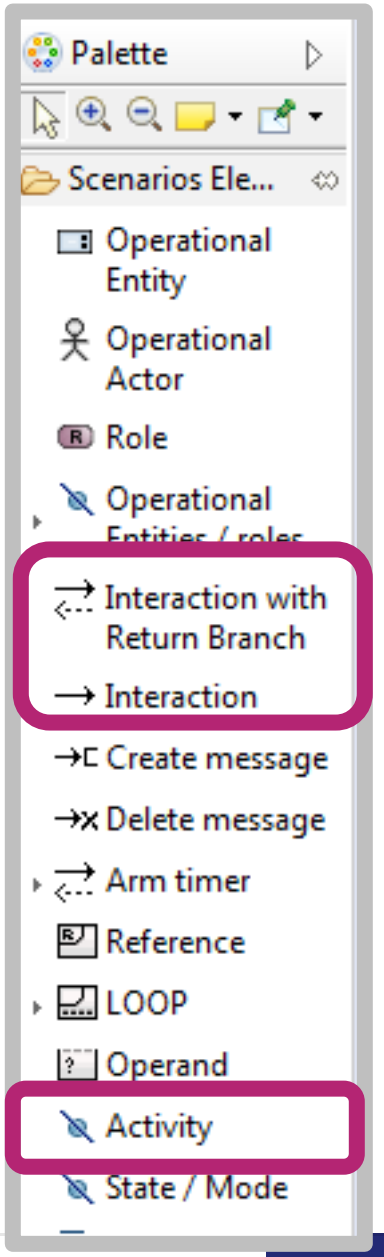
Operational Entity Scenario



REF xxxxxxxxxxx rev xxx – date Name of the company / Template: 87211168-DOC-GRP-EN-007

