



Human Computer Interaction course

Part 1

ENSEEIHT

November 2024

WARNING

- This course heavily relies on interactive demos, which are not in the slides. Your attendance is recommended.
- Your exam will consist in developing a small interactive application with technologies you will discover in this course.
- Tutorial sessions will be dedicated to helping you develop your application.

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 architecture 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

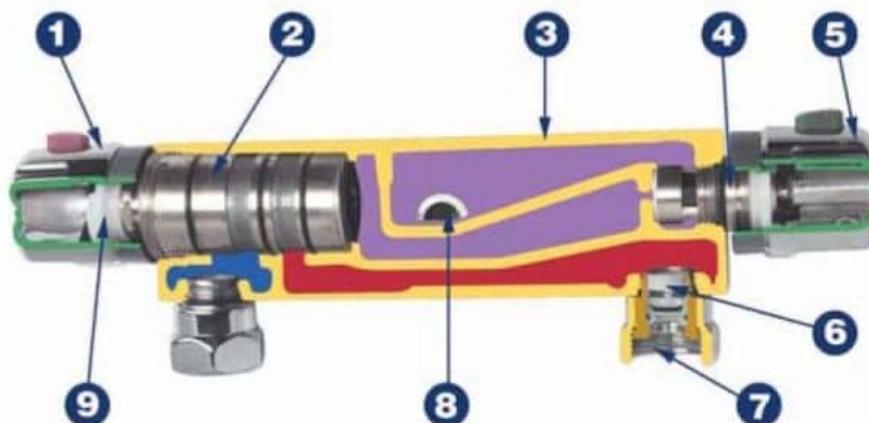
The essence of HCI design



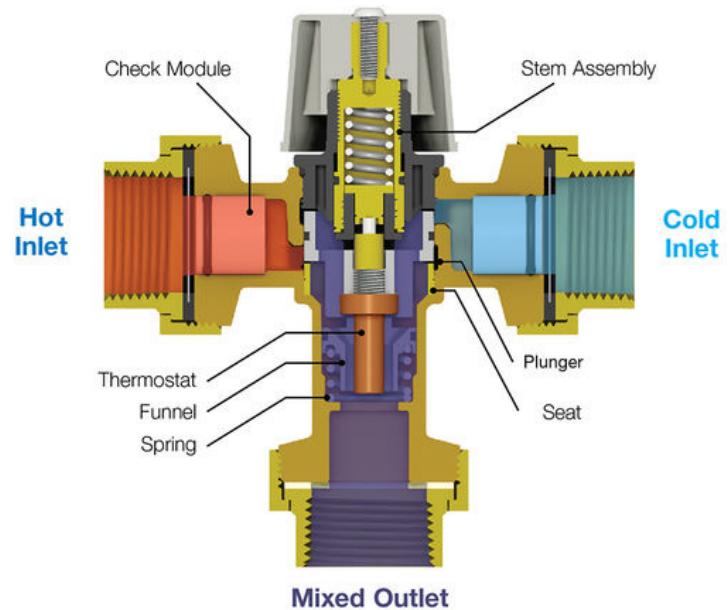
The essence of HCI design

- Do you take showers ?

Mitigeur thermostatique

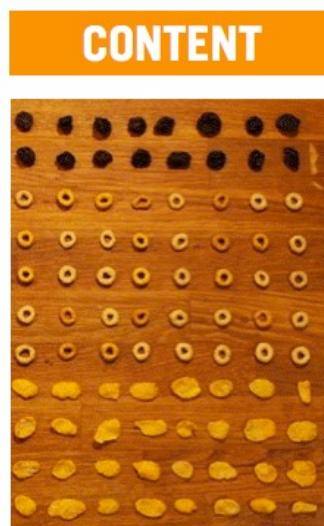


- ① Sélecteur de température
- ② Cartouche thermostatique
- ③ Corps
- ④ Tête céramique
- ⑤ Sélecteur de débit
- ⑥ Clapet antiretour
- ⑦ Écrou prisonnier
- ⑧ Sortie flexible de douche
- ⑨ Système d'étalonnage

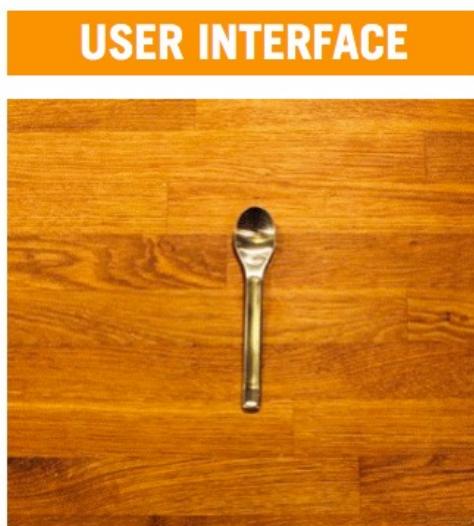


- Identify relevant system data, data to be displayed, and data to be manipulated by the users
- Define the logic between system data and user data (a.k.a. HCI functions)
- Find the best forms for data presentation and manipulation

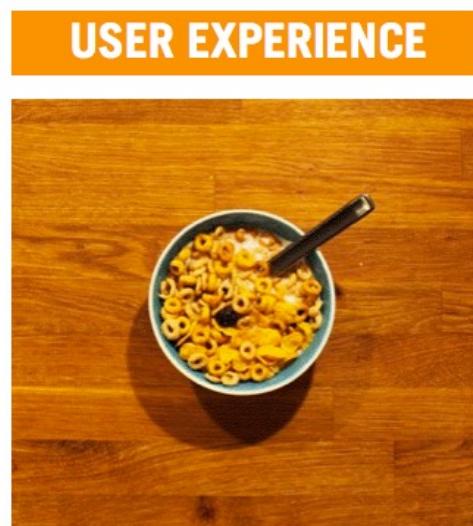
The essence of HCI design



What people are looking for.



The tool that serves it up.

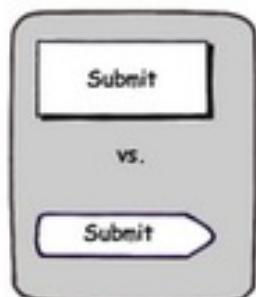


Consumption.



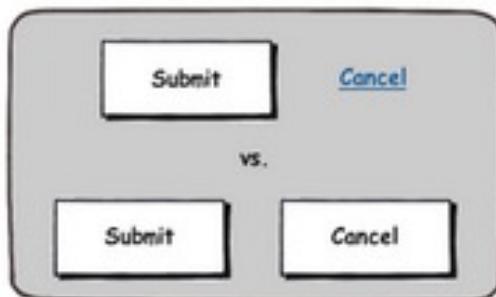
DESIGNING THE PRODUCT DESIGNING THE EXPERIENCE

UI Design



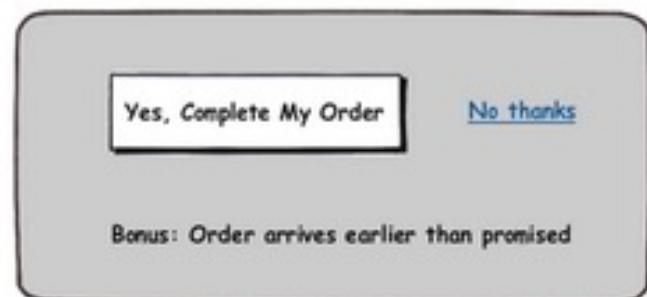
Function: It works.

Usability Design



Action: It works well.

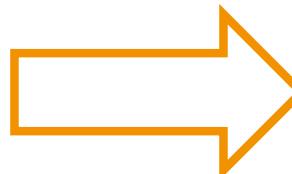
User Experience Design



Emotion: It works well and makes me say Wow!

Which expertise and methodology for HCI ?

