System Engineering Methods

ENSEEIHT

January 2024

Course content

- Course 1
  - HCI, HSI, distributed systems, interactive software engineering
  - First contact with Ingescape
  - Presentation of the exam
- Course 2
  - Exam groups
  - HCI & UX methodologies
  - Visual programming with Ingescape
- Course 3
  - Software design patterns for HCI development
  - Generating code and crossing models for interactive applications
  - Verification & Validation applied to interactive systems
- **Course 4**
  - **Methodologies for multidisciplinary and iterative System Engineering, notions of HSI**
  - **Human Factor assessments, why and how**
  - **Co-simulation and data record/replay with Ingescape**
- Course 5
  - Practical exchanges on your exam projects using system architecture models

Context of System Engineering

- How to tackle big engineering projects ?
  - Complex systems of systems
  - Several companies

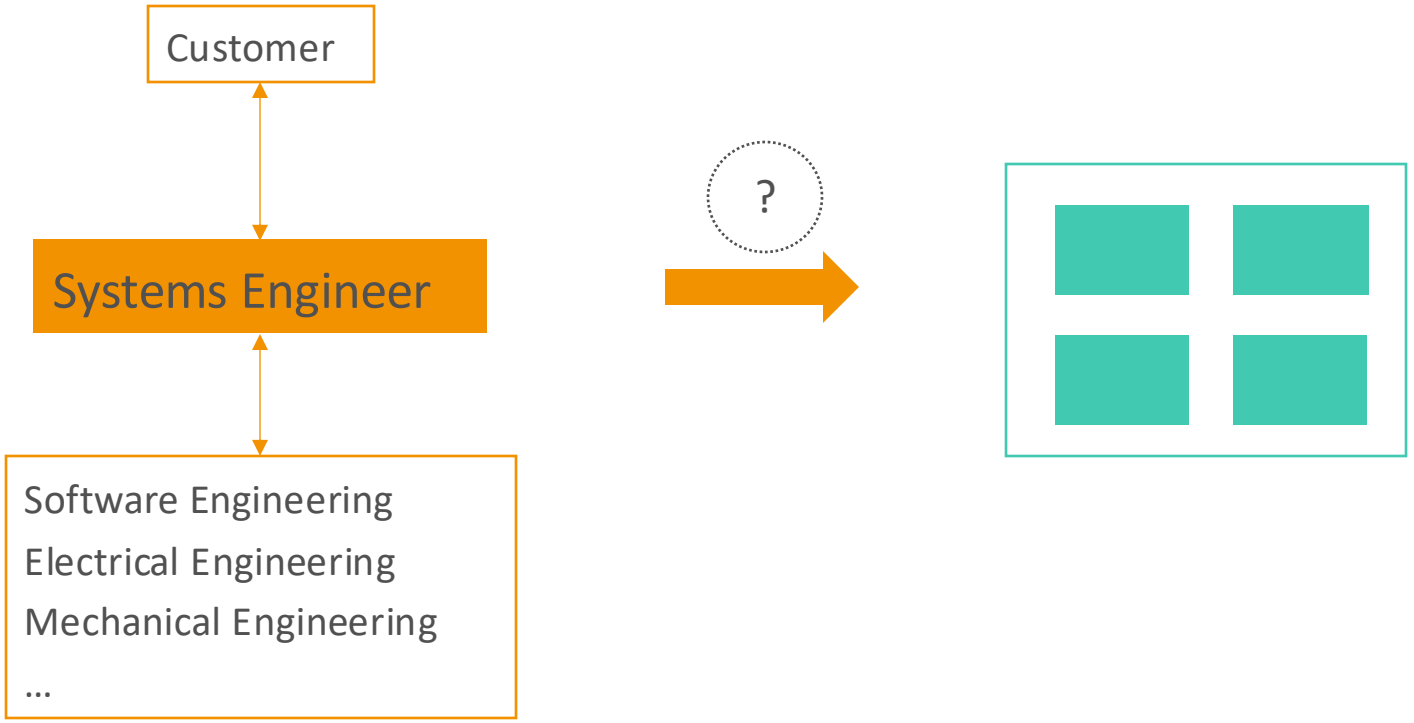
For efficiency, safety, reliability, error management…

System Engineering : presentation

- How to build complex systems ?

« Systems Engineering is a transdisciplinary and integrative approach to enable the successful realization, use and retirement of engineered systems, using systems principles and concepts, and scientific technological and management methods »

INCOSE



Systems Engineering : presentation

- Build the right system :
  - Define the customer's needs
  - Identify constraints : requirements, design, cost…
  - Define the right system to build
- Build the system right :
  - Follow development and construction
  - Manage risk & Cost
  - Integrate
  - Verify & Validate
  - Assess the system's value
- Manage the system :
  - Maintain the system
  - Manage the resources
  - Manage the end of life

- There are different Systems Engineering approaches. One of the most common ones is called Model-Based Systems Engineering.