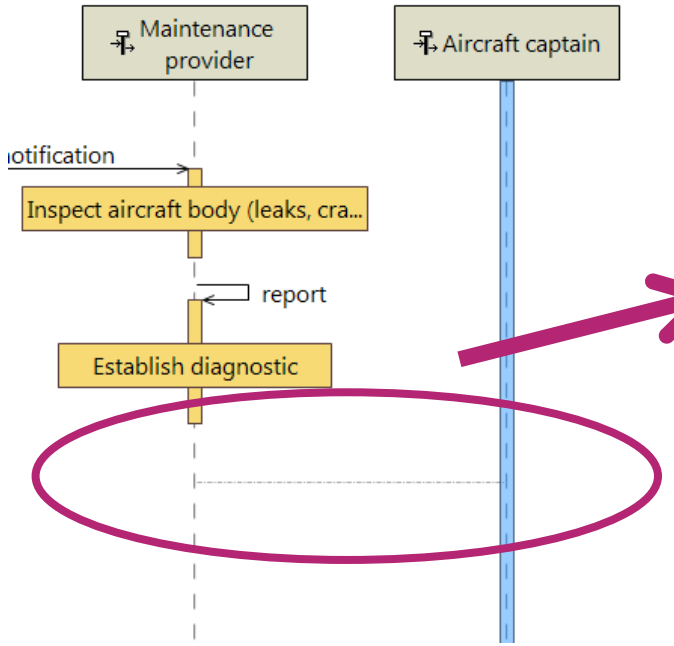
Operational Entity Scenario

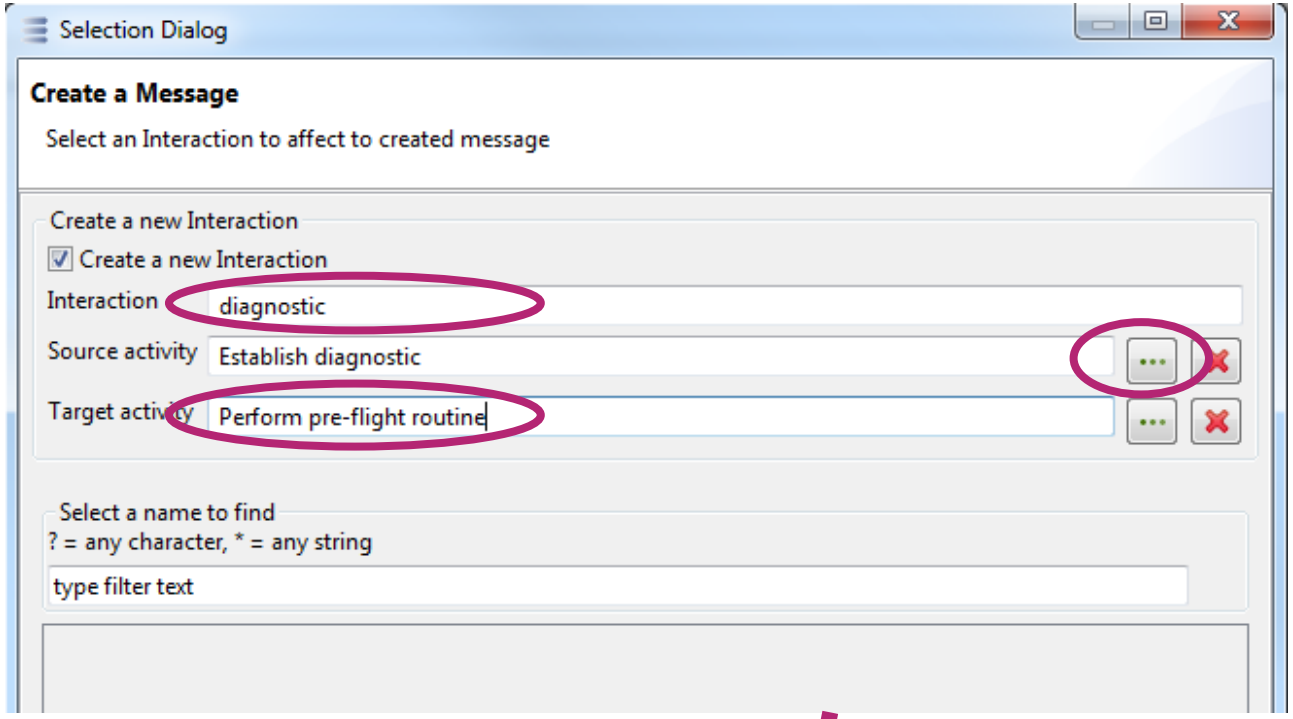


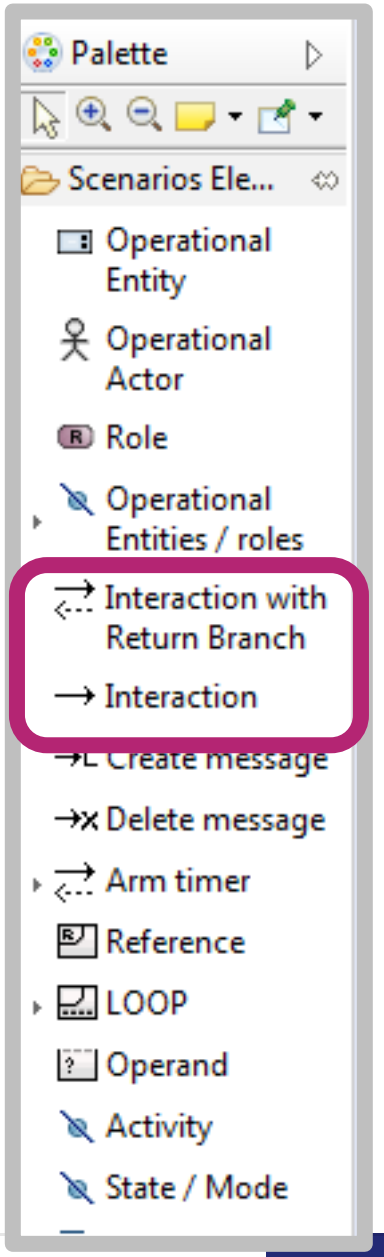


We can also use what has already been modeled

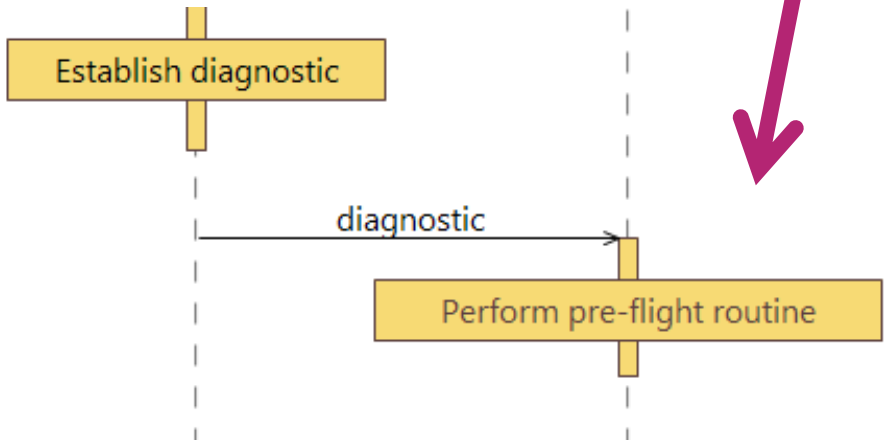
Operational Entity Scenario



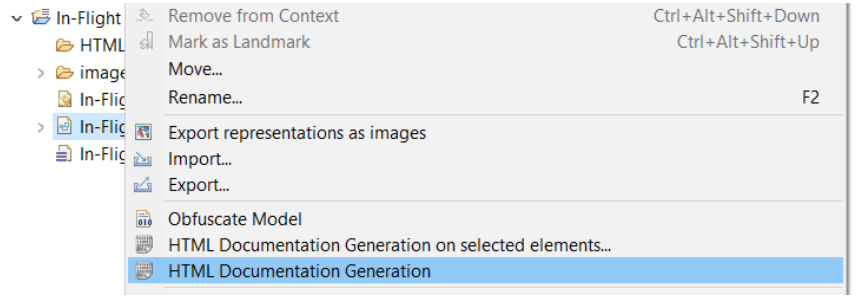


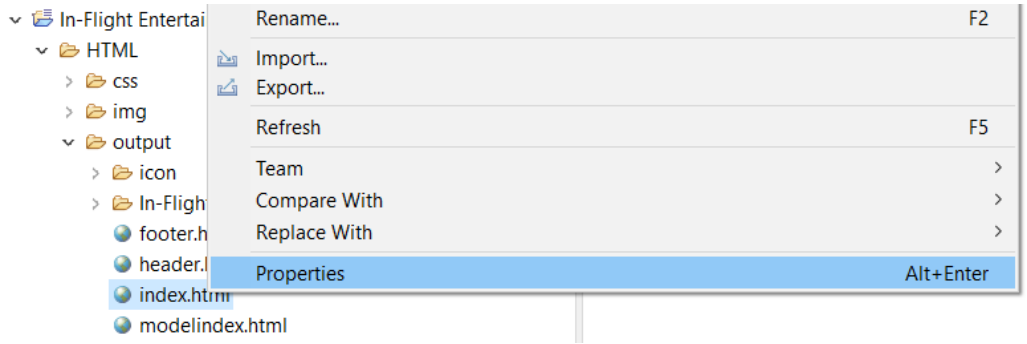


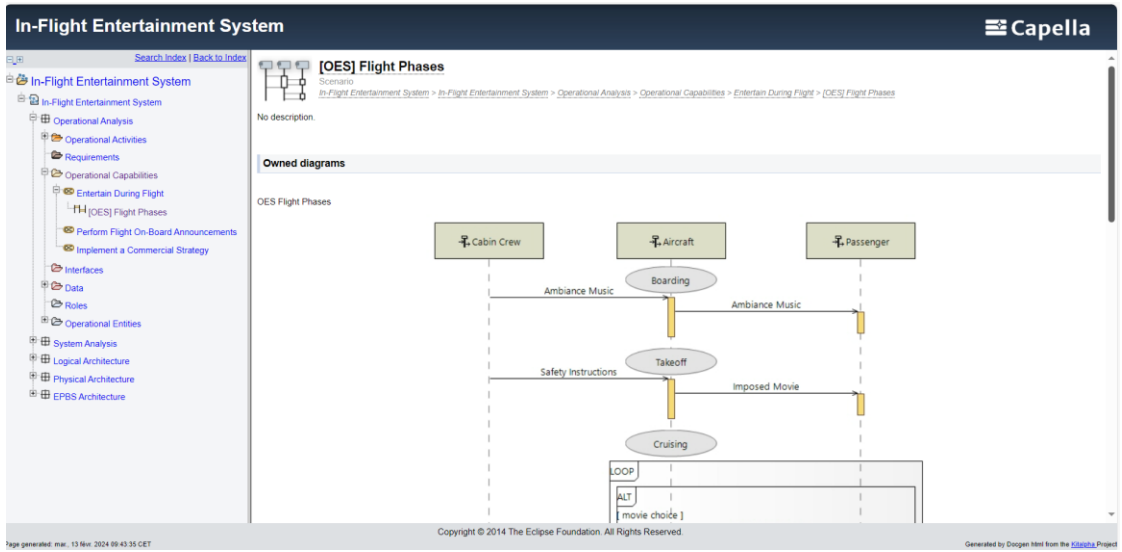
Creation of a new interaction



Export HTML add-on







Exercise 1

Exercise 1 – Context

- **France regularly organizes events with thousands of national and international participants**
  - Recent examples: COP21, UCL Final Match, Taylor Swift European Tour, Olympic Games 2024, …
- **The authorities have found that such events often cause major disruption, not only to the daily lives of the French people, but also to law enforcement and other private and state agencies**
  - They can even lead to public debates and political consequences!

The country intends to set up a system (to be defined) to improve the management of such events.

- **Studying past experiences is one good way to start working on this**