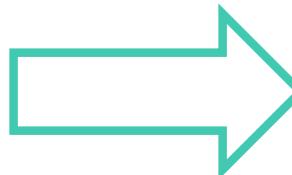
System
+
Human



Multidisciplinary

- System expertise = engineers
- Human expertise = ergonomists
- Creators = designers & engineers

Analysis
+
Creativity
+
Evaluation



Iterative

- Express the problems
- Create and improve solutions
- Evaluate the problems & solutions

User-centered

- Human is the key to acceptability and performance
- A system is only a tool, even with A.I. and automation

System users are not only the “end-users”

- Any system has to be

Designed
Built
Validated
Used
Maintained
Disposed

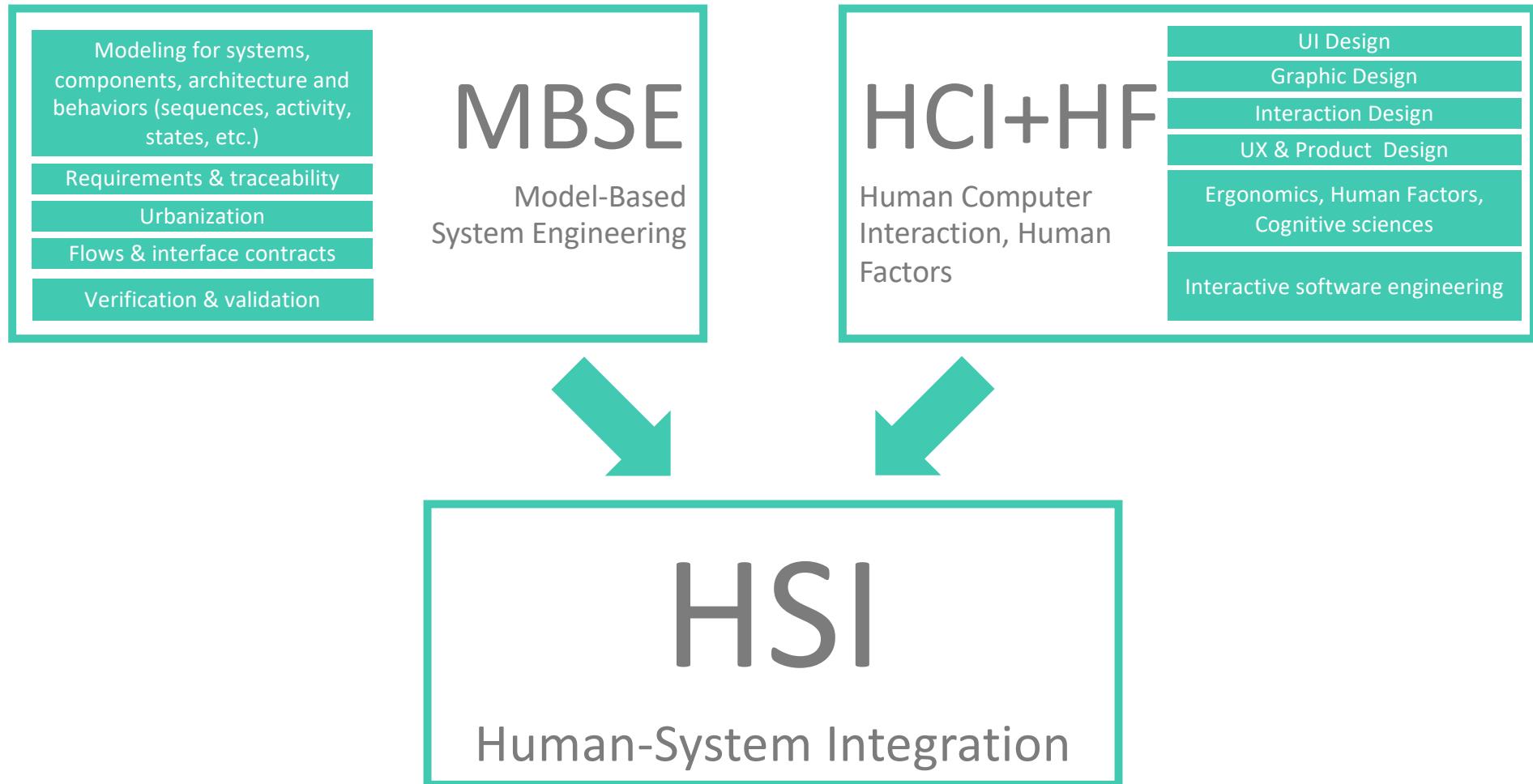
All these steps require users in the loop, who interact with the system in various ways.

The key is to maintain consistency at all stages of the system lifecycle.

Shocking revelation: This is not done very well in most industries and most companies, because people lack

- A shared & evolutive vision, supported by a “common language”
- Really collaborative environments, practices and tools
- Properly trained managers and organizations

A comprehensive approach to engineering interactive systems



What are the challenges?

- Multidisciplinary teams



- Iterative approaches



**Full continuity of the models & requirements,
iteratively refined during the whole project lifecycle**

Design, development and deployment of interactive operational environments

Ingenuity io

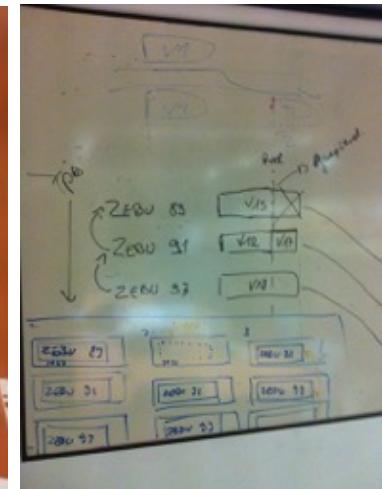


Full-scale real-time supervision and regulation for RER A & B



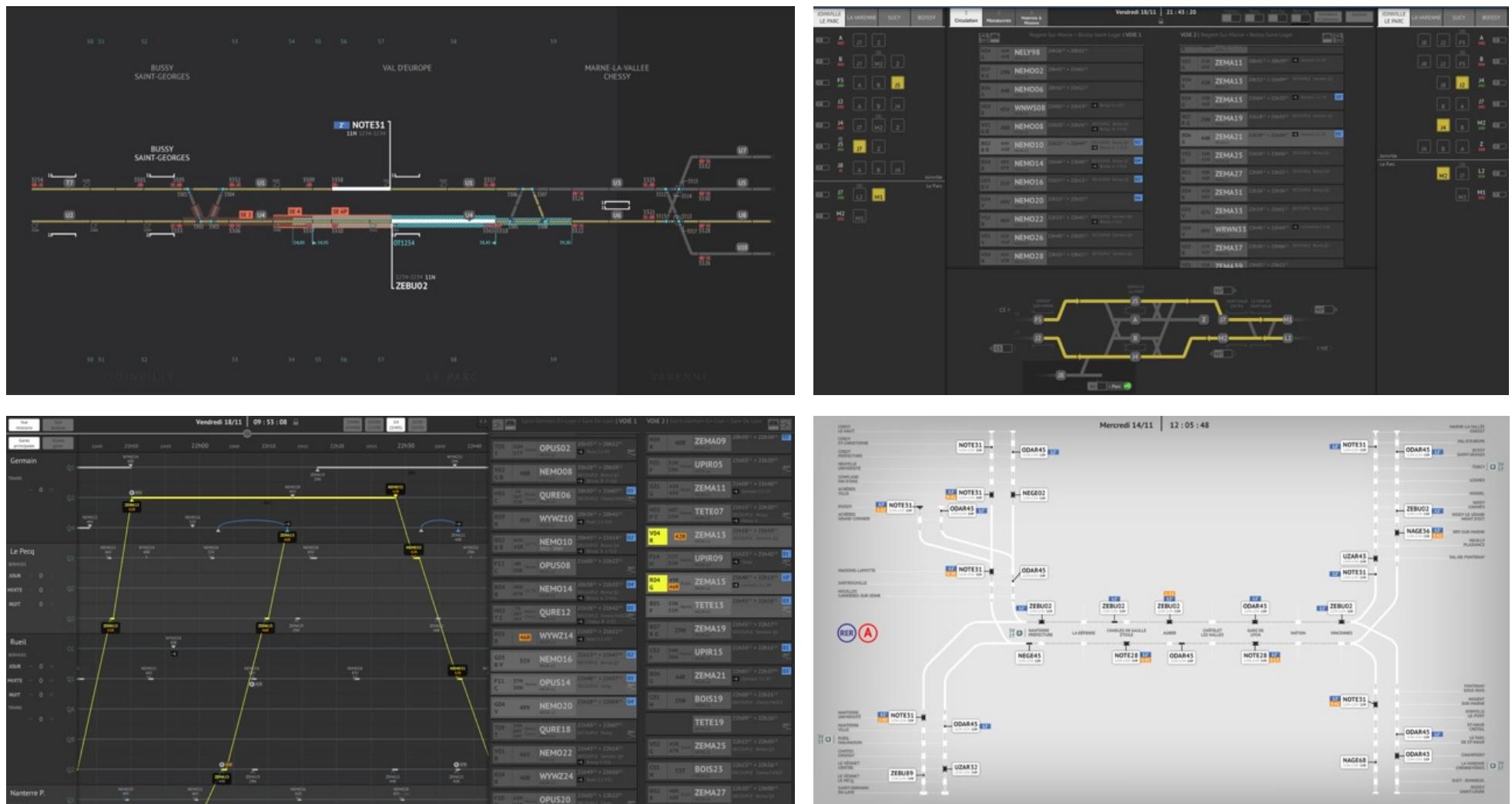


User research, ideation





UI/UX design





MBSE

LIBRARY

Classes

Search a Class or a Package...

