



# INGESCAPE

by Ingenuity i/o

## A breakthrough tool suite for Extended System Engineering, Systems Interoperability and Human-System Integration

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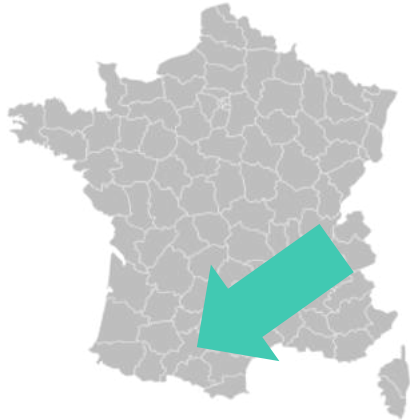
How to **break the complexity wall** in modern systems and  
**support multidisciplinary teams** at all steps of **complex systems lifetime**?

[vales@ingenuity.io](mailto:vales@ingenuity.io)

<https://ingescape.com>

# Ingenuity I/O

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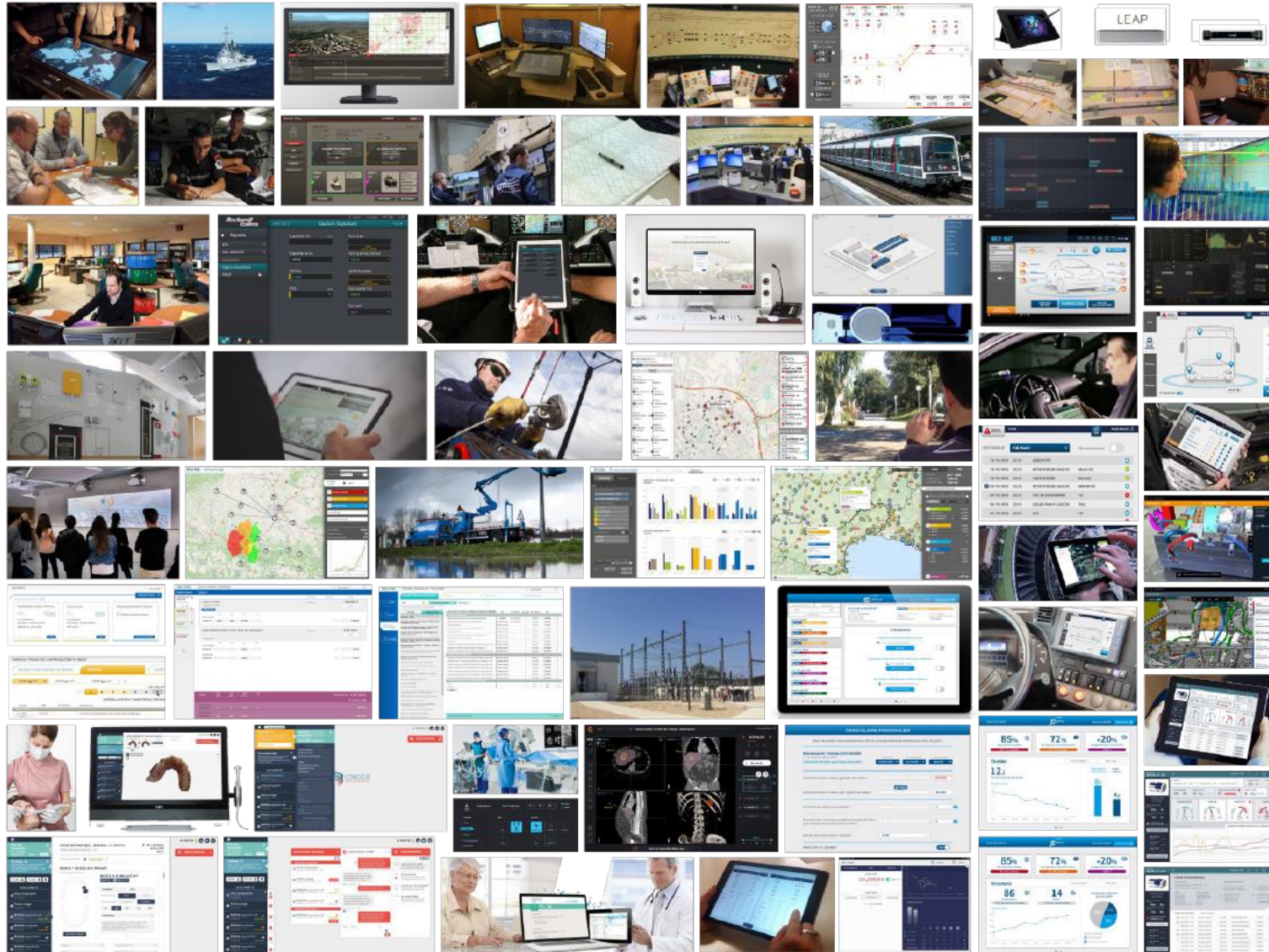


- Toulouse, France
- Since 2012
- Designers + human factors specialists + engineers + software developers

design, develop & deploy  
complex **systems of systems**  
with **humans & automation** in the loop,  
in the **real world**, for projects of **various sizes**

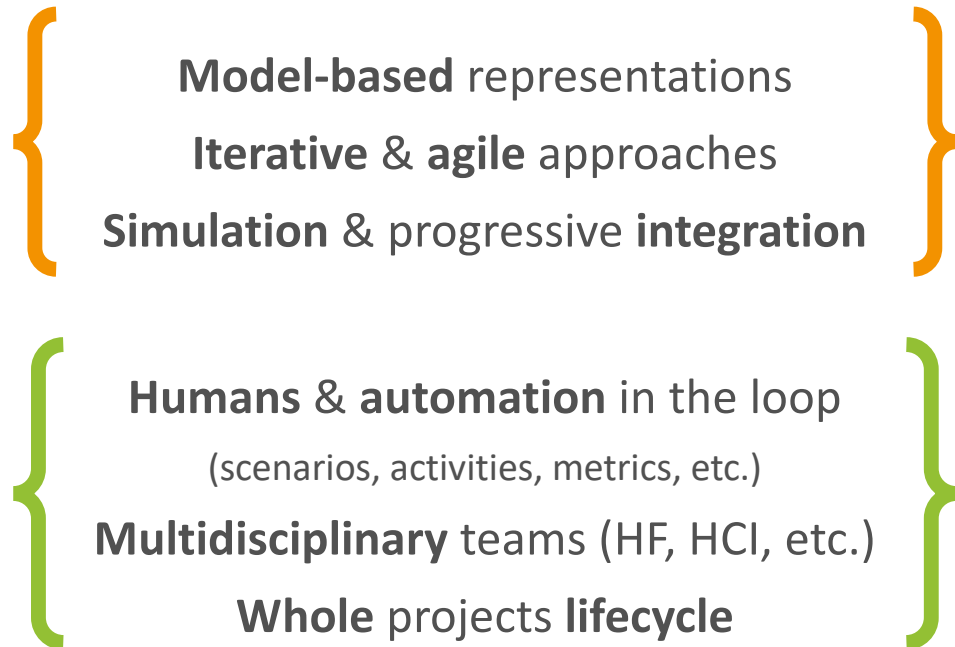
# Ingenuity I/O

- More than 60 projects, 75% of them deployed in production



# Breaking the complexity wall in modern systems ?

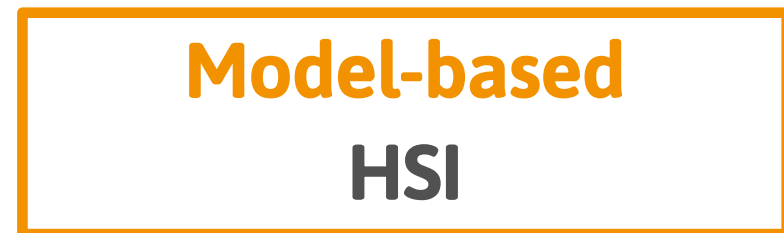
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**Extended MBSE**