First steps of any SE : understanding the needs of the customer

- Example : « I want to have a robot on Mars that can go around and collect samples. »
- Questions to answer :
  - What samples should be collected ? Dust, earth, stones.. ? Is drilling required and at what depth ?
  - Do you want to send the samples back ? To analyze them on Mars ?
  - How autonomous should the robot be ?
  - How far should the rover go ?
  - What's the budget ?
  - …

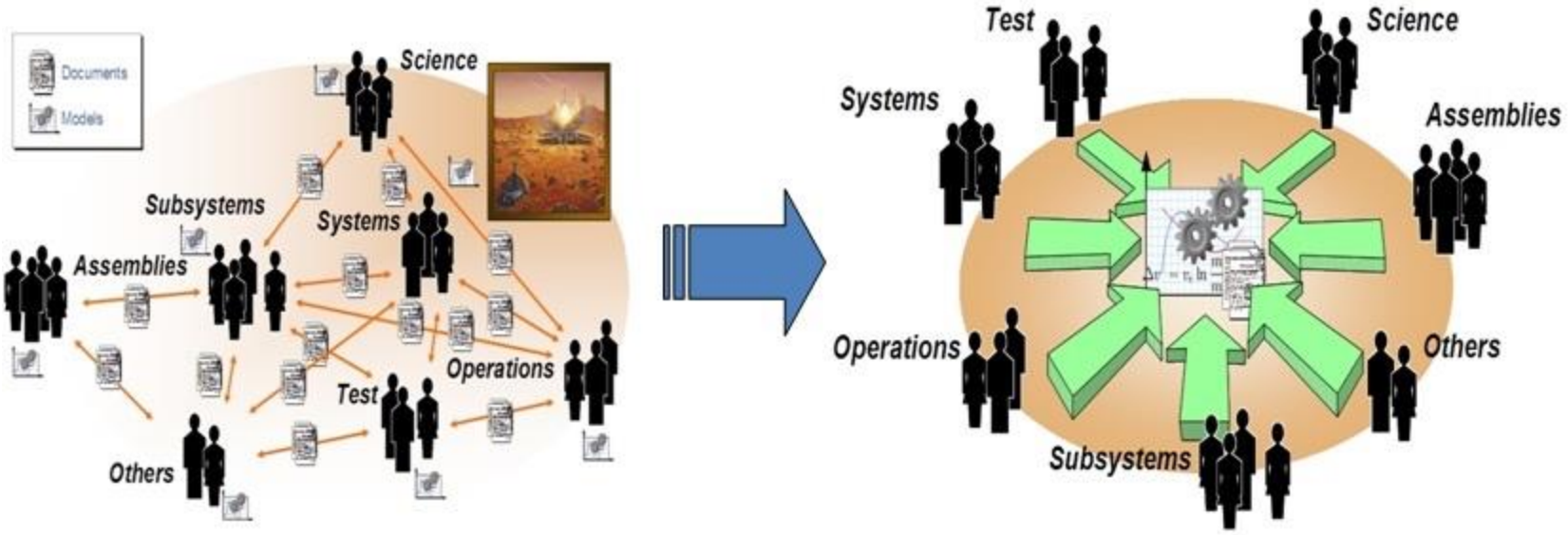
Model-Based Systems Engineering

Model-Based Systems Engineering : presentation

- Formalized methodology for the development of complex systems used to support requirements, design, analysis, verification and validation
- Why models ?
  - Simplified representation
  - Illustrate behavior, functions, caracteristics
  - Share information with less complexity

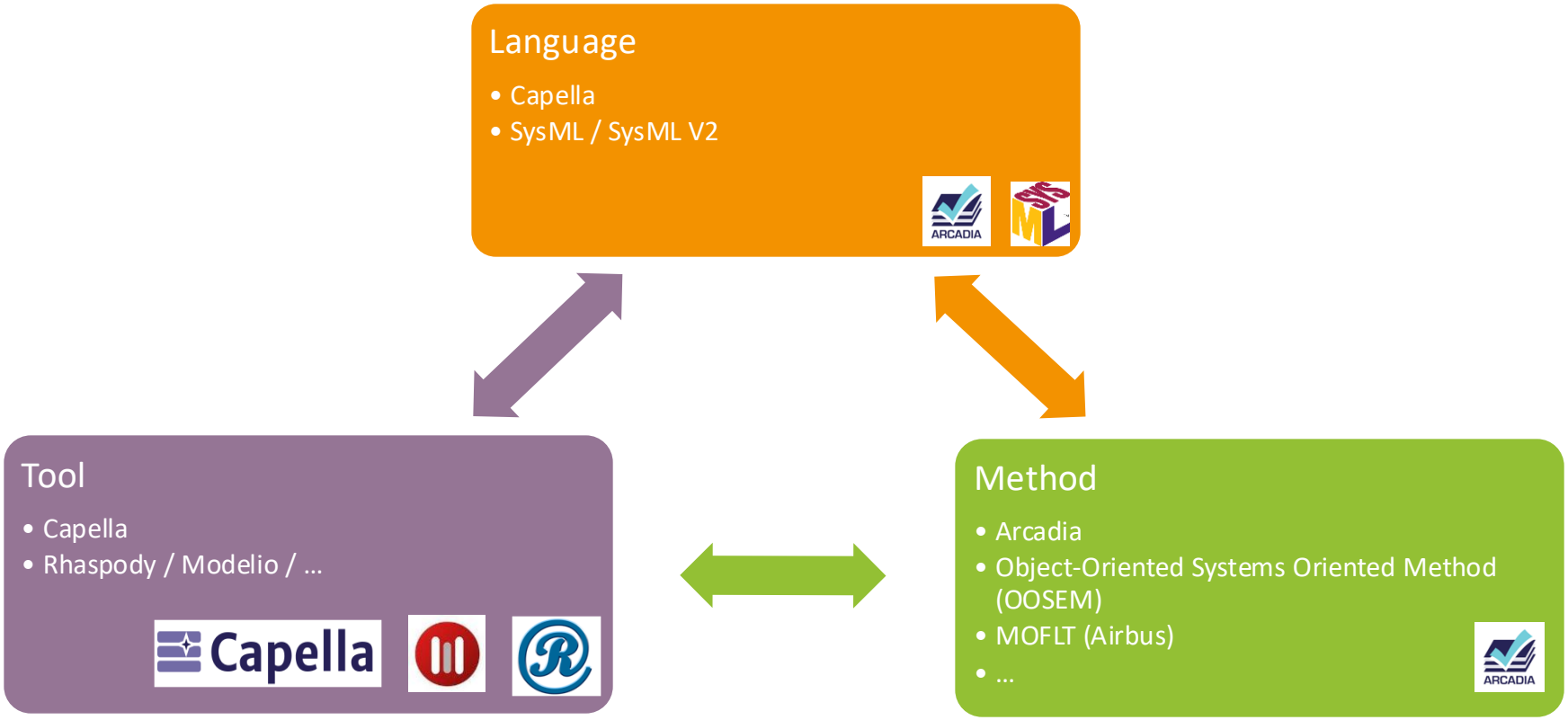
Systems Engineering : origins of Model-Based Systems Engineering