< **Package-Tasman** ... +

Envoi des commandes poste

Fonctions Support

Gestion des Alarmes >

Gestion des Manoeuvres >

Gestion des Matériels

Gestion des prises de commandes >

Liste des Missions

TASMAN_Commandes

TASMAN_Supervision

SystemName_Library

CCU > Package-Tasman

TASMAN_Commandes

DESCRIPTION

Le système TASMAN constitue l'interface informatique pour le contrôle et la commande nominal des postes de signalisation au sein des CCU à disposition notamment des Aiguilleurs et des CREG.

INPUTS (17)

- TK**

Télécontrôle _ Décrit les états de contrôles des objets de la ligne permettant la gestion des manœuvres. Les objets sont les suivants : itinéraires, autorisations, cycles, KF, contre-sens, zones, aiguilles, signaux de manœuvres, ATs.
Un TK peut prendre uniquement 3 valeurs : éteint, clignotant ou fixe. Un TK avec les valeurs « 1 1 » sont rejetés et l'anomalie est loguée.

TK
Le message contient les éléments suivants :
String Type de TK
Int Numéro du PRS
String Nom de l'objet dans les équations TE14
Booléen Valeur fixe (0 : non fixe, 1 : allumé fixe)
Booléen Valeur clignotante (0 : non clignotant, 1 : clignotant)
- TC_TK_indisponible**

Décris les états d'indisponibilité des Télécontrôle et Télécommandes. Les TC/TK indisponibles sont transmises par la conversion TC/TK lors de la perte partielle (un CDST) ou totale d'un SITUP.

TC_TK_indisponible
Le message contient les éléments suivants :
String Type de la TC ou de la TK
Int Numéro du PRS
String Nom de l'objet dans les équations
Booléen État d'indisponibilité de la donnée : 0 = disponible et 1 = indisponible
- Jeton_commande_PRS**

Search...

DESCRIPTION

INPUTS (17)

- TK
- TC_TK_indisponible
- Jeton_commande_PRS
- Demande_jeton_commande_PRS
- Alarme_Sans_Filtre
- Alarme_Filtre_Habilitation_2
- Materiel_atelier
- Offre_transport
- Mission
- Mission_passage
- Missions_liste
- Service_conducteur
- Service_conducteur_segment
- Evenement
- Materiel_faisceau_RATP
- Suivi_mission_RATP

OUTPUTS (4)

- Acquittement
- Commande_poste
- Materiel_faisceau
- TC

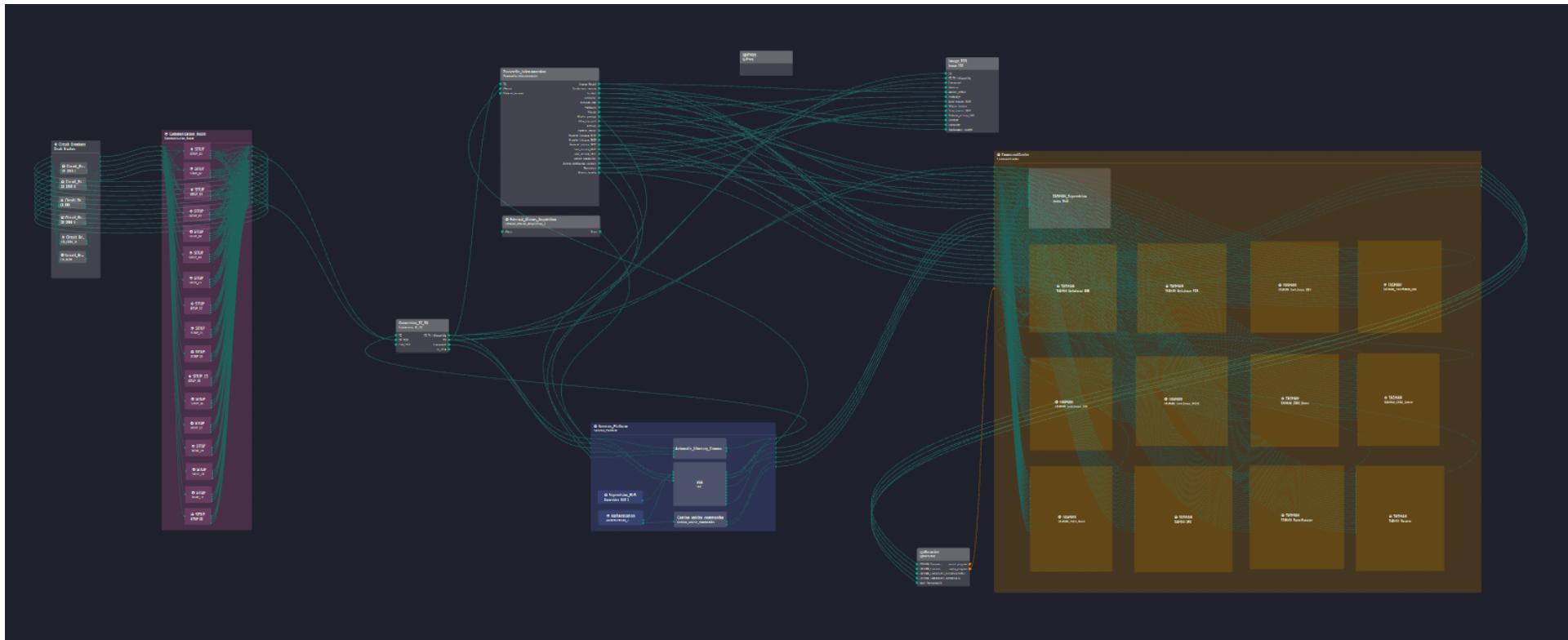
ATTRIBUTES (0)

SERVICES (13)

- receive_TC_TK
- open_session
- close_session
- error_login
- get_TASMANCommandes_data
 - receive_TASMANCmd_data
- get_TOTEM_data
- receive_synchro_BDD



MBSE





MBSE: requirements

This screenshot shows a MBSE tool interface for managing requirements. The left sidebar lists various system components and their sub-components, with some items highlighted in orange. The main area displays requirements details for specific entries, and the right side shows associated actors and stakeholders.

LIBRARY

Requirements

Search a reference...