**Human-System  
Integration**



**+ TANGIBILITY**

# Practical support for Model-Based SE & HSI during the whole project lifecycle



Making  
Systems of Systems

observable  
actionable  
measurable  
verifiable



# The Ingescape solution

## Open-source

### INGESCAPE Library

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

- Interoperability for any language, any OS, web, mobile, cloud & edge
- Highly supervised + fully decentralized
- Model-based

## Commercial



### INGESCAPE CIRCLE

<https://ingescape.com>

- Very innovative productivity & **collaboration** tool suite addressing the **whole lifecycle** of complex systems, involving all stakeholders **continuously and iteratively**



System specs  
& design



Code  
generation



Iterative coding  
and integration



Verification  
& validation



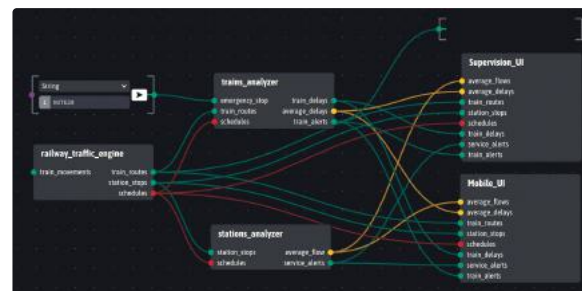
Operational  
supervision



Training

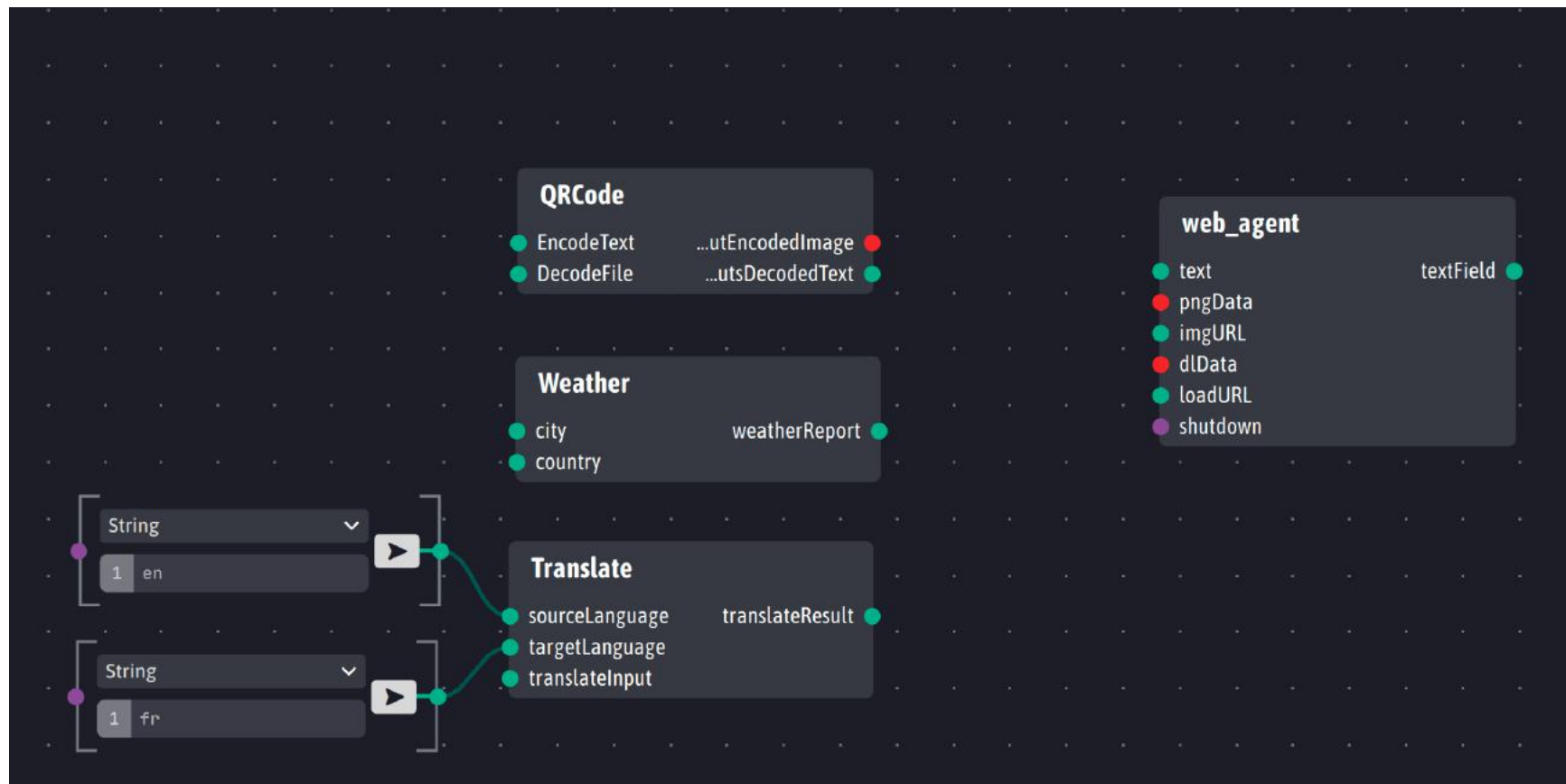


Maintenance



# Demo #1

- A sample Ingescape platform



# Ingescape is already used in many demanding industries



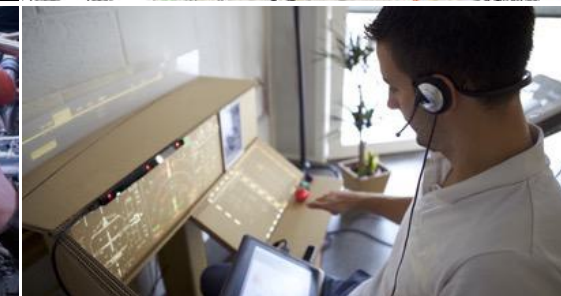
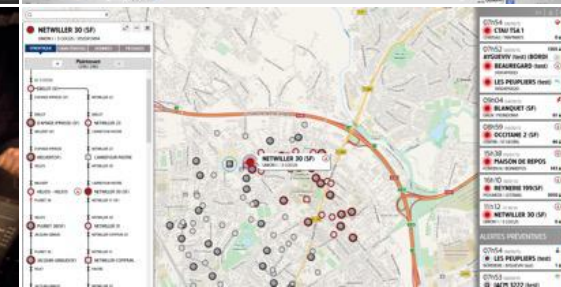
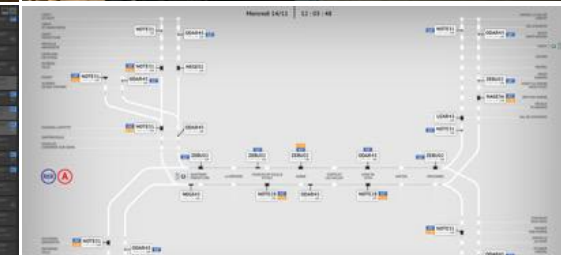
AIRBUS



Atos



THALES





# How it all started with Airbus...

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[https://www.youtube.com/watch?v=9Gr1Le\\_F7jU](https://www.youtube.com/watch?v=9Gr1Le_F7jU)