Document-Based System Engineering vs Model-Based System Engineering



Source: INCOSE MBSE Workshop, Jan 2014

MBSE

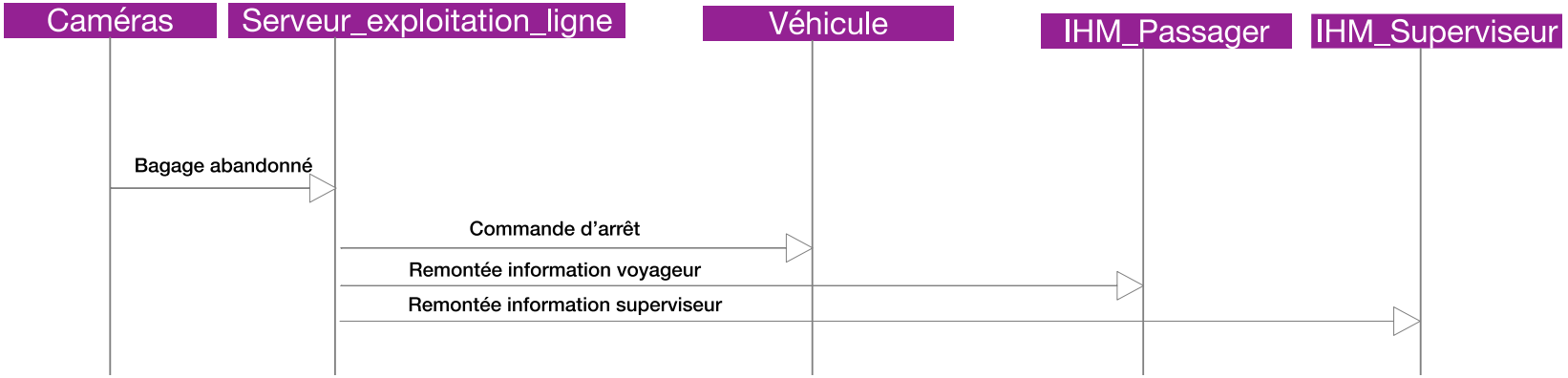

Language
• Capella
• SysML / SysML V2
ARCADIA
Tool
• Capella
• Rhaspody / Modelio / …
Capella
Method
• Arcadia
• Object-Oriented Systems Oriented Method (OOSEM)
• MOFLT (Airbus)
• …
ARCADIA

How to describe a system : requirements, structures, behaviors

- Requirements : What is the system capable of ?
  - High-Level specifications → Detailed, verifiable requirements
- Structure : How is the system structure ?
  - High-level structure → individual systems
- Behavior : How does the system work in different scenarios ?
  - Workflows
  - Message exchange sequences
  - Descriptions

Examples


Vehicule_1
Vehicule_N
Feux
Cameras
Serveur_exploitation_ligne
IHM_Superviseur
IHM_Agent_terrain
IHM_Passager

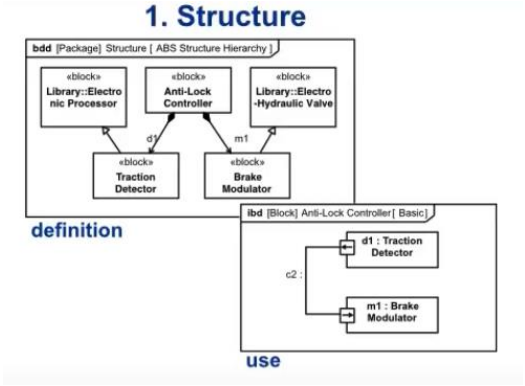

Caméras
Serveur_exploitation_ligne
Véhicule
IHM_Passager
IHM_Superviseur
Bagage abandonné
Commande d'arrêt
Remontée information voyageur
Remontée information superviseur

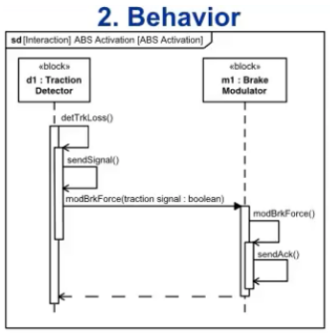
Exercise : Client Specifications

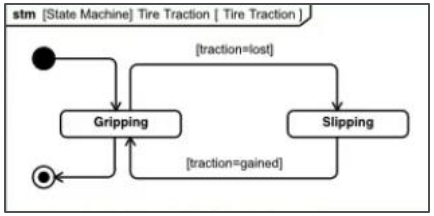
- Goal : « I want to have a robot on Mars that can go around and collect samples. »
- Client specifications :
  - The robot should be able to receive a sample collection site position from the orbiter.
  - The robot should drive autonomously on Mars from its position to the sample collection site.

