



INGESCAPE

by Ingenuity i/o

**Industrial feedback
on accelerated Model-Based Systems Engineering
for RATP RER A in Paris**

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RER A in Paris



- 1.2M pax & 600 trains /day
- 6000+ monitored devices
- Operated 18/7 + maintenance
- 60+ systems
- 9000+ requirements
- Legacy from the 80s/90s



Before the modernization...



Phases	Build	Qualification	Run
1- Experimentation	8 months	4 months	1 year
2- Industrialization	24 months	8 months	10+ years

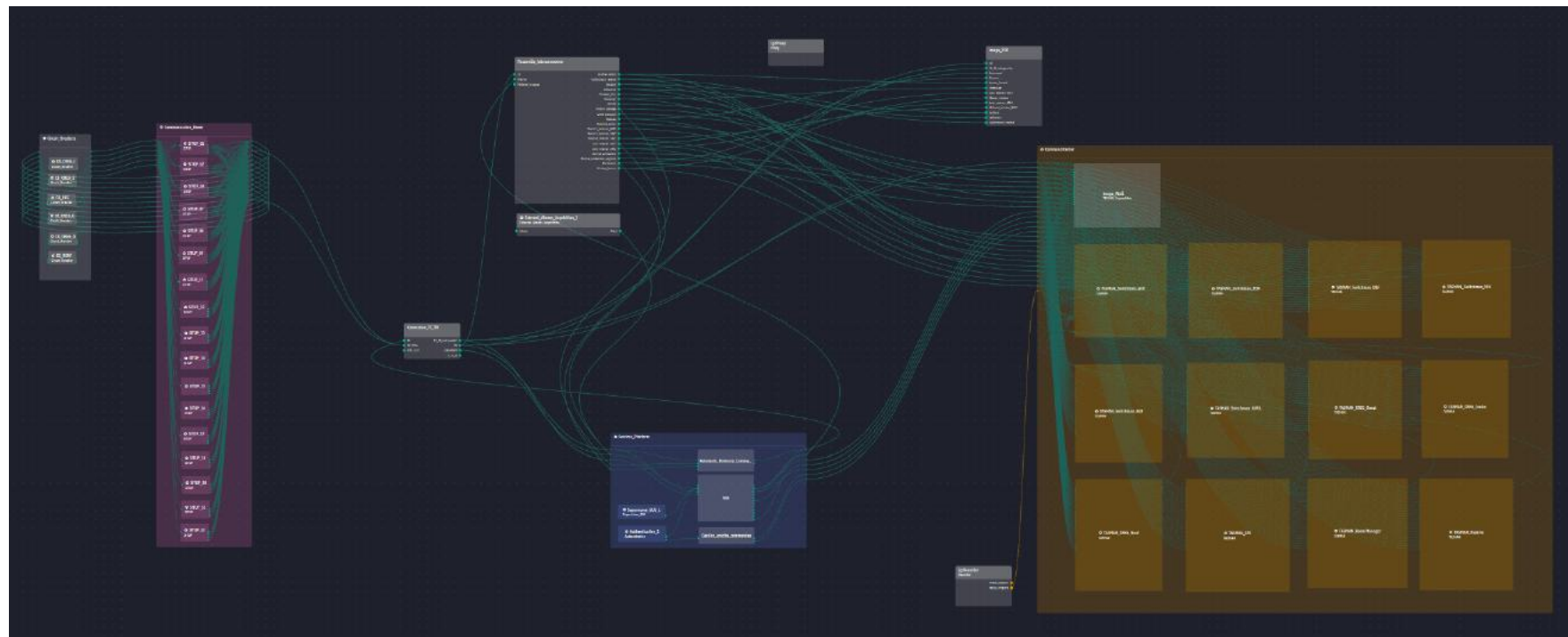
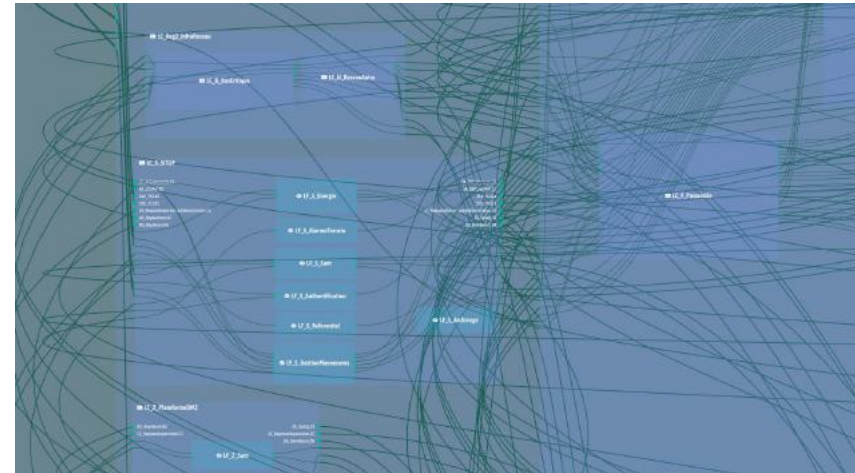
Our innovative approach to accelerate MBSE