# A non-exhaustive list of software, hardware and gateways already orchestrated with Ingescape

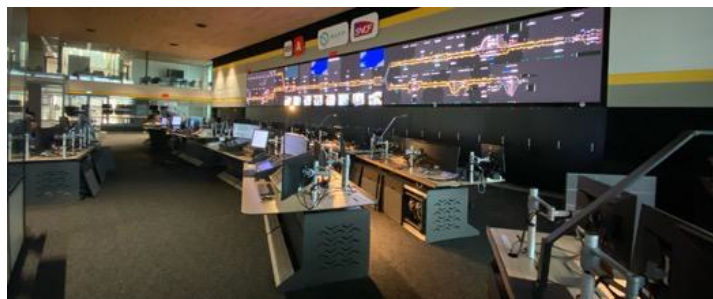
Operating Systems	 macOS iOS	 Windows	 Linux	 FreeBSD	 ROS	 android		
Languages	 C	 C++	 C#	 python™	 JavaScript	 Java	 HTML	 Rust
Frameworks & environments	 node	 unity	 Qt	 Apple	 Microsoft .NET	 eclipse	 LLAMA C++	 TensorFlow
Gateways with network	 TCP UDP	 ØMQ	 kafka	 MQTT	 RabbitMQ	 {REST:API}	 Websockets	
Gateways with protocols	 protobuf Protocol Buffers	 SNMP Simple Network Management Protocol	 Modbus	 VRPN				



# A real-world railway operational system designed & developed using MBHSI

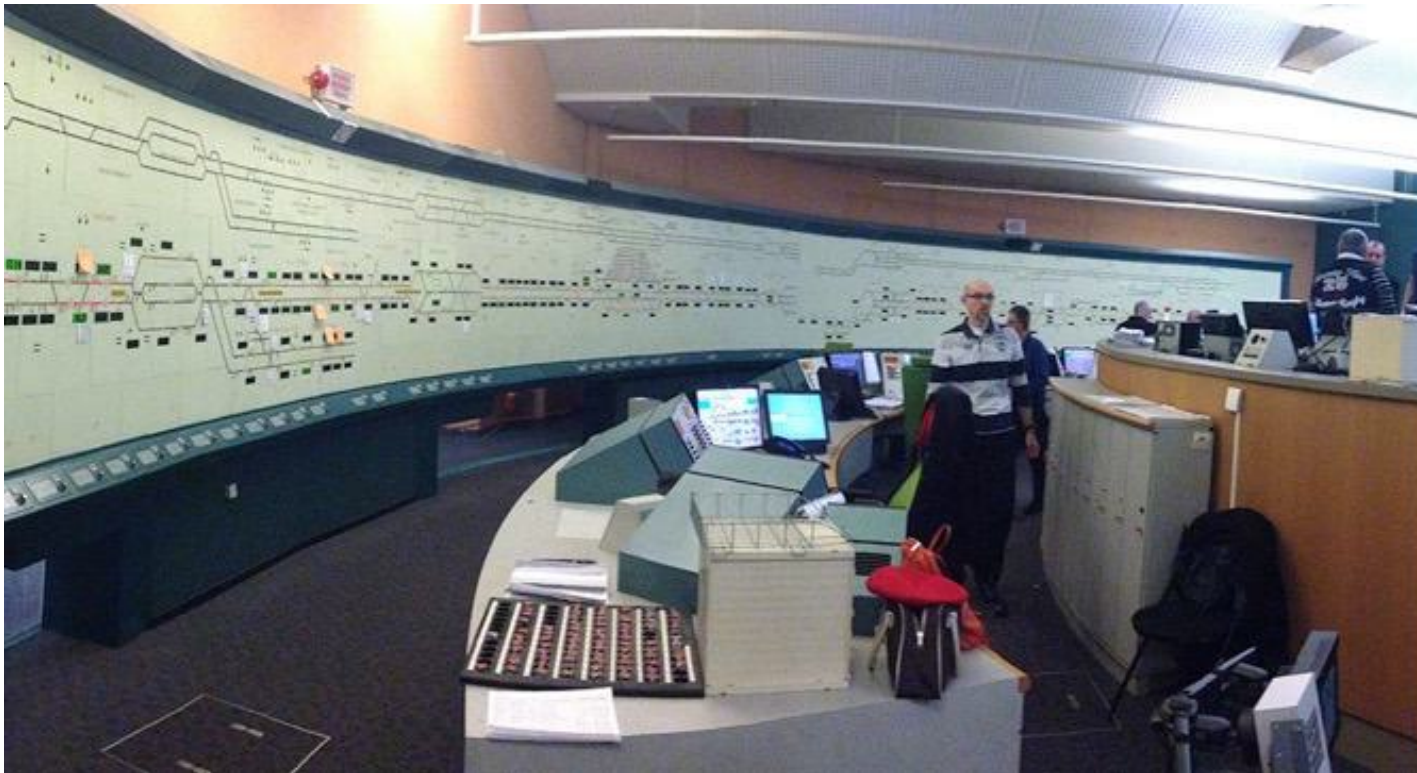


- **RATP RER A in Paris**
  - Largest urban train line in Europe (1.2M pax/day, more than 250 trains/day)
  - New system deployed in January 2024
- **64 systems orchestrated with Ingescape**
  - Field equipment command & control, alerting, authentication, archiving, itineraries, trains parking, missions/trains/drivers management, etc.
  - 598 inputs/outputs
  - 438 services
  - 6664 monitored field equipment
  - 1580 messages/second
- **21 real-time gateways to external systems**
- **9000+ applicable requirements**
- **16 workstations and an 18-meters wide LED display (5 x UHD)**