- > Organisation du terminal TASMAN
- > Principes et ergonomie des commandes
 - ✓ Principes de commande
 - EXI_MOP_SPF_397-C_750
 - EXI_MOP_SPF_397-C_751
 - EXI_MOP_SPF_397-C_752
 - EXI_MOP_SPF_397-C_753
 - EXI_MOP_SPF_397-B_754
 - EXI_MOP_SPF_397-B_755
 - EXI_MOP_SPF_397-B_756
 - > Ergonomie des commandes
 - > Colorimétrie
 - ✓ Contrôler l'accès des utilisateurs
 - EXI_MOP_SPF_397-B_330
 - ✓ Administration de l'annuaire
 - EXI_MOP_SPF_397-C_440
 - EXI_MOP_SPF_397-C_441
 - EXI_MOP_SPF_397-C_442
 - EXI_MOP_SPF_397-C_443
 - EXI_MOP_SPF_397-C_444
 - ✓ Ouverture de session
 - EXI_MOP_SPF_397-B_450
 - EXI_MOP_SPF_397-B_451
 - > Fin de session
 - ✓ Gérer les profils utilisateurs
 - ✓ Gérer les métiers
 - EXI_MOP_SPF_397-B_480
 - EXI_MOP_SPF_397-B_481
 - ✓ Gérer les zones de responsabilité
 - EXI_MOP_SPF_397-C_490
 - EXI_MOP_SPF_397-C_491

SystemName_Library

EXI_MOP_SPF_397-C_750

Emission d'une commande d'itinéraire

L'émission de la commande d'un itinéraire en DA s'effectue par une simple pression sur le repère de destination depuis la zone de commandes itinéraires. La réception du contrôle de l'itinéraire formé en DA est matérialisée par l'état suivant :



Required constraint

```
{  
    ask "Effectuer un appui simple sur l'itinéraire S3/S5 de Boissy"  
    assert TASMAN_Commandes_1.TC = "TC_IT_DA 18 IT_S3/S5_DA 1"  
}
```

Assumed constraint

```
TASMAN_Commandes_1.TK = "TK_IT_DA 18 S3/S5_DA 0 0"  
TASMAN_Commandes_1.TK = "TK_IT_TP 18 S3/S5_TP 0 0"
```

TASMAN

- + Actor
- + Stakeholder

Input TASMAN.TK

- + Actor
- + Stakeholder

SGE

- + Actor
- + Stakeholder

EXI_MOP_SPF_397-C_751

Etats d'un service provisoire

Lorsqu'un SP est commandé et qu'il est à l'état activé, un objet graphique est présenté sur l'écran de contrôle. Cet objet graphique peut présenter 2 états :



- Clignotant : Le SP est en cours d'activation ou de désactivation
- Fixe : Le SP est activé.

EXI_MOP_SPF_397-C_752

Déclenchement alarme lors d'une perte de TC-TK

Le sous-système SGE doit générer des alarmes liées à un dysfonctionnement du système de signalisation lors de la perte des TC/TK (1 alarme globale pour chaque PRS).



MBSE: Verification & Validation

SystemName_Library

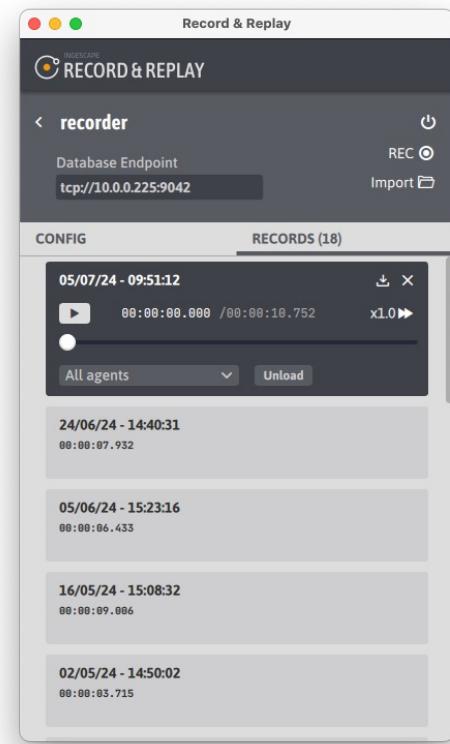
TASMAN_02-02-SIG-ItineraireSimple Run

...

```
1 // Ce test permet de valider les commandes et contrôles liés à des itinéraires hors groupe de voie de faisceaux disponible
2 uniquement en DA
3 // LAPP_1BE;D406-1;4.6.1.1;4.7.1;4.8
4
5
6 //Ouverture de session (droits aiguilleur) et attribution des jetons de commande
7 TASMAN_Commandes_1.open_session("TASMAN", "RATP", "AIG", "12345", "1")
8 TASMAN_Commandes_1.Jeton_commande_PRS = "JETON_PRS 18 TASMAN_Commandes_1"
9
10 // Changement d'onglet
11 whisper TASMAN_Commandes_1 "TASMAN_ONGLET_PRS 18"
12 sleep 1000
13
14
15 "EXI_MOP_SPF_397-B_810; EXI_MOP_SPF_397-B_850;EXI_MOP_SPF_397-B_2470; EXI_MOP_SPF_397-D_2310; EXI_MOP_SPF_397-B_2300;
16 EXI_MOP_SPF_397-B_2320" "Acquisition des états de contrôle sur un itinéraire non disponible en TP" {
17     "Itinéraire détruit" {
18         // Comparaison Iti V1
19         //whisper TASMAN_Commandes_1 "TASMAN_SNAPSHOT /home/i2/Documents/TestsAutomatises/TASMAN/Images/Test 02_02_itiv1_detruit"
20         sleep 1000
21         //compare "/home/i2/Documents/TestsAutomatises/TASMAN/Images/Test/02_02_itiv1_detruit.png" "/home/i2/Documents/
22 TestsAutomatises/TASMAN/Images/Ref/02_02_itiv1_detruit.png" 734*1966+0+154
23
24         // Comparaison Troncons
25         //whisper TASMAN_Commandes_1 "TASMAN_SNAPSHOT /home/i2/Documents/TestsAutomatises/TASMAN/Images/Test 02_02_Troncon_detruit"
26         sleep 1000
27         //compare "/home/i2/Documents/TestsAutomatises/TASMAN/Images/Test/02_02_Troncon_detruit.png" "/home/i2/Documents/
28 TestsAutomatises/TASMAN/Images/Ref/02_02_Troncon_detruit.png" 2315*780+765+1393
29     }
30
31     "Itinéraire enregistré" {
32         TASMAN_Commandes_1.TK = "TK_IT_DA 18 R4/B1 0 1"
33         sleep 1000
34
35         // Comparaison Iti V1
36         //whisper TASMAN_Commandes_1 "TASMAN_SNAPSHOT /home/i2/Documents/TestsAutomatises/TASMAN/Images/Test
37 02_02_itiv1_DA_enregistre"
38         sleep 1000
39         //compare "/home/i2/Documents/TestsAutomatises/TASMAN/Images/Test/02_02_itiv1_DA_enregistre.png" "/home/i2/Documents/
```



MBSE: Validation & Qualification



Continuous model-based supervision
System is always observable & actionable

Model-based scripting
+ No-code data record, replay & export
For testing, assessments, in-depth analysis & training

Model-based Validation & Qualification
With scenarios, context, simulations and humans in the loop, in addition to the system itself
Supporting multidisciplinary & regulated strategies