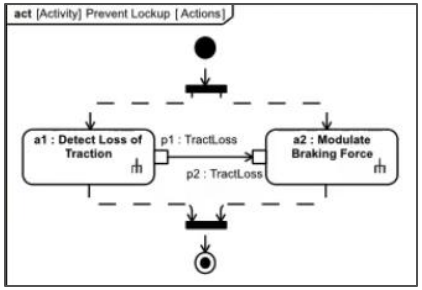
- Let’s build a model together !
- Requirements : What is the system capable of ?
- Structure : How is the system structure ?
- Behavior : How does the system work?

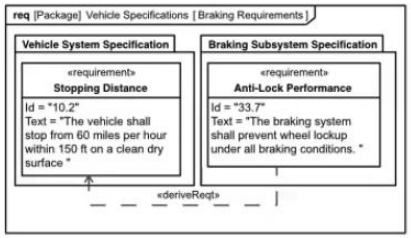
SYSML

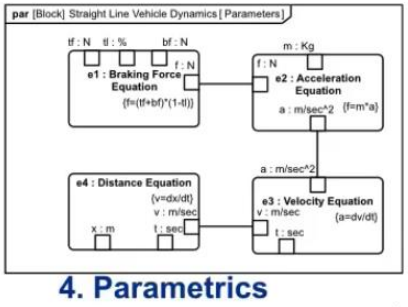