# How it was before...

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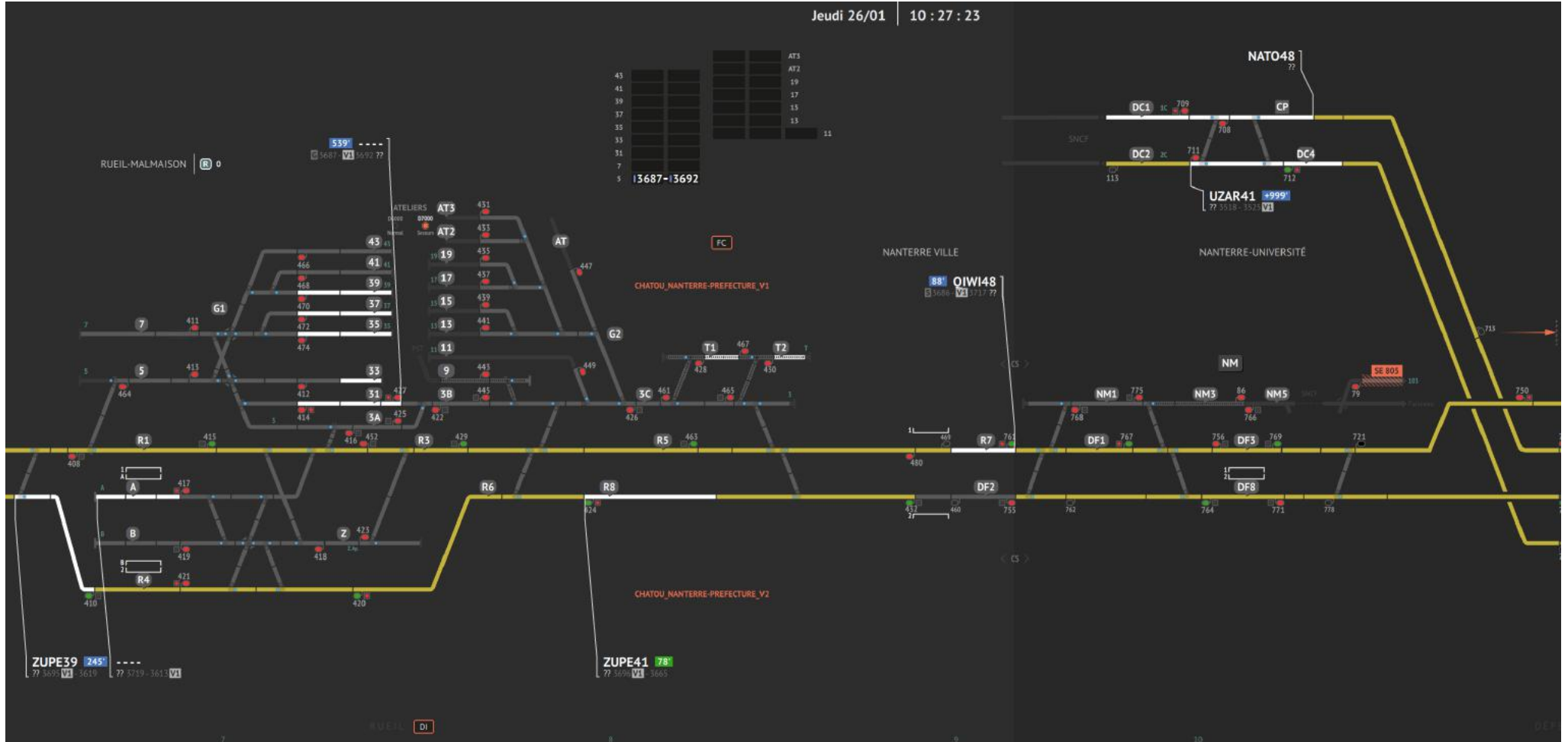


# Activity analysis + Participatory design + Iterative prototyping + Formative assessment

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# Real-time supervision

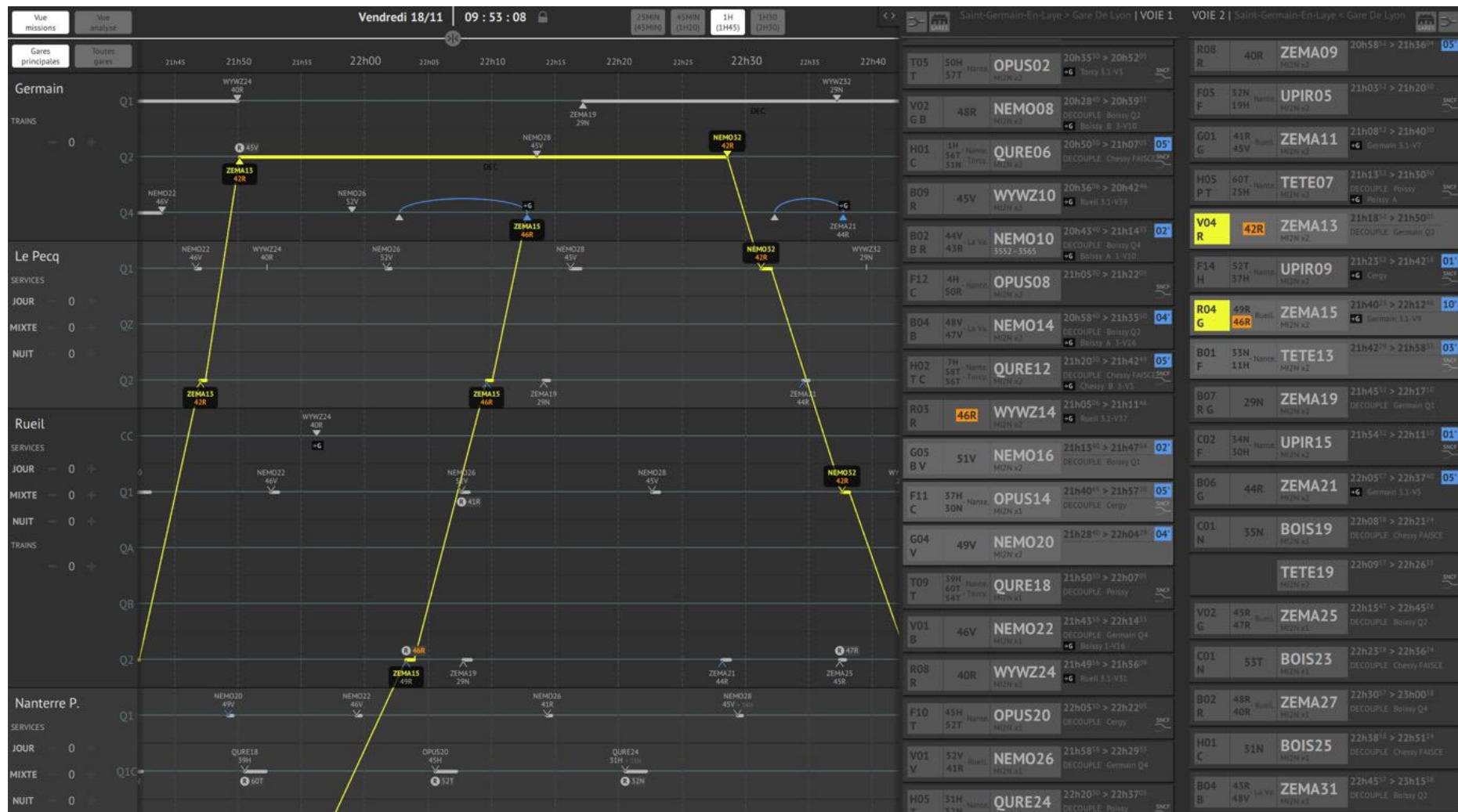


# Command application on a touch tablet

The screenshot displays a railway command application interface on a touch tablet. The interface is organized into several functional areas:

- Top Navigation Bar:** Shows station names (JOINVILLE LE PARC, LA VARENNE, SUCY, BOISSY) and the current date and time (Vendredi 18/11, 21:43:20). It also includes tabs for 'Circulation', 'Manœuvres', and 'Matériels & Missions', along with various status indicators like 'Traction', 'Zones', 'Circ. Alg.', 'Rech. Alg.', 'Annulation P. Catégories', and 'Alarmes'.
- Central Panel:** Displays train schedules for two directions: 'Nogent-Sur-Marne > Boissy-Saint-Leger | VOIE 1' and 'VOIE 2 | Nogent-Sur-Marne < Boissy-Saint-Leger'. Each train entry includes a train ID (e.g., NELY98, NEMO02, NEMO06), a type (e.g., R04, B07, B06), and scheduled times. Some entries are highlighted in blue, indicating specific operational status.
- Right-Side Panel:** Features a grid of buttons for various train types and identifiers, such as A, B, F5, J2, J4, J5, J7, J8, M1, M2, and Z. Some buttons are highlighted in yellow, suggesting they are currently active or selected.
- Bottom Section:** Contains a schematic diagram of the railway track layout, showing stations (JOINVILLE LE-PONT, NOGENT-SUR-MARNE, SAINT-MAUR CRETEIL, LE PARC DE SAINT-MAUR) and signal points (V1, V2, VUT, CS, AU). The tracks are color-coded (yellow and grey) to represent different operational states or directions.