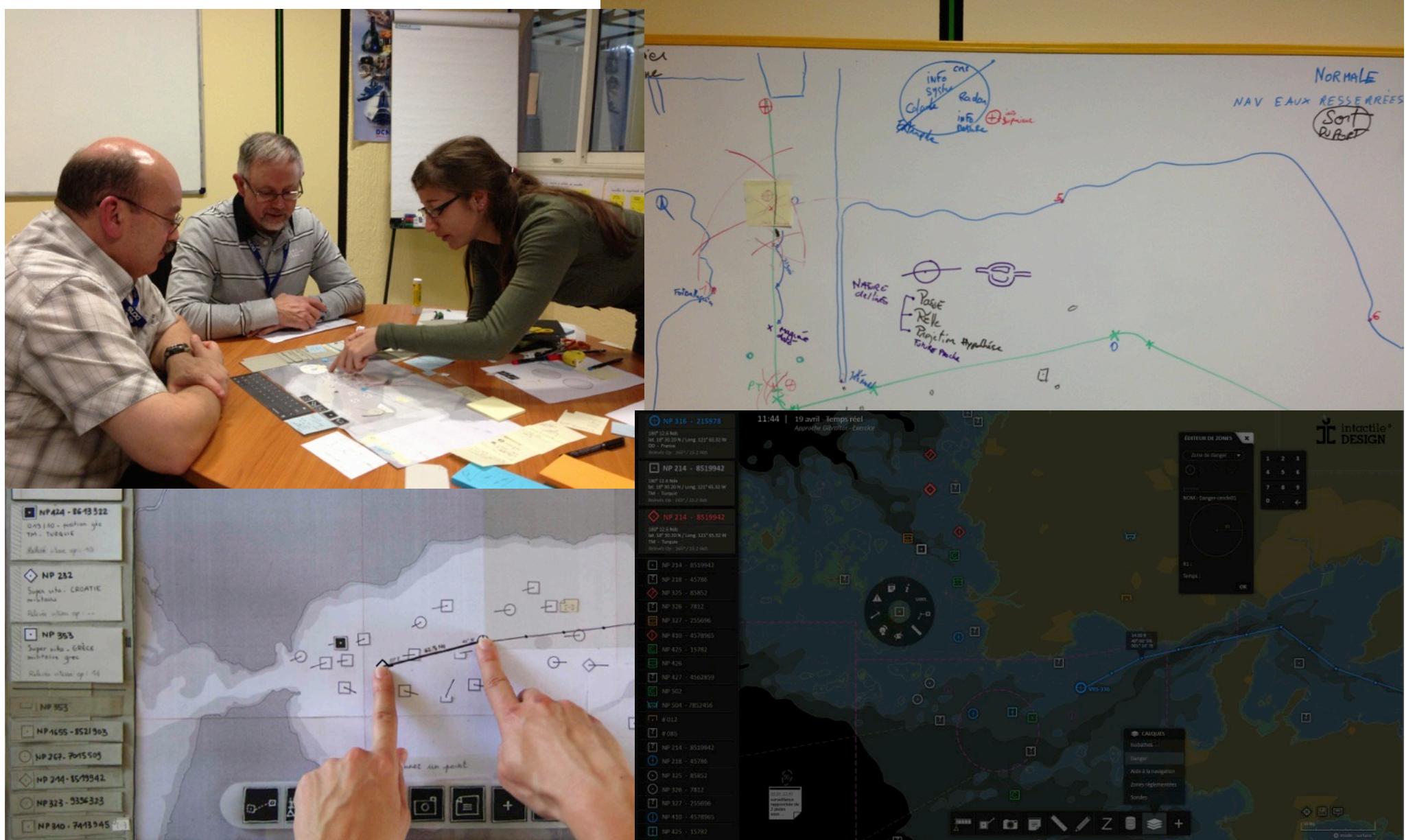


Collaborative table for tactical operations embedded in military ship's operational center

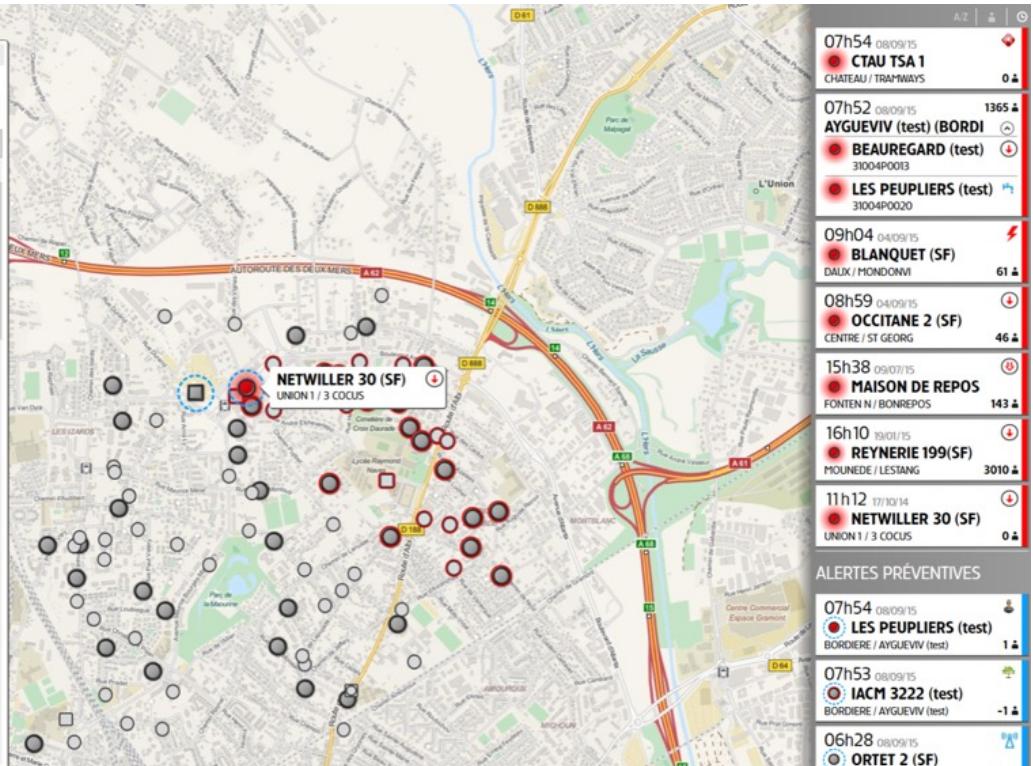
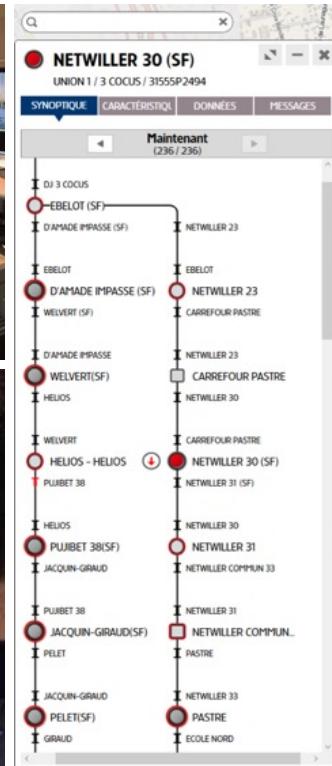


NAVAL

GROUP

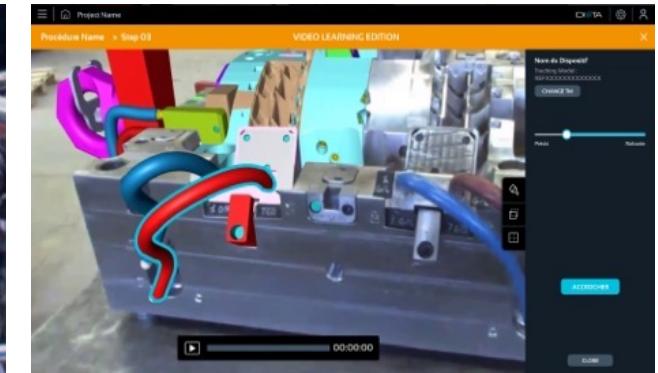


Smart grid supervision with thousands of IoT devices, Big Data and augmented reality