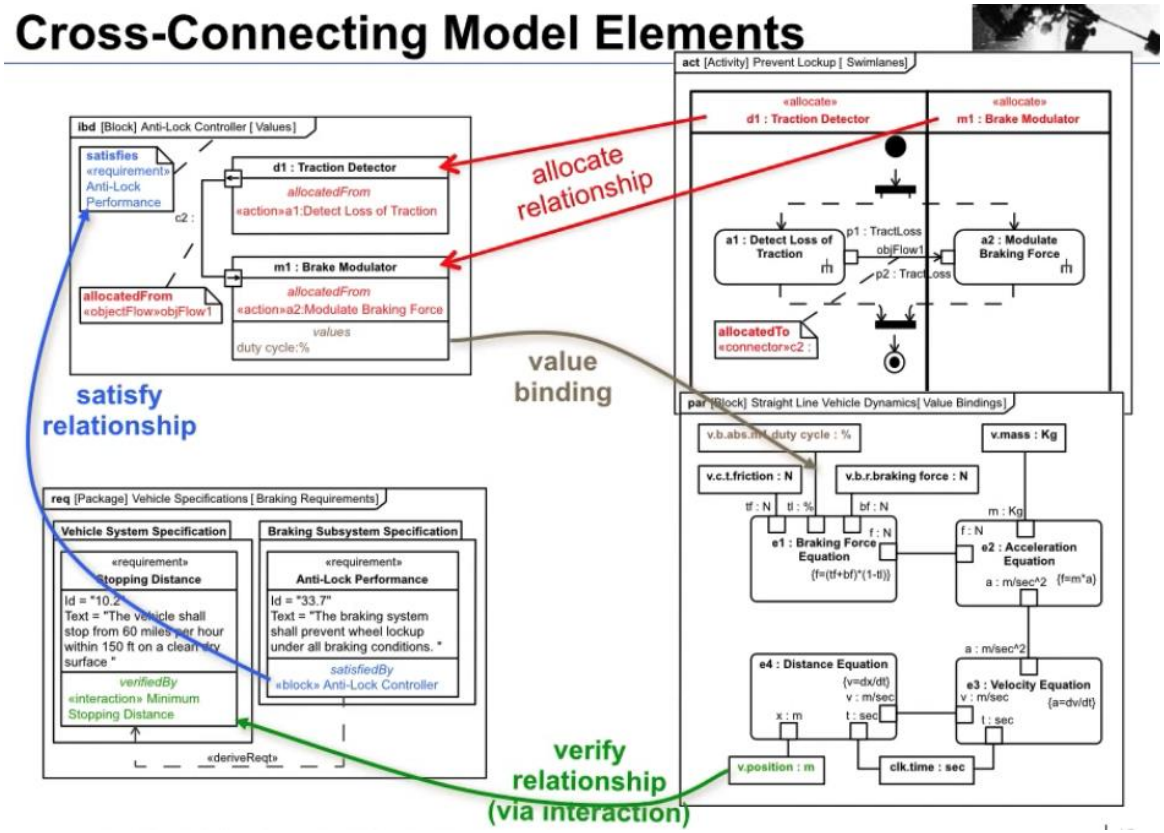






Source : https://www.youtube.com/watch?v=998UznK9ogY

SYSML



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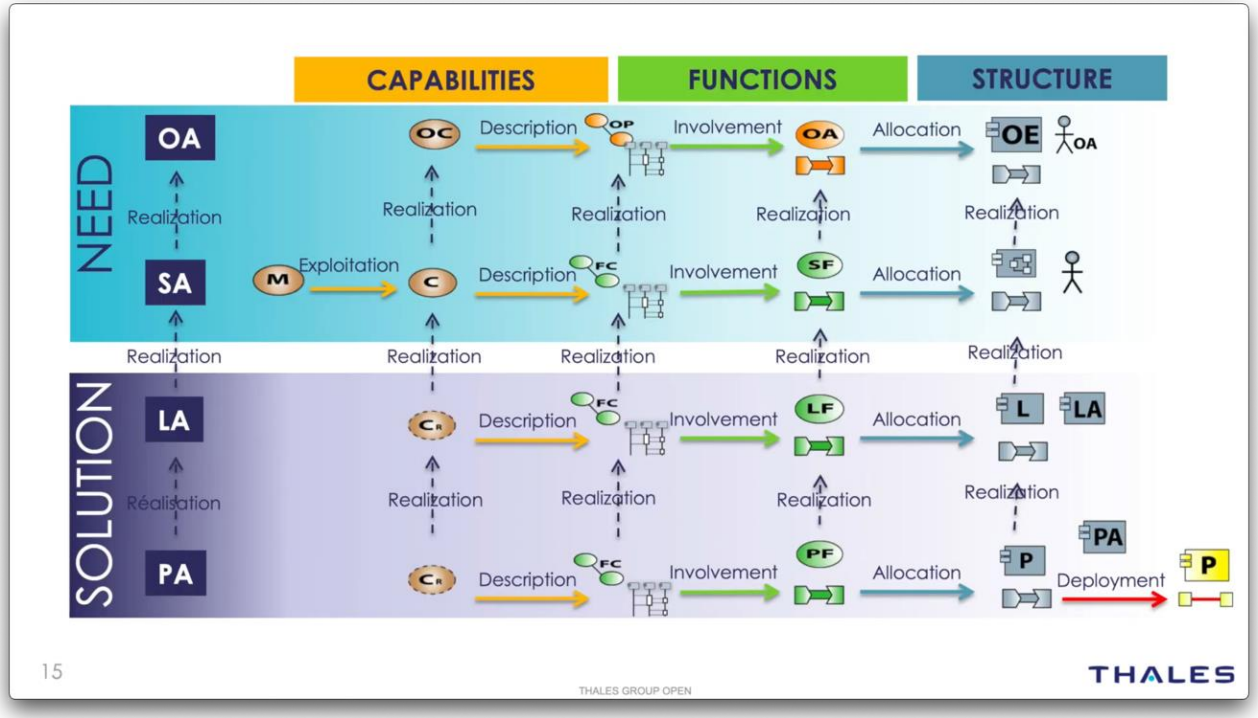
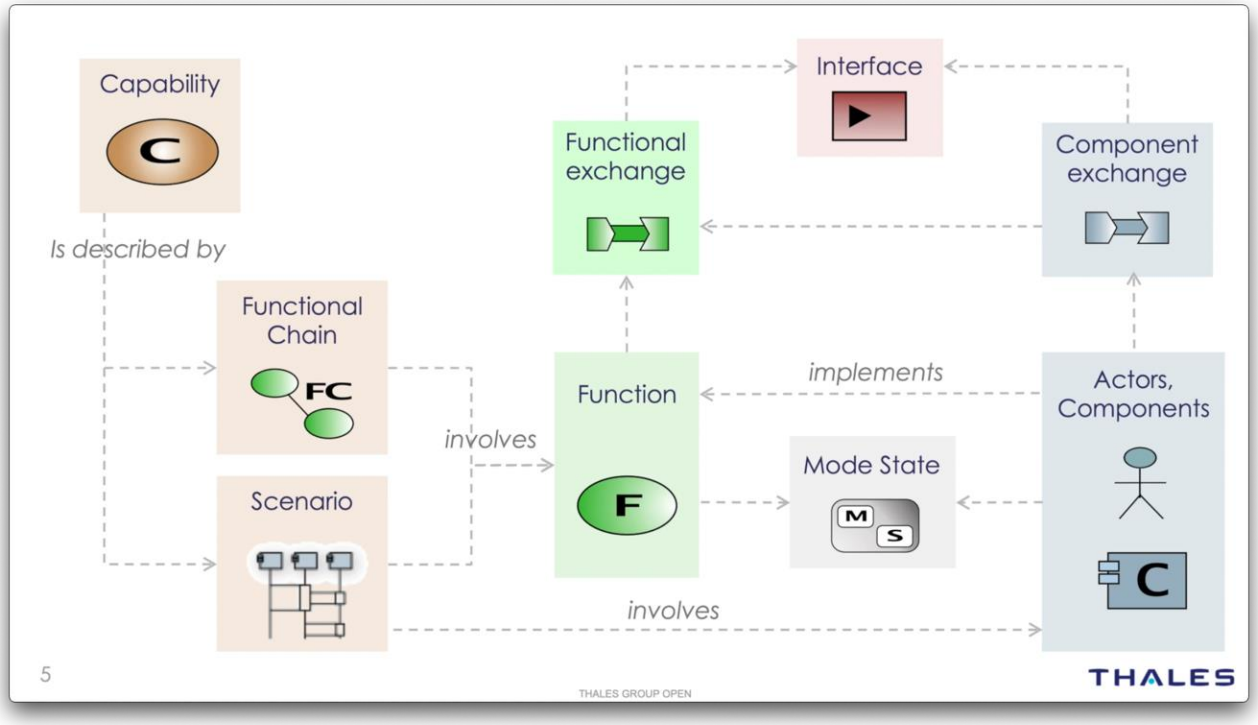
ARCADIA by Thales