# Real-time regulation with decision helpers



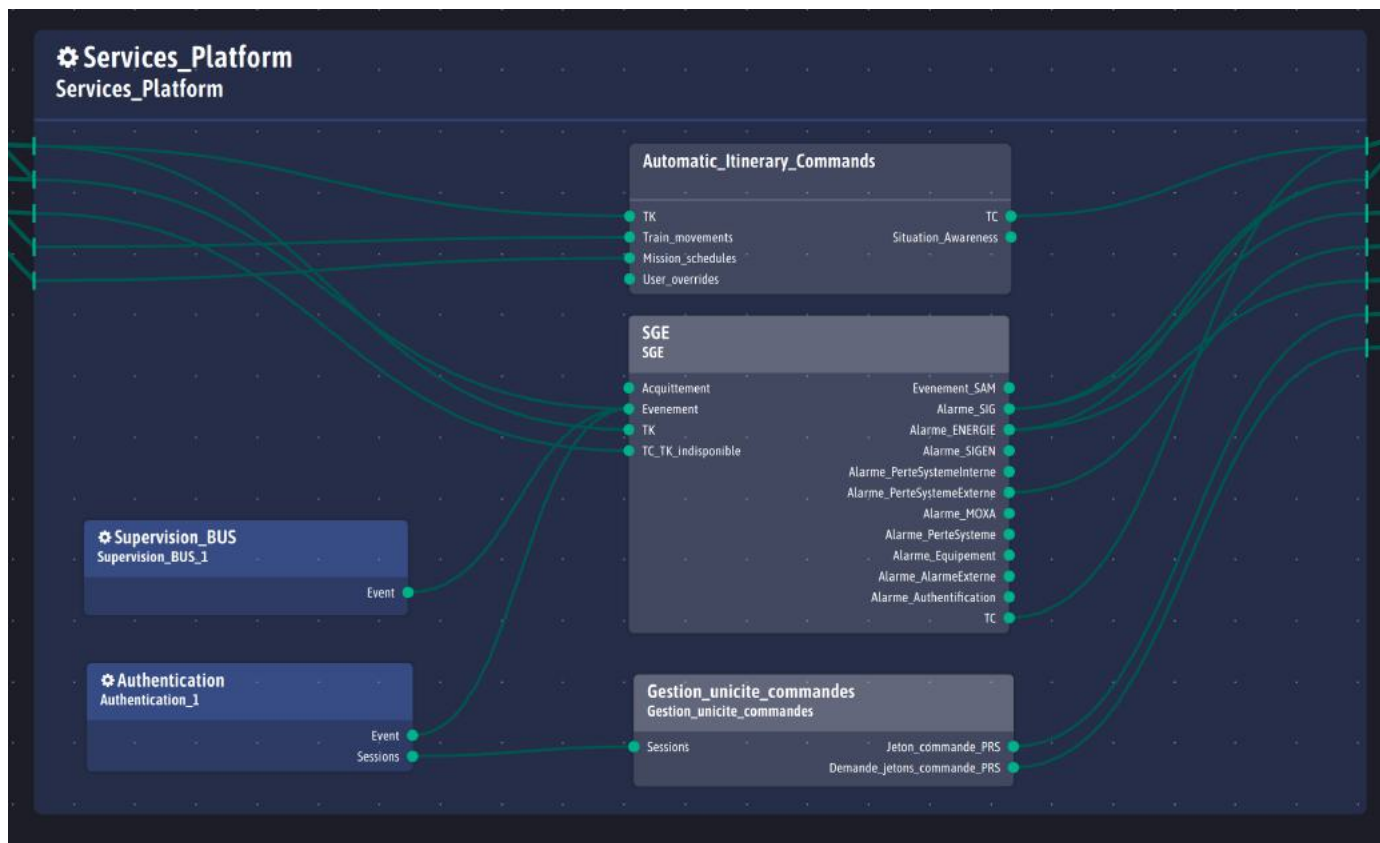


# Overview of the resulting control room



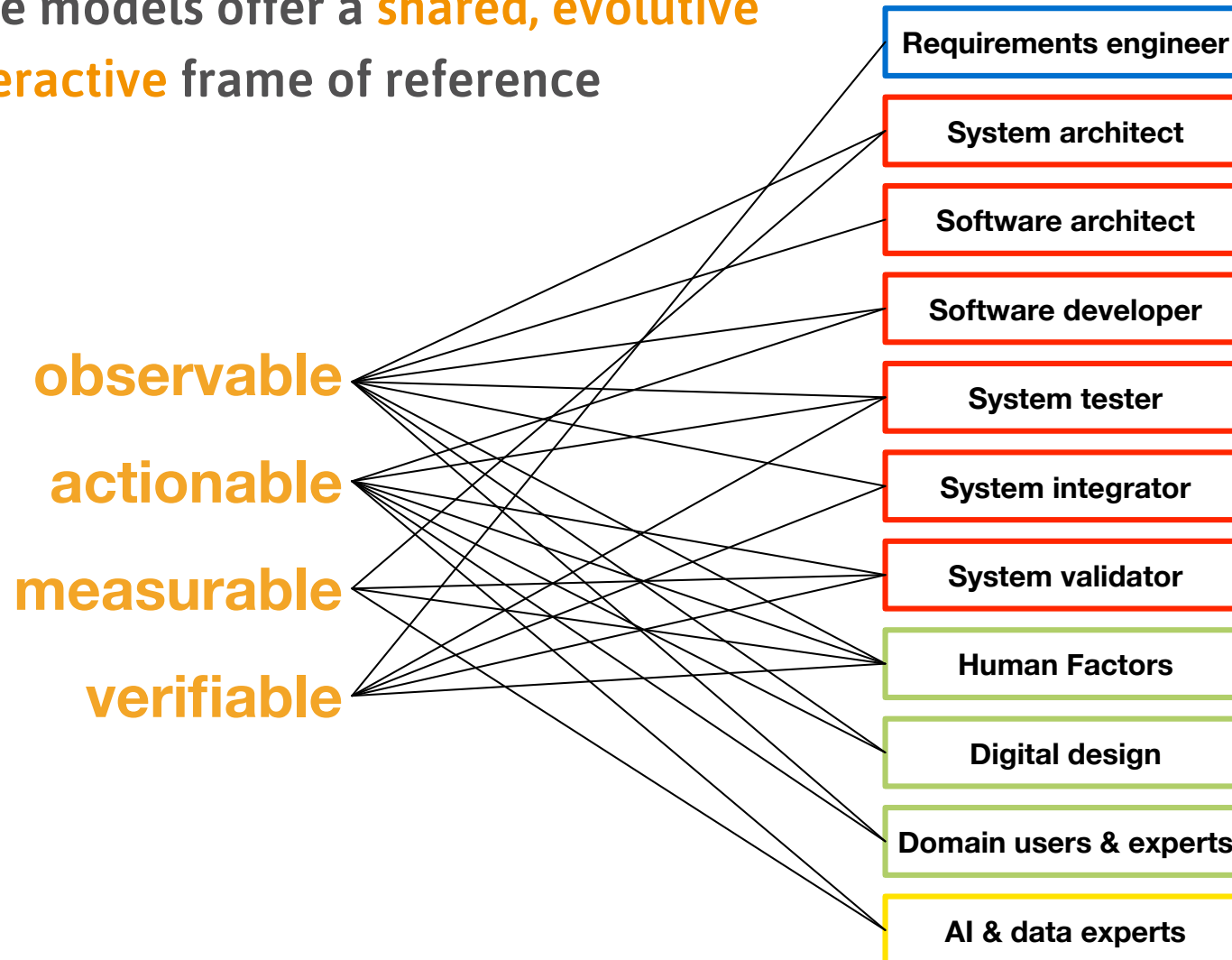
# Demo #2

- Three examples of Ingescape systems
  - An import from Capella
  - An activity structure from the spring school use cases
  - The railway operational system

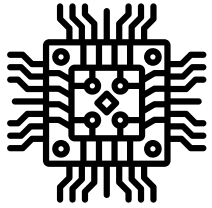


# Make all profiles collaborate together

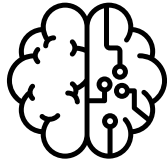
- Tangible models offer a **shared, evolutive and interactive** frame of reference



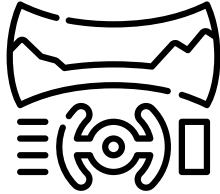
# Unified platforms for Simulation & Integration & Operations



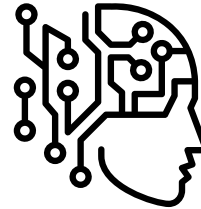
Hardware & test benches



Simulations & algorithms  
(Matlab, etc.)



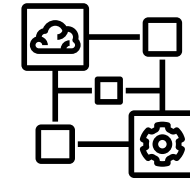
Environments & simulators



A.I. & automation engines



Human operators



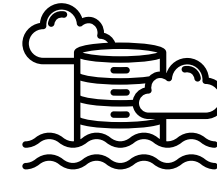
System-wide logic & services

Ingescape agents and gateways



**INGESCAPE  
PLATFORM**

fully-decentralized + highly-supervised



Record / Replay  
Export / Analyze

**User-centred  
scenarios & metrics**

Human-In-The-Loop  
Simulation (HITLS)