MBSE + Operations (and simulations)

An elastic process fitting inside larger processes
bridging **MBSE, simulations & operations**
to provide **high-quality feedback** to all actors
continuously **from early design to qualification & exploitation**

Models for structure, flows and services

- Started on Capella
 - Logical layer only, not fitting the needs for development, specs and IVVQ
- Quickly moving to Ingescap
 - to install a practical collaboration between all the actors



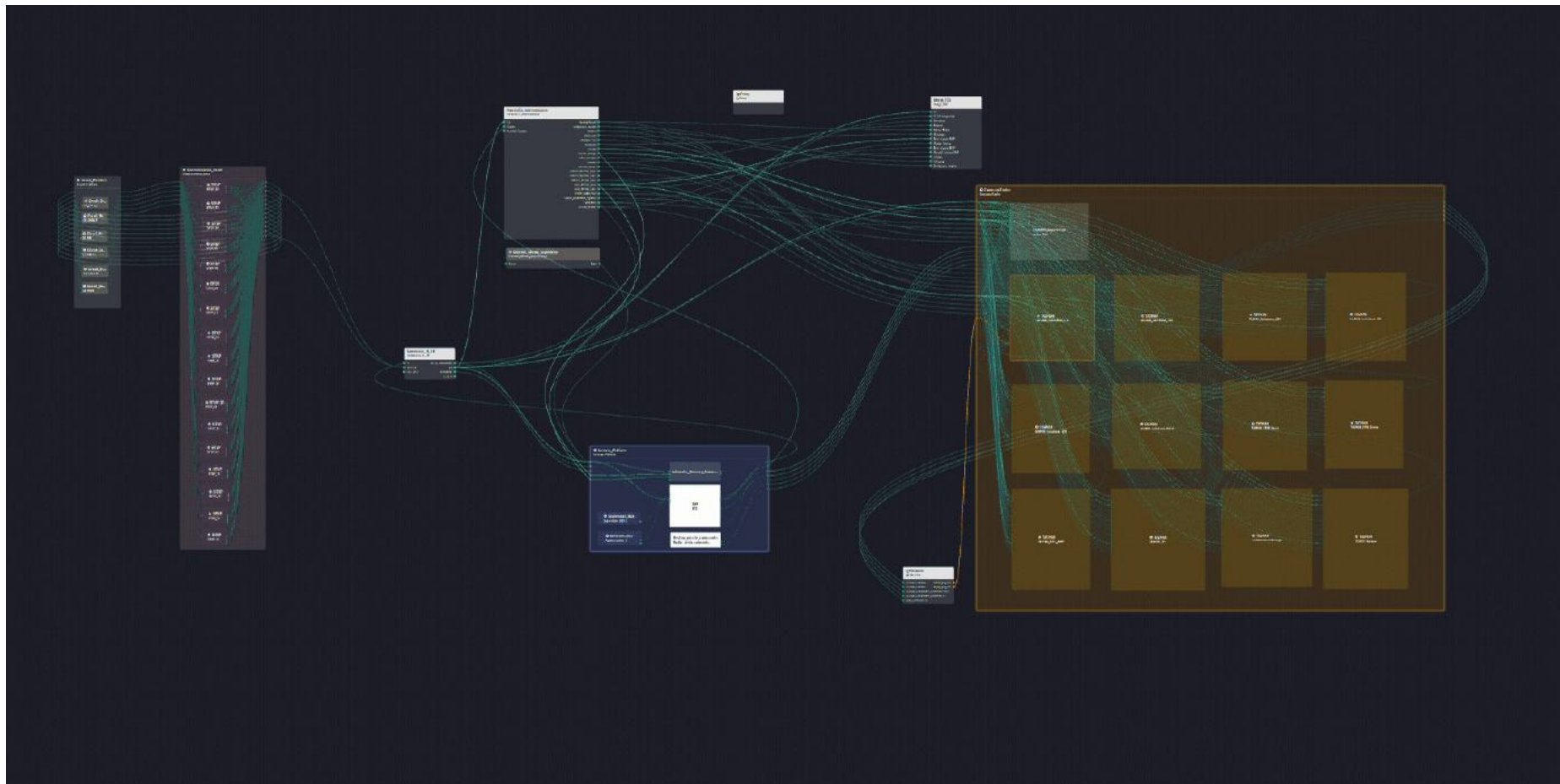
A non-exhaustive list of software, hardware and gateways already orchestrated with Ingescape