- **The French Senate produced a report about the incidents at the Stade de France on May 28, 2022: "CHAMPIONS LEAGUE FINAL AT THE STADE DE FRANCE: AN INEVITABLE FIASCO"**

Exercise 1.1 – Stakeholders

1. Read the document « FINALE DE LA LIGUE DES CHAMPIONS AU STADE DE FRANCE : UN FIASCO INÉVITABLE »

2. Identify all the stakeholders

- To simplify, start by identifying the stakeholders that are involved in:
  - Coordinating the entrance of participants: ticketing, transportation, entrance controls, …
  - Preparation and execution of law enforcement in the event zone
- Produce an Operational Entity Breakdown (OEB) view with the stakeholders represented as Operational Entities or Operational Actors
  - Use the « contained in » link to represent organizational dependencies (e.g. Police Forces contains several kinds of Police Units)

3. Characterize the stakeholders

- For each stakeholder, characterize it as follows:
  - **Their role, i.e. what they do / are supposed to do** for planning the event and during the event day
  - **What are their concerns:** what bothers them? What would satisfy them?
- Use the Description field of each Operational Entity or Operational Actor to document this

4. Analyze the stakeholders

- Define:
  - The stakeholders **influence and level of interest matrix**
  - The stakeholders **engagement tactics** that you propose to put in place as the provider of the system that will improve the management of events (whatever this system is!)
- Use the Description field of the Operational Analysis perspective to document this

Exercise 1.2 – Operational Scenarios

1. Based on the work done in Exercise 1.1: Produce an Operational Scenario (OES) view representing a « story » (chronology) of what went bad

- Focus on the interactions (or lack of interactions) between entities/actors
- Don’t forget to cover the full life-cycle: most often the problems arise at D-Day, but they've been stewing for a long time!
- Choose one scenario among these topics:
  - Coordinating the entrance of participants: ticketing, transportation, entrance controls, …, or
  - Preparation and execution of law enforcement in the event zone, or
  - Crowd Congestion in RERs and in Stade de France

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