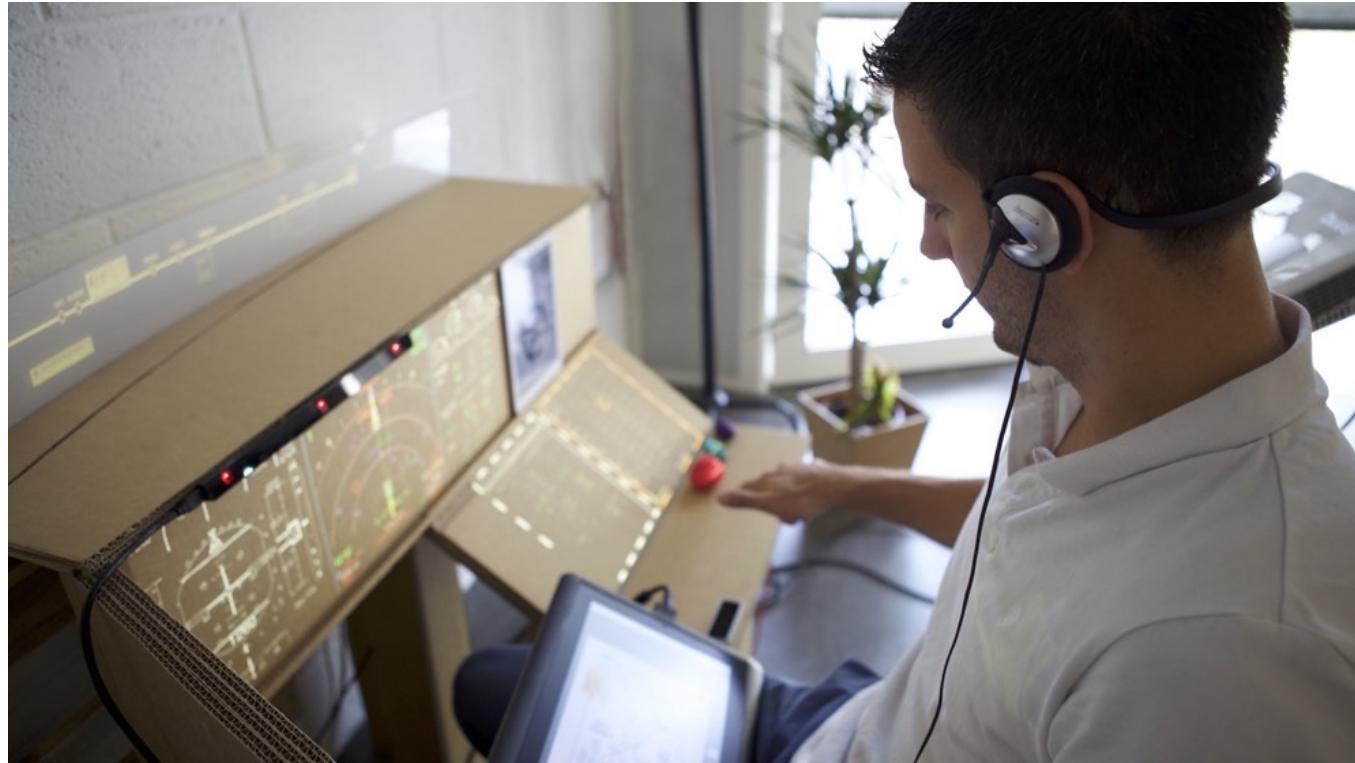


**Live guidance and collaboration for industrial assembly
and quality control, using 3D and augmented reality**



AIRBUS

Advanced cockpit prototyping supporting state-of-the-art iterative and multidisciplinary methodologies



https://www.youtube.com/watch?v=9Gr1Le_F7jU

How did we handle these projects ?

- We have structured multidisciplinary collaborations in software teams and (re)conciliated agile, user-centered and iterative methodologies.
- We have developed the technologies and tools to support and accelerate the resulting processes.



INGESCAPE

Distributed software systems

Why have distributed systems become so important ?

- Geography
 - Systems and data are now decentralized and distributed
 - Resources and software now spread on multiple locations
- Heterogeneity
 - Systems gather many technologies, making interoperability a major stake
 - Teams want to work with their own techniques & tools in agile dynamic contexts
- Reusability
 - Despite the ambient complexity, problems often repeat themselves, and so should the solutions
 - Service-oriented architectures are a real solution but often poorly designed or implemented
- Collaboration
 - Humans and machines are parts of the same interactive environments
 - Interactions always happen in parallel and on-the-fly, sometimes concurrently

State of the art for distributed systems

Client/server

Web services : HTTP, SOAP/REST, XML/JSON

SOA : Service Oriented Architectures

ESB : Enterprise Service Bus

Cloud : virtualization, containerization

Messaging & protocols



MBSE / MDA

MBSE : Model-Based Software Engineering

MDA : Model-Driven Architecture



Ingescape...