Operating Systems	     
Languages	       
Frameworks & environments	       
Gateways with network	      
Gateways with protocols	   



Deployment model

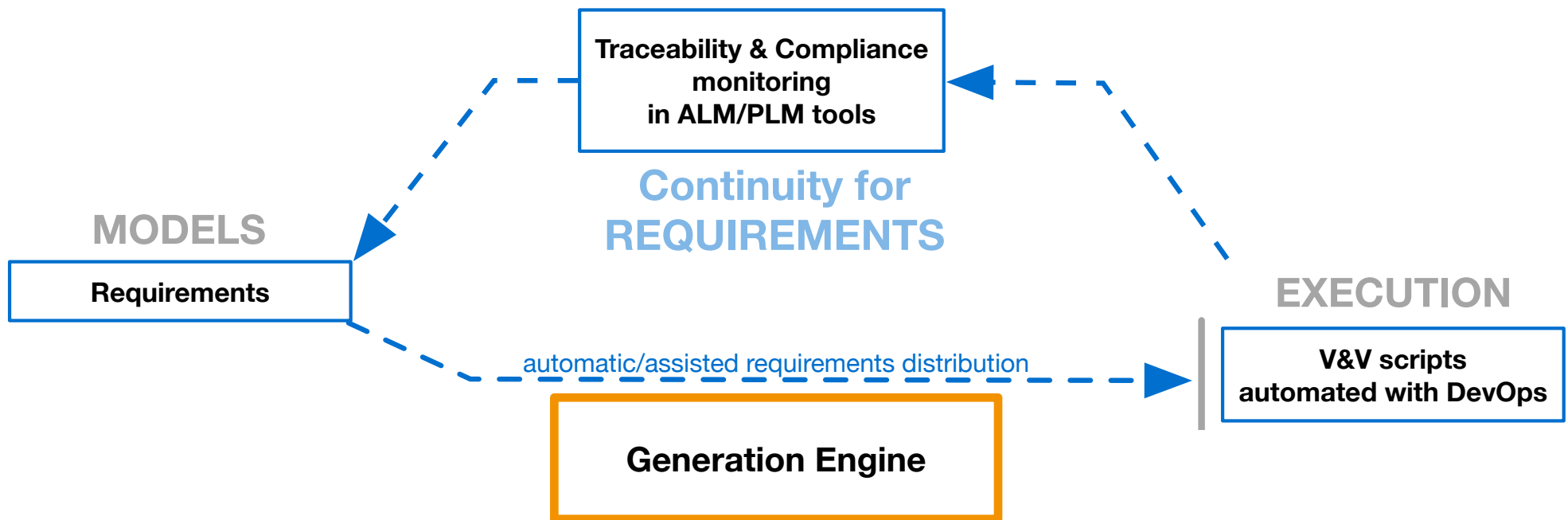
interactively exposing the actual system



Make the system of systems
Observable + Actionable + Measurable + Verifiable
through its models