Source : https://www.youtube.com/watch?v=BtzhIZUaWA8&list=PLfrEYVpSGVLz4i-rHdkgWbl5jdVzHMRUn&index=3

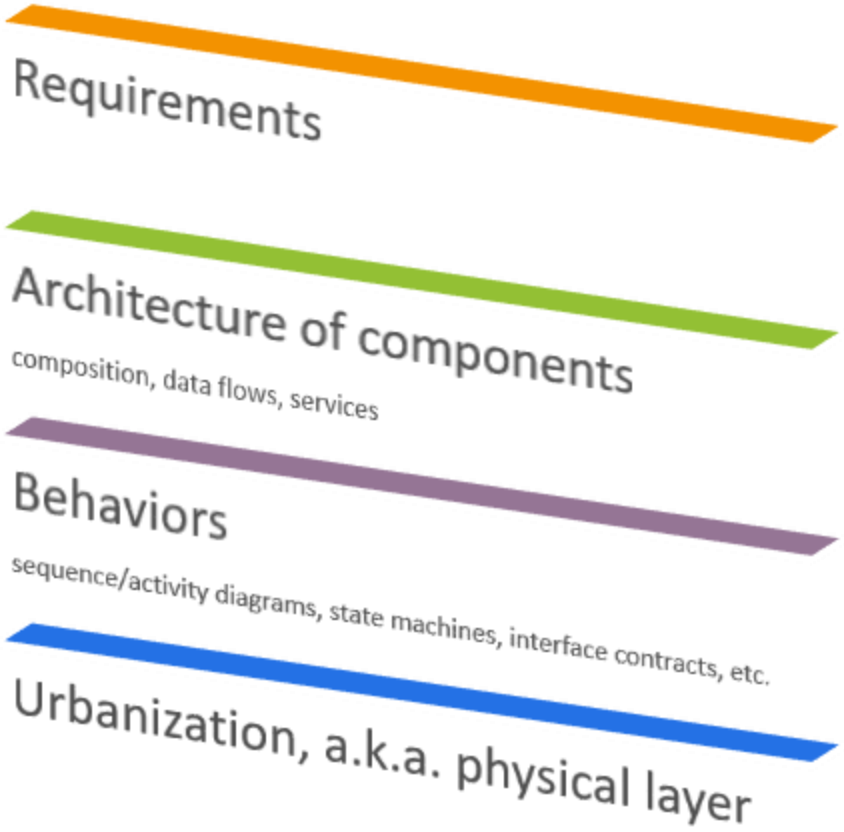
ARCADIA by Thales



Source : https://www.youtube.com/watch?v=BtzhIZUaWA8&list=PLfrEYVpSGVLz4i-rHdkgWbl5jdVzHMRUn&index=3

Core concepts for MBSE

- Commonly expressed reproaches about MBSE
  - “Frightening / boring”
  - “Generates complexity”
  - “Not iterative / not agile”
  - “Bad tools”
  - “Not very collaborative / centered on architects”
  - “Expensive / time consuming”
  - “Does not help coding / makes coding harder”
- The fundamental causes
  - Non-minimal concepts
  - No support for **collaboration** and **iterations**



Core activities for systems engineering and dev.