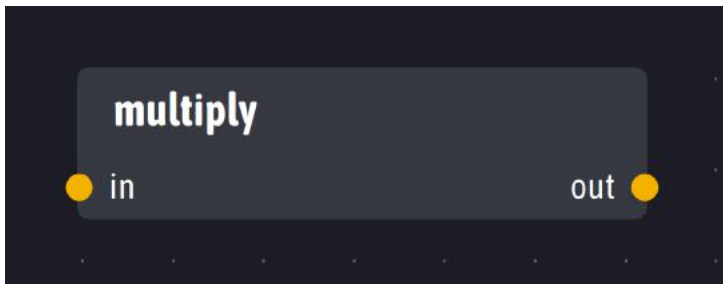
**System  
behaviors & metrics**

**Operational &  
simulation data**

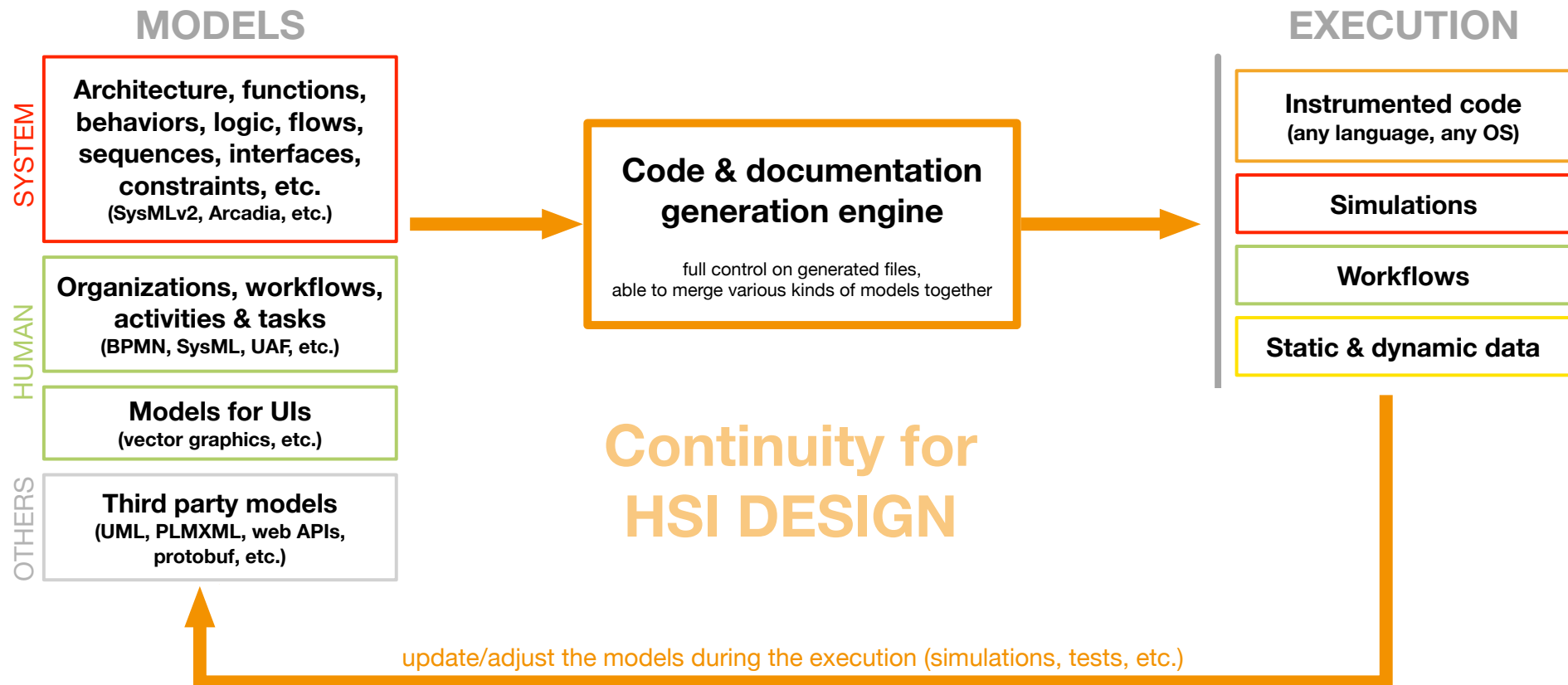
Leverage data  
from the real-world

# Demo #3

- Creating a new agent using code generation
- Global record/replay features



# Continuous & iterative model-based design



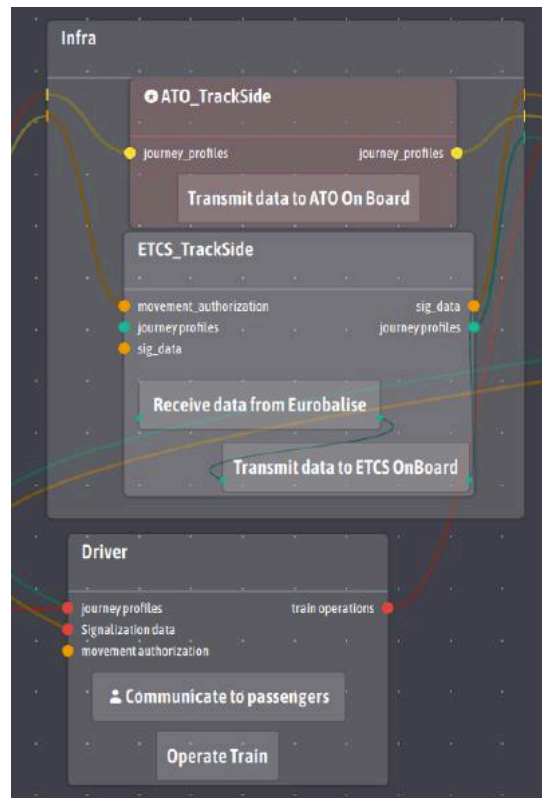
# Capturing & measuring organizations, workflows, tasks and activities



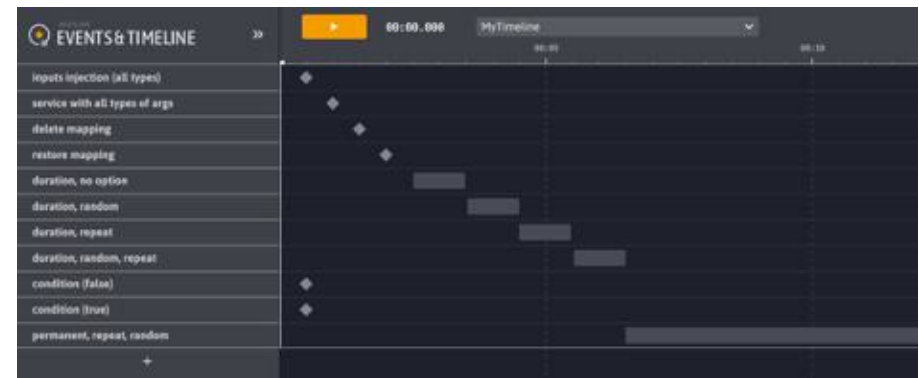
## Workflows



## Organizational structure



## Timelines & scenarios



## Metrics & resources



# Scientific assessment

The screenshot shows the configuration interface for a scientific experiment titled "Étude de l'effet tunnel". The interface is divided into several sections:

- Plan d'analyse:** Shows the analysis plan "S10-A2-C2-N4" and a list of FDG and EDG protocols, including "protepor\_enviroment\_immersif - v1.2" and "protepor\_enviroment\_semi\_immersif - v2.3".
- Description:** A text area containing placeholder text (Lorem ipsum).
- Hypothèses:** A section for adding hypotheses, with one hypothesis listed: "1- Lien entre la détection d'alarmes et la synchronisation cardiaque".
- Variables indépendantes:** A table listing independent variables: "Types d'alarme" (Visuelle; Visuelle et sonore), "Synchronisation cardiaque" (Synchrone; Asynchrone), and "Niveau de charge mentale" (niveau1; niveau2; niveau3; niveau4).
- Variables dépendantes:** A table listing dependent variables: "Nombre d'omissions" (module\_analyse\_participant nb\_omissions, type int) and "Temps de réaction" (module\_analyse\_participant temps\_reaction, type double).
- Marqueurs:** A table listing markers: "Agitation" (ponctuel) and "Phases de vol" (décollage; vol; atterrissage, type continu).
- Questionnaires:** A table listing questionnaires: "Evaluation du niveau de charge mentale".

The screenshot shows the live evaluation session interface for "Passation P1/A1-C1-N1". The interface includes:

- Session Information:** Camera IDs, microphone, and capture card details.
- Marqueurs:** A list of markers with status indicators: "Agitation", "Hésitation", "Panne moteur", "Panne écran", "Surveillance piste sous-marine", "Surveillance piste surface", "Phase de stress" (set to "Elevé"), "Interception de la menace", and "Brouillard".
- Phase de stress dialog:** A pop-up window for selecting stress levels: "Arrêter le marqueur", "Bas", "Modéré", and "Elevé".
- Timeline:** A horizontal timeline showing the duration of the simulation (01:30:00.000) and the timing of various markers and questionnaires.