Continuous & automated Model-based Verification

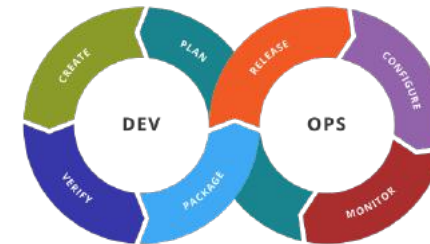
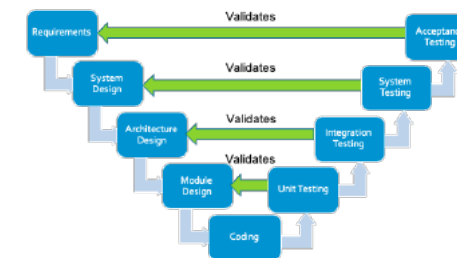
- A model-based language for IVVQ, accessible to non-developers
- Involving scenarios, system models, requirements and metrics



Verification automation for the RATP RER A project

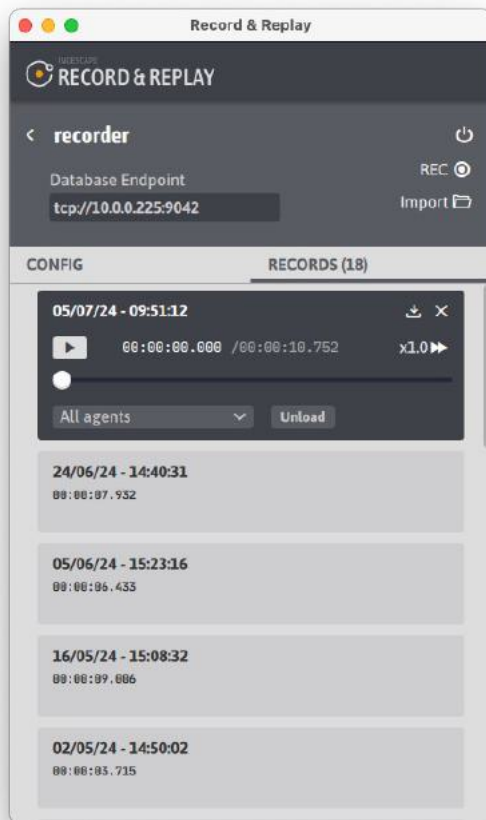


- 9000+ requirements translated into
 - 116 scripts
 - 144 392 lines
 - 20 189 test blocks
- 320 requirements with human-assisted verification
- 2537 requirements verified automatically
 - Tested via DevOps at every change
 - Results sent to HP ALM after each DevOps cycle



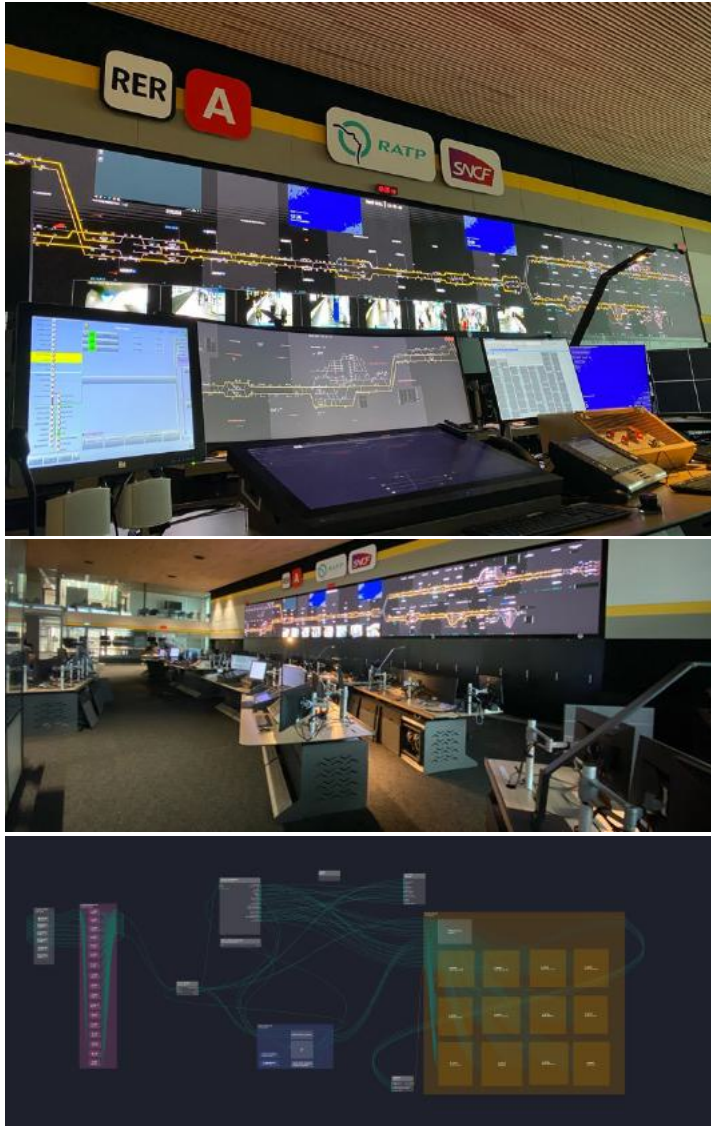
```
convTGTK_01_TKTE14_en_TKmetier_PML11.igsscript
convTGTK_01_TKTE14_en_TKmetier_PML11.igsscript No Selection
123 Conversion_TC_TK.TK_TE14 = "TE14_TK 11 0_05 00063"
124 sleep 200
125
126 "Placement de la valeur Fixe de l objet DI_AG à 1" "Numero de ligne : 5765 -
Equation: {<21100100, > 51100002}" {
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 DI_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 DI_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.TK == "TK_RONFLEUR 11 Ronfleur_SIG 0 0"
139 assert Conversion_TC_TK.TK == "TK_DI_AG 11 DI_AG 0 0"
140 assert Conversion_TC_TK.TK == "TK_DI_AG 11 DI_AG 0 0"
141 }
142 sleep 600
143
```