Full-scale software interoperability



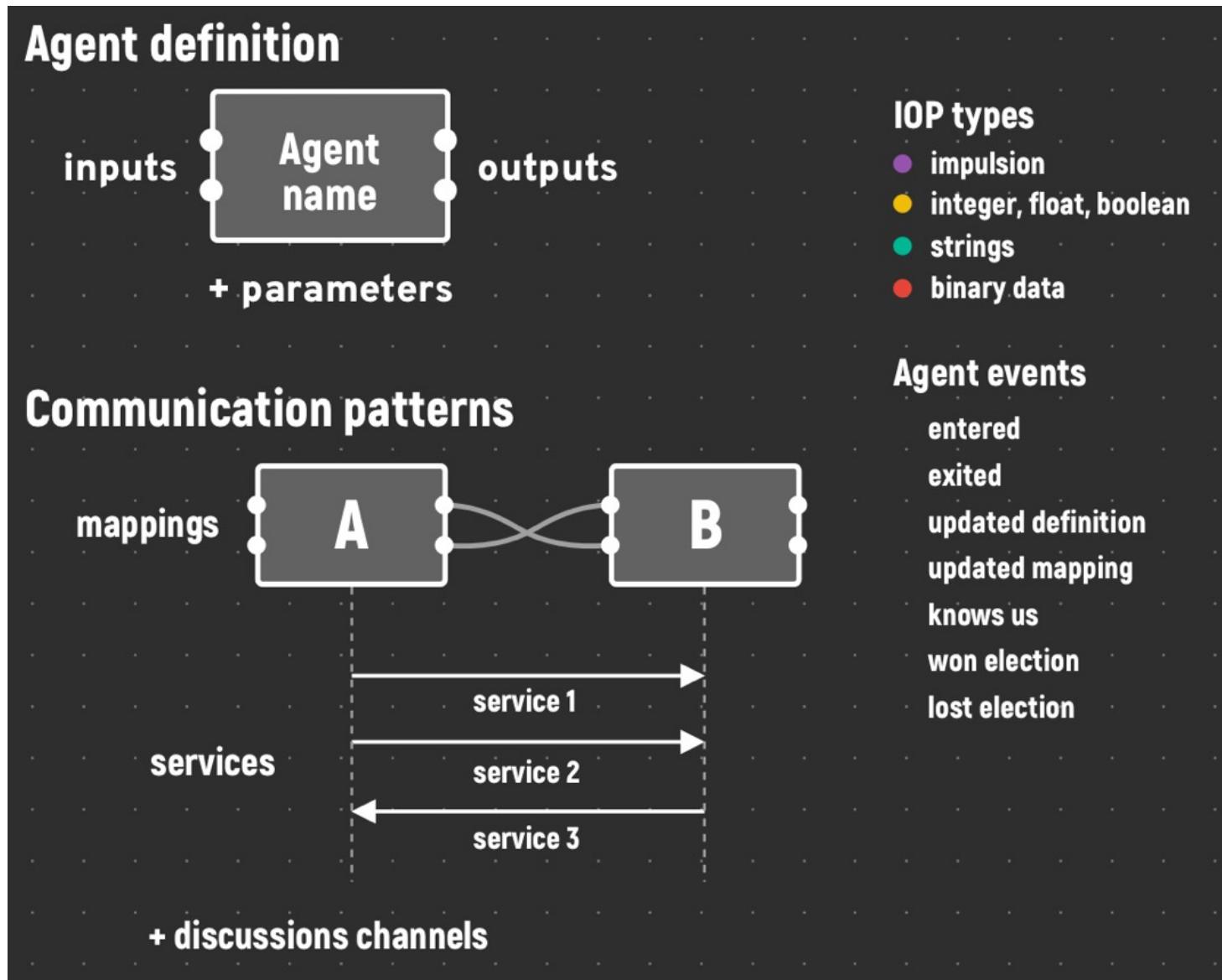
INGESCAPE
Library

Any language, any OS, web, cloud, **open source**

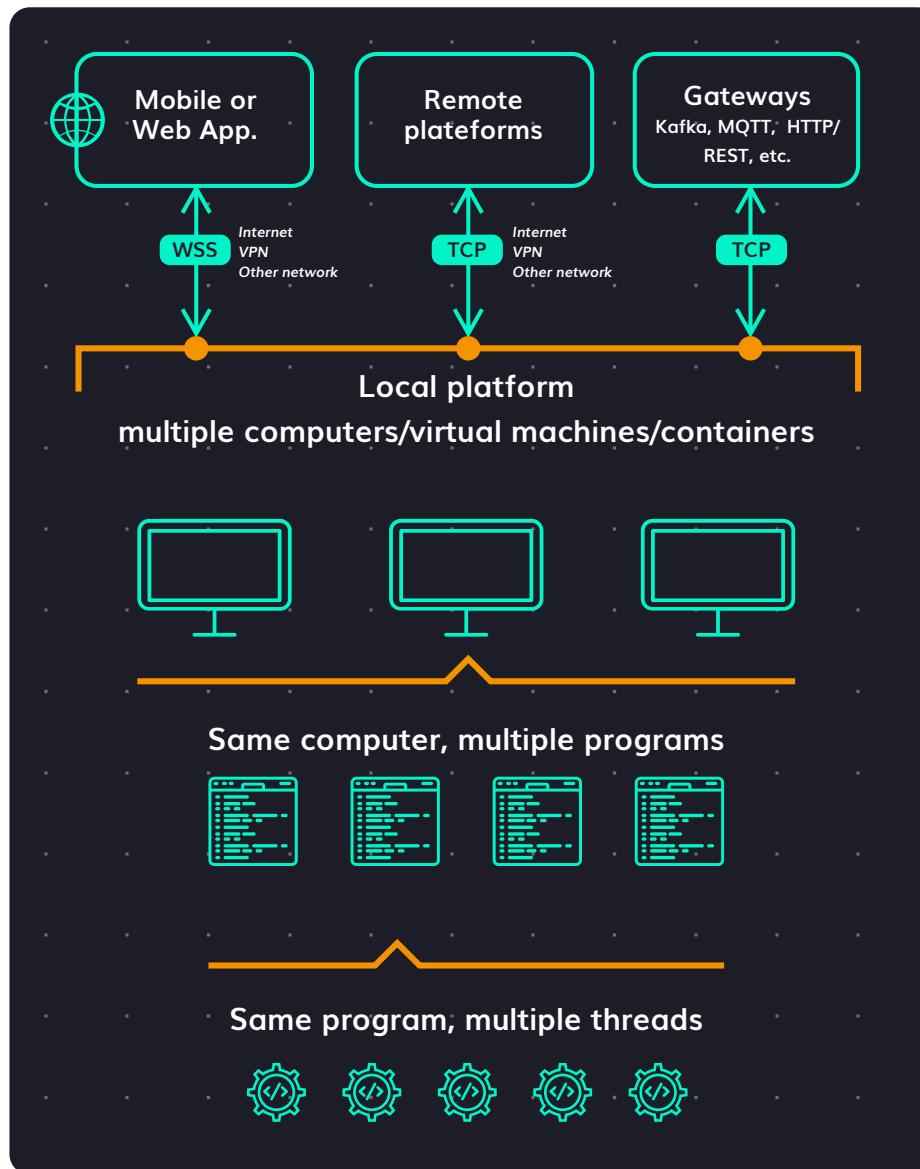
Highly-supervised + fully-decentralized
Model-based

<https://github.com/zeromq/ingescape>

The Ingescape concepts in a single picture



Scalability from worldwide systems to CPU-level high performance computing





A cornerstone for all phases in an industrial project

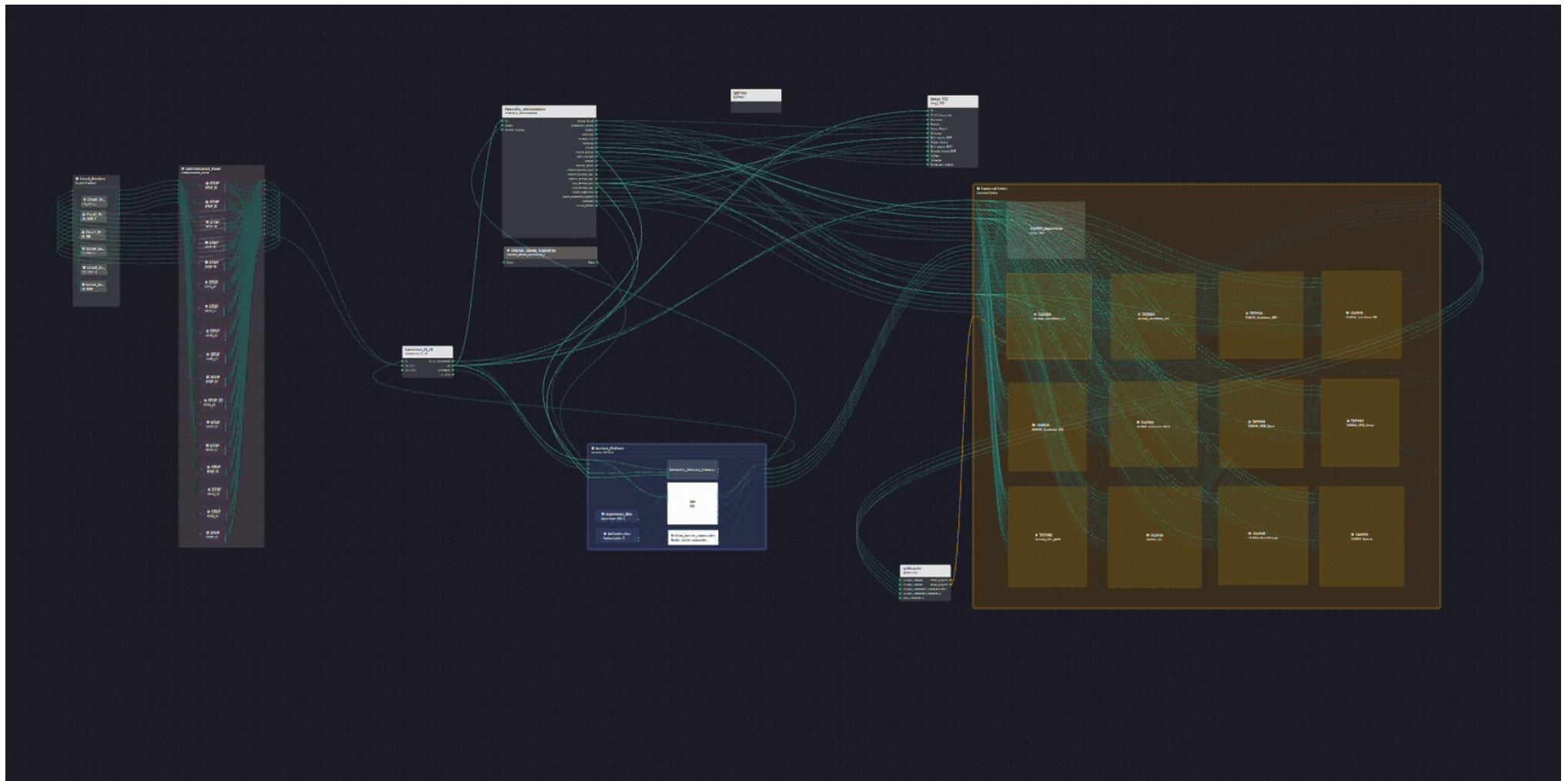


- Mix models for architecture, software classes, network protocols, UI graphics, etc. to generate fully customizable code, preserving your preferred languages and frameworks
 - ⇒ Use code generation to bootstrap apps without losing control on your code
 - ⇒ Architecture model remains embedded in the code
- Give developers efficient visual tools that help them on a daily basis
 - ⇒ Enable iterative coding with active architect/developer collaboration
- Continuous model-based testing at unit, local and global levels
 - ⇒ Enable collaborative & constructive testing, avoiding surprises and tensions
 - ⇒ Open to iterative automatable Verification & Validation (V&V)

Ingescape is OPEN

- Open source
 - The Ingescape library is hosted on ZeroMQ's github pages as a full part of the ZeroMQ community, under the MPLv2 license
 - The Ingescape security layer is based on the libsodium encryption library
- All Ingescape models are transcribed in JSON
 - Easy to read, parse and generate
 - Open to third-party and home-made tools
- Ingescape embeds or instantly connects to many industry standards
 - Protobuf for serialized binary data
 - MQTT, Apache Kafka, RabbitMQ and other software buses
 - HTTP/REST, websockets, TCP, UDP and many other protocols
- Ingescape already provides bootstrap projects for
 - Cmake, Qt, Visual Studio, Xcode, NodeJS, etc.
 - C/C++/Obj-C, C#, Python, Java, HTML/CSS/JS, etc.
- Ingescape Circle is customizable and extensible
 - with any kind of specialized tools and modules that would address specific or generic needs.