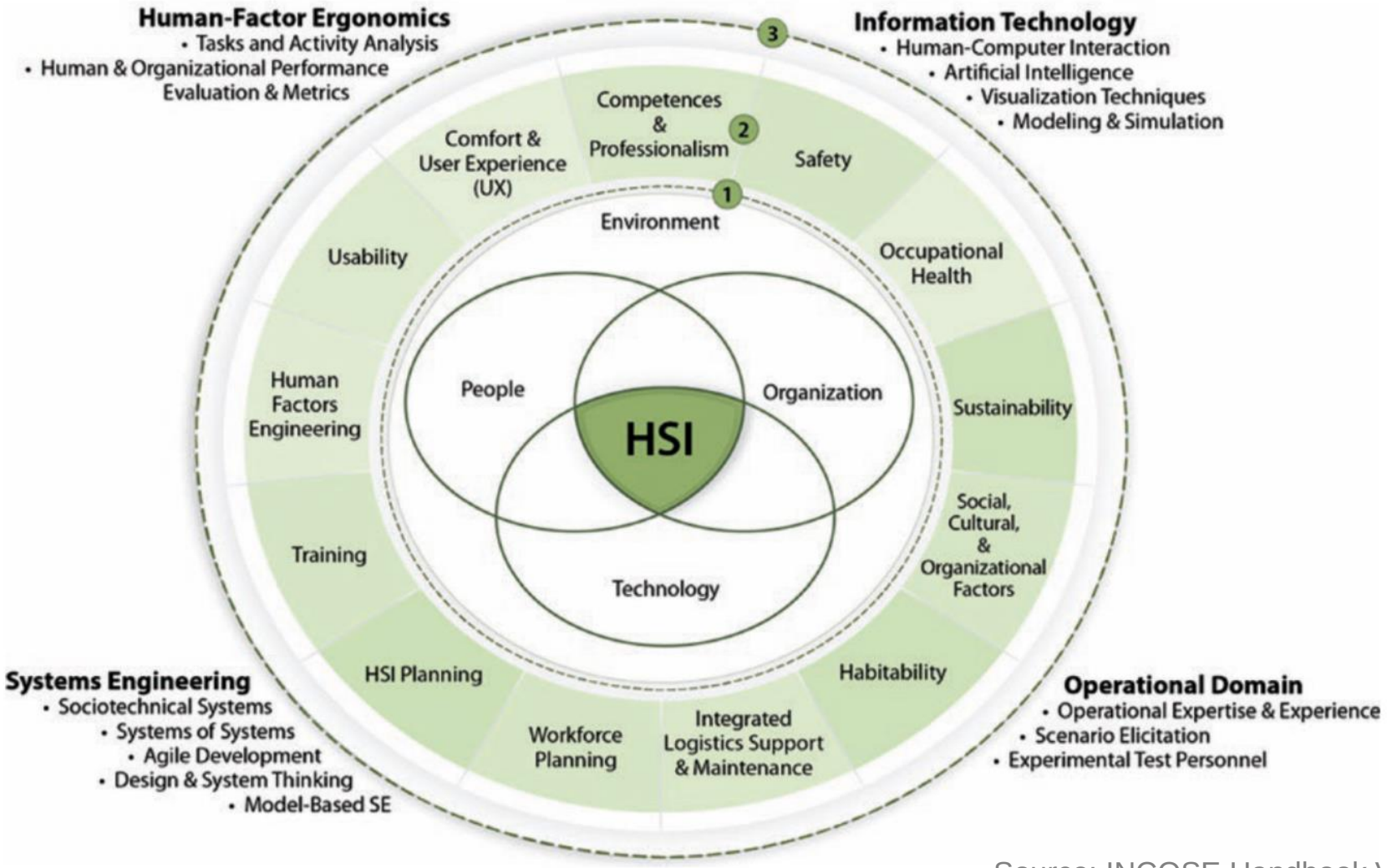
- Required qualities
  - Make the system observable and open from the beginning
  - Continuous assessment against requirements, external systems and the end-users
  - Minimize the cost of iterative tests and changes
  - Offer **continuity** between the activities, models, etc.

Back to the roots : the agile manifesto

Source : https://plays-in-business.com/pibold/wp-content/uploads/2011/03/agile-manifesto1.gif