Model-based support to 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

Measured benefits



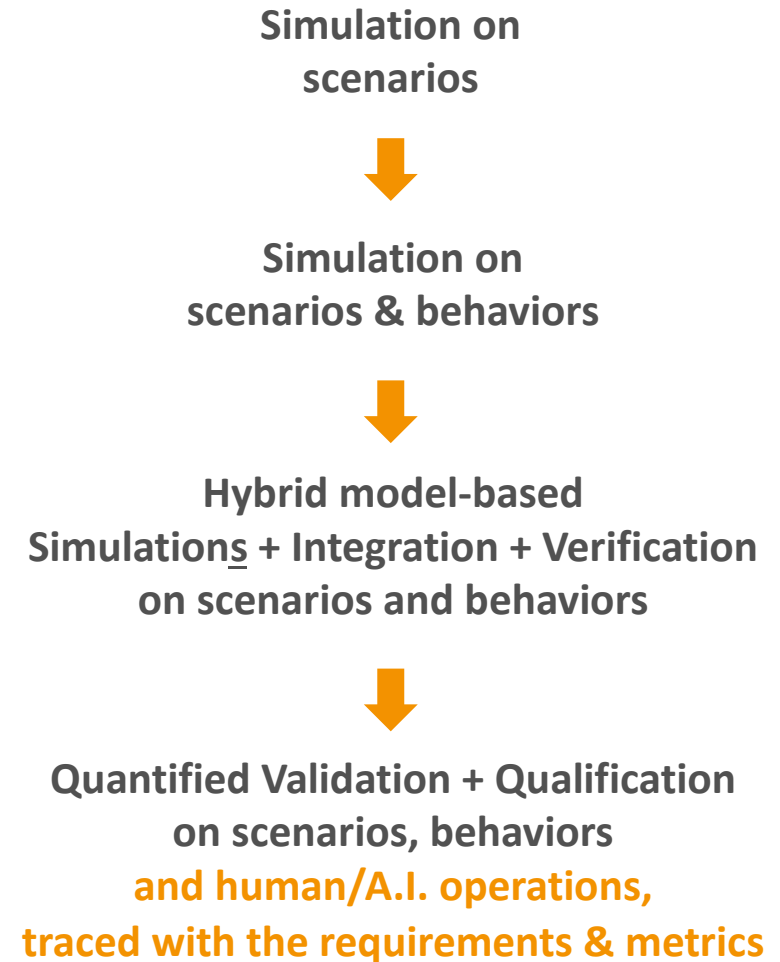
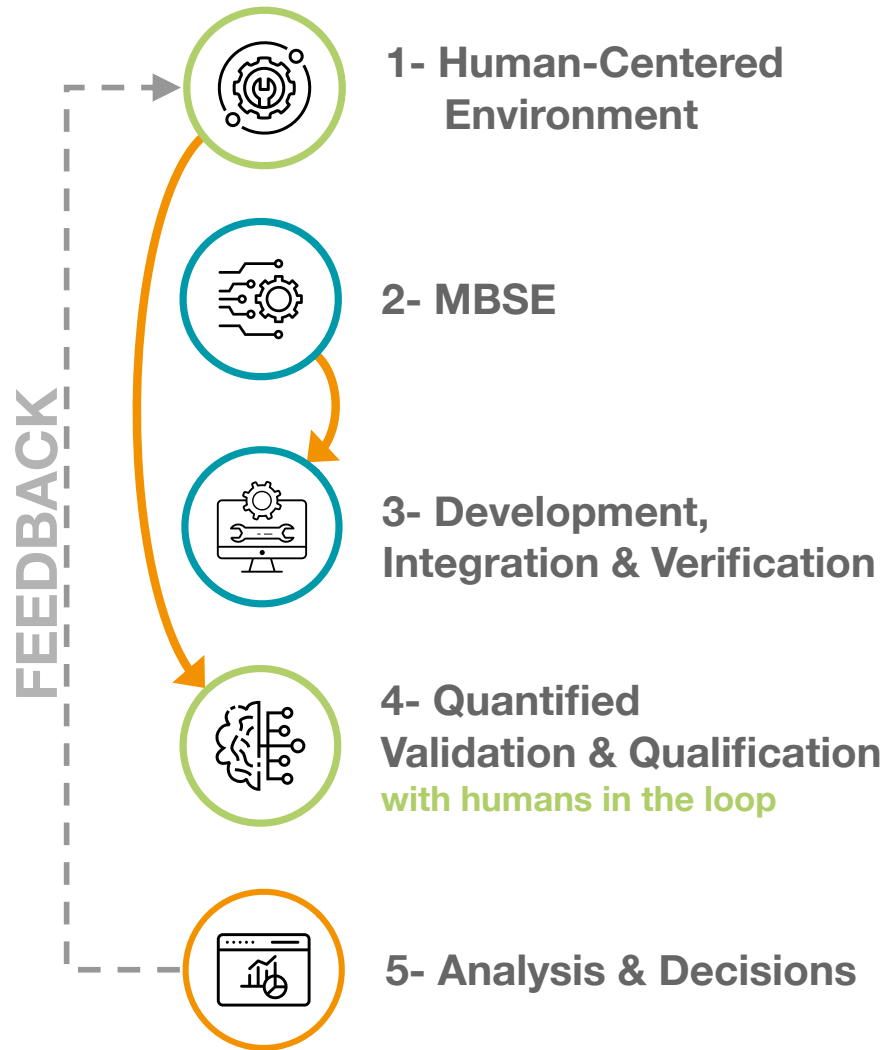
■ Integration & Verification time divided by 5