- Detailed protocols for scientific proof
  - Hypotheses
  - Scenarios
  - Variables
  - Participants
  - Markers
  - Questionnaires
- Assistance to live evaluation sessions
- Automatic data collection & structuration with statistics
- Easy export to advanced statistics & data analysis solutions
- Assistance to data analysis and reporting



# Demo #4

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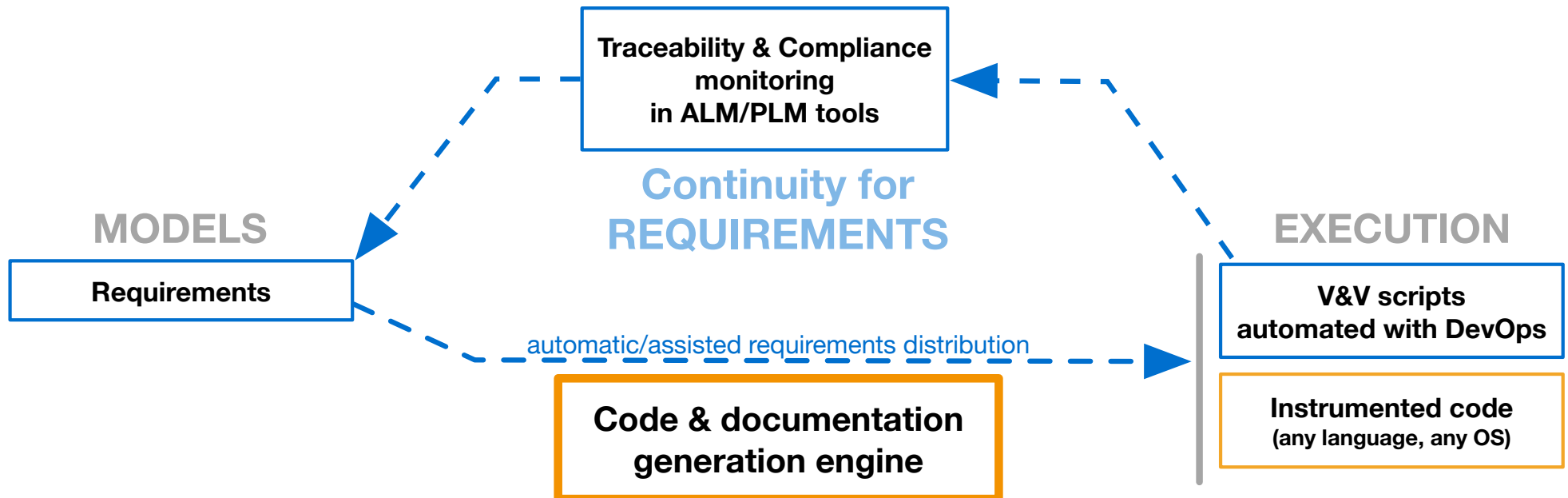
- Let's do some Verification & Validation

```
"REQ 1.0.1" "range of values"{  
  multiply.in = 2.5  
  assert multiply.out = 5.000000  
  multiply.in = 0  
  assert multiply.out = 0.000000  
  multiply.in = -2.5  
  assert multiply.out = -5.000000  
}
```

- <https://ingescape.com/verification-validation-using-ingscape/>

# Continuous and automated Verification & Validation

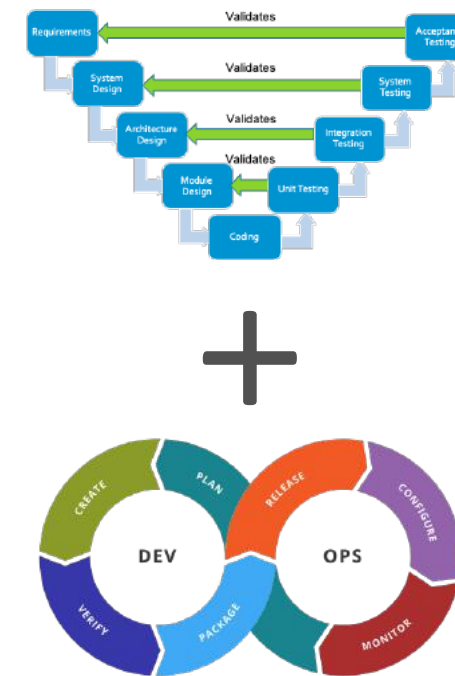
- A dedicated language for V&V, accessible to all profiles
- Involving system + human metrics



# V&V automation for the RATP RER A project



- 116 scripts
- 144 392 lines
- 20 189 test blocks
- 320 requirements with human-assisted verification
- 2537 requirements verified automatically
  - Tested via DevOps at every change
  - Results sent to HP ALM after each DevOps cycle



```
convTGTK_01_TKTE14_en_TKmetier_PML11.igsscript
convTGTK_01_TKTE14_en_TKmetier_PML11.igsscript No Selection
123 Conversion_TC_TK_TK_TE14 = "TE14_TK 11 0_05 00063"
124 sleep 200
125
126 "Placement de la valeur Fixe de l objet DI_AG à 1" "Numero de ligne : 5765 -
Equation: {<21100100, > 51100002}" {
127 block.timeout = 1000
128 Conversion_TC_TK_TK_TE14 = "TE14_TK 11 0_05 00061"
129 assert Conversion_TC_TK_TK = "TK_DI_AG 11 OI_AG 1 0"
130 assert Conversion_TC_TK_TK = "TK_RONFLEUR 11 Ronfleur_SIG 1 0"
131 assert Conversion_TC_TK_TK = "TK_DI_AG 11 OI_AG 1 0"
132 assert silence Conversion_TC_TK_TK 100
133 }
134 Conversion_TC_TK_TK_TE14 = "TE14_TK 11 0_05 00063"
135 "Envoi de la TC d acquittement de l alarme" {
136 block.timeout = 1000
137 Conversion_TC_TK_TC = "TC_ACQ 11 ACQ_OI_AG 1"
138 assert Conversion_TC_TK_TC = "TK_RONFLEUR 11 Ronfleur_SIG 0 0"
139 assert Conversion_TC_TK_TC = "TK_DI_AG 11 OI_AG 0 0"
140 assert Conversion_TC_TK_TC = "TK_DI_AG 11 OI_AG 0 0"
141 }
142 sleep 600
143
```

# Ingescape measured benefits

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**Model-based architecture and interface contracts**

up to **75%** **50%**  
Time & effort reduction

**Continuous and iterative Testing**

up to **90%**  
Effort reduction

**Verification & Validation**

up to **80%**  
Effort reduction

**Global gains**  
in projects range between  
**30% and 47%**

**Bootstrap software projects**

 **In a few seconds**  
In full accordance with your practices

**Real-time system supervision**

**100%** **Automated**  
No additional code

**Thank you!**

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<https://ingescape.com>