Introduction of Human System Interaction

HSI Stakes



Source: INCOSE Handbook V5

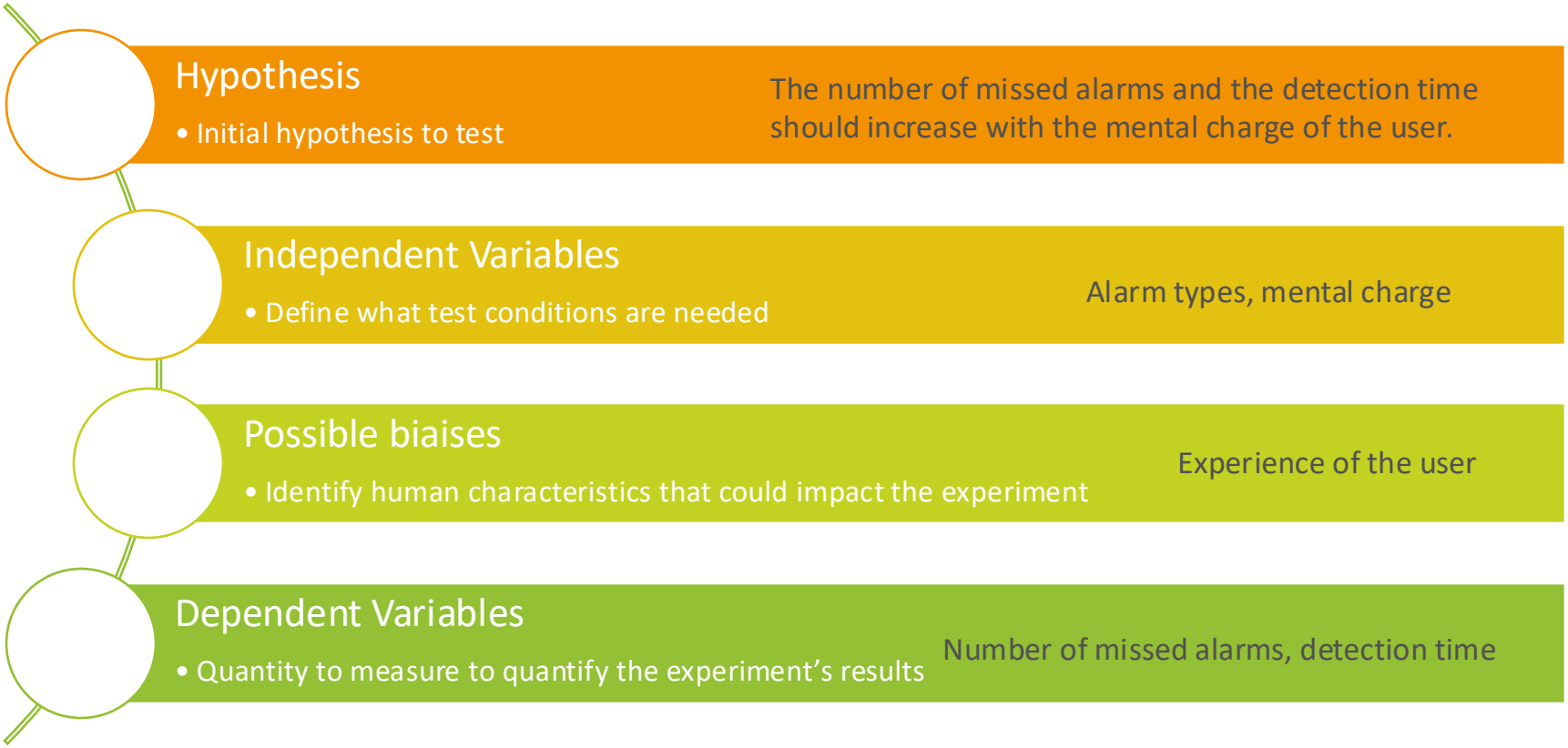
HSI Process


HIGH-QUALITY FEEDBACK
1- Context design
(Domain, organizations, scenarios, tasks, high-level structure, metrics, reqs, ...)
2- Solutions design
(MBSE, UX design, data engineering, reqs allocation, isolated simulations, ...)
models blending & code generation
3- Build, Integration & Verification
incl. digital twins, HW, SW & hybrid simulations
context injection
4- Quantified Validation & Qualification
with Humans + HW + A.I. in the loop
5- Analysis & Decisions

Human In The Loop

- Use domain specific simulators (Simulink)
- Refine user-centred activities
  - Inject and observe data
  - Describe scenarios, procedures
- Perform metrics
  - Record / Replay / Stats
  - Make scientific assessments and Human In The Loop simulations

Design a quantitative experimentation



Define analysis plan

Alarm Type (Visual / Auditive)

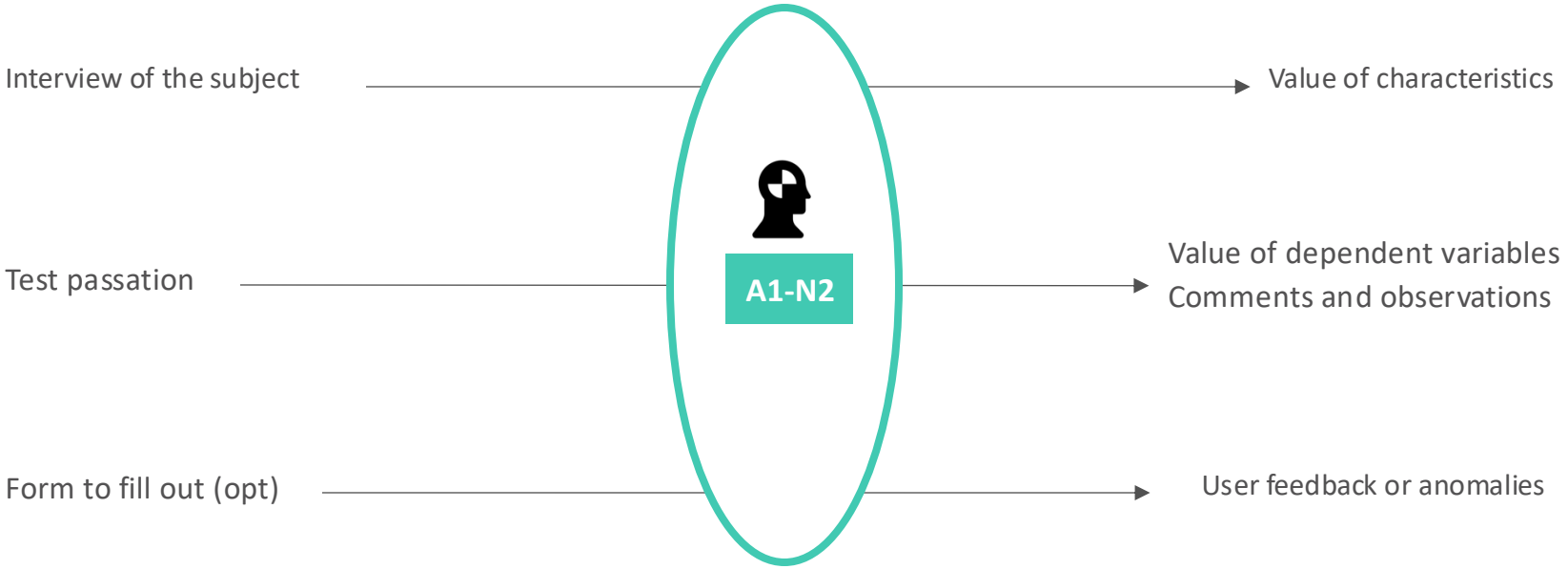
Mental Charge (Easy / Middle / High)

A1-N1	**A1-N2**	**A1-N3**
A2-N1	**A2-N2**	**A2-N3**

Divide into groups that passes one or several test conditions depending on :

- Number of subjects
- Links between independent variables
- Need for completeness

Test Passation



Analyze the data

- For each test passation
  - Independent variables (test configuration)
  - Dependent variables (measured values)
  - Characteristics (interview with the subject)
- Confirm Hypothesis
  - Check for anomalies and biaises
  - Statistical methods to analyze the data

Conclusion

- How to design, integrate and manage complex systems ?
- MBSE :
  - Design structure, behavior, requirements for systems
- HSI :
  - Add human consideration for better performance, usability and reliability
  - Evaluate the system during its development with simulation and assessment
- What can help ?
  - Cosimulation : integrate existing simulations
  - Data record & replay : develop with real data