Before & after Ingescape



Networked Systems of Systems become **observable, actionable, measurable & verifiable**
Seamlessly combine design, simulations, development, IVVQ & operations

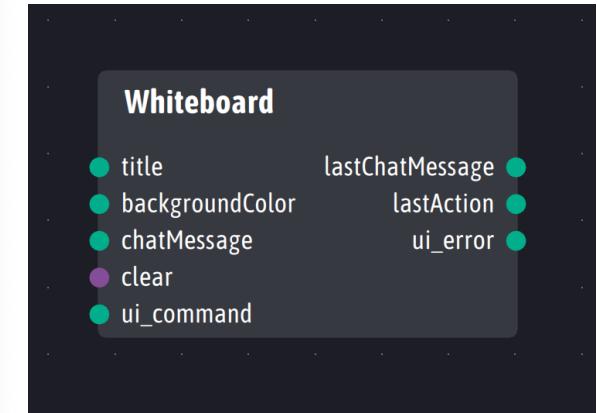
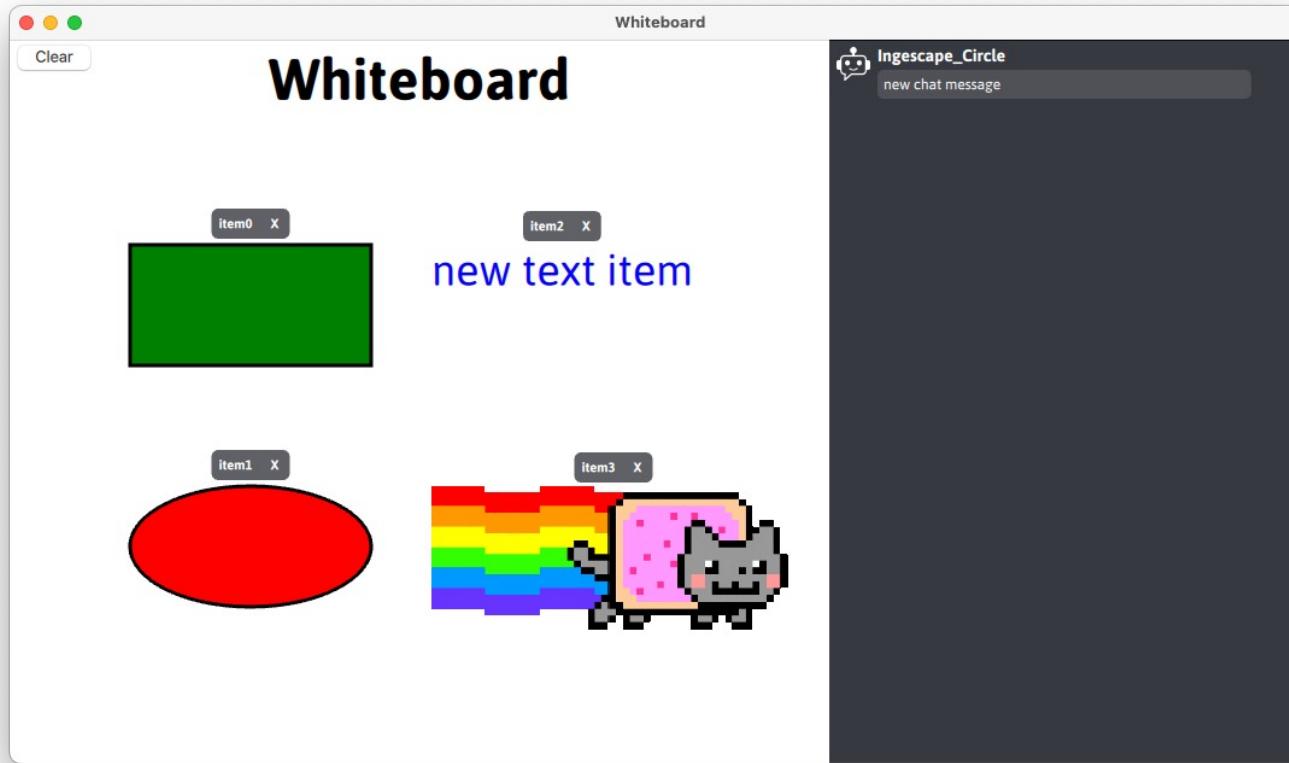
Your HCI project

Students project philosophy

- Exploring HCI/HSI principles by the creation of a system of systems involving the contribution of groups of 3 students each
- Enabling groups to collaborate between them and with the teachers
- Applying good industrial practices
 - Multidisciplinary design (UX, MBSE, software) with a user-centered approach
 - Iterative prototyping and development
 - Specification and model-based V&V
- Reaching an actual result in record time (around 1 month)
- Ultimately making you touch what it takes to design an interactive system that actually works

We provide one agent...

- The WhiteBoard application
 - Fully described in the **WhiteboardDemo.igssystem** file



...you provide the others around it

A

Android app

Send pictures, add text and draw figures to the white board. Show what is on the white board and enable real-time interaction.

- Or you can propose your own agent...

...you provide the others around it

A	Android app Send pictures, add text and draw figures to the white board. Show what is on the white board and enable real-time interaction.
B	Speech recognition and synthesis Convert vocal commands to interact with the white board. Tell what happens on the white board.
C	AI-based image generation Text-based image generation sent as image to the white board. Image generator as a service from the white board chat.
D	VR or Web client Display the content of the white board. Provide interactions and ability to contribute (text, geometry, images) in real-time.
E	IoT environment Use IoT devices and hardware to enrich the white board experience by notifying events and enabling physical interactions.
F	Chatbot Conversational agent to interact with the white board, both to query its state and event, and to contribute to the content (text and geometry).

- Or you can propose your own agent...

Examples of students' projects

Whiteboard

The interface includes a text-based log of player inputs and errors, and a visual representation of a complex red and white blocky maze on a black background.

Musée Virtuel

The interface shows a list of items corresponding to the displayed images, likely representing a digital catalog or exhibition.

EndlessMazeRace

The interface includes a text-based log of player status and a message indicating all players are ready for the game to start.

Whiteboard

The interface includes a text-based log of player inputs and errors, and a chatbot window with commands like 'l'aide' and 'prochain <couleur>'.

Evaluation criteria

- Quality of the proposed User eXperience /5
 - Utility, efficiency, comfort, robustness
- Completeness of the integration with the white board /5
 - Use of the white board's inputs, outputs and services in your own agent
 - Bonus points if you interact with other agents for an extended user experience.
- System engineering /5
 - Agent requirements
 - Minimal specifications for your agent (less is more)
 - Complete V&V scripts with traceability to your requirements
- Coding /5
 - Documentation
 - Ability for the teachers to compile and run the code
 - Clarity, concision and robustness

Calendar

Friday December 6th

- Groups formation (3 students per group)
- Each group registers by sending an email to n7@ingenuity.io with the student names and subject chosen

Calendar

Friday December 6 th	<ul style="list-style-type: none">Groups formation (3 students per group)Each group registers by sending an email to n7@ingenuity.io with the student names and subject chosen
Monday December 16 th	<ul style="list-style-type: none">1st practical work session, assisted by the Ingenuity teamTechnical choices, compilation, debug environment
Wednesday December 18 th	<ul style="list-style-type: none">Practical exchanges on your exam projects<ul style="list-style-type: none">Short briefs
Wednesday January 8 th	<ul style="list-style-type: none">2nd practical work session, assisted by the Ingenuity teamContinuous testing, V&V scripting, live integration
Friday January 10 th	<ul style="list-style-type: none">Last practical work session, assisted by the Ingenuity teamIntegration and testing with the white board and other agents
Monday February 3 rd	<ul style="list-style-type: none">Project delivery to n7@ingenuity.io (less than 9MB) or Github<ul style="list-style-type: none">Documentation, ingescape platform for integration and tests, V&V scripts, source code, compiled code

The (multidisciplinary) team involved in this course



Stéphane



Mathieu



Alex



Chloé



Madeline



Aurélien

Where to get Ingescape and other resources ?

- The open source Ingescape **library repository**
 - <https://github.com/zeromq/ingescape>
- The Ingescape **Circle installer**
 - <https://repository.ingescape.com/circle-v4/>
- The **license and resources for this course**
 - <https://ingescape.com/n7>
- The open repository for the **Whiteboard agent**
 - <https://gitlab.ingescape.com/learn/whiteboard>
- Cheat sheets for Ingescape
 - Python: <https://ingescape.com/ingescape-python/>
 - NodeJS: <https://ingescape.com/ingescape-nodejs/>
 - Java: <https://ingescape.com/n7/java/>
 - C# and HTML/CSS/JS: Ask us.