- Continuous model-based integration
- Formal expression of the requirements, always consistent with the system
- Verification automated and reusable in DevOps
- Always using realistic data

■ On-site Validation & Qualification time divided by 8

- Most of the work was already **reliably** achieved on integration platforms with **trusted** context & data

An elastic process to bridge Simulations + Integration + Operations



Improve the models progressively,
keep them useful & up-to-date for all and at all times,
contribute to a Single Source of Truth.

Ingescape is already used in many demanding industries



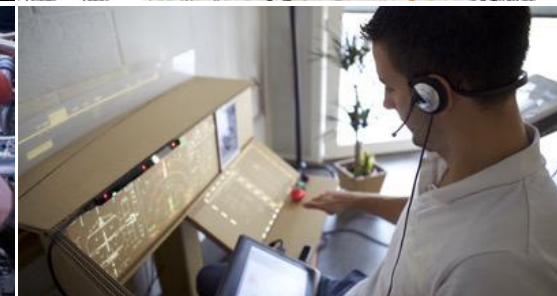
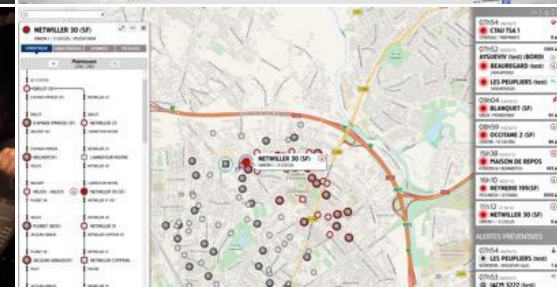
AIRBUS



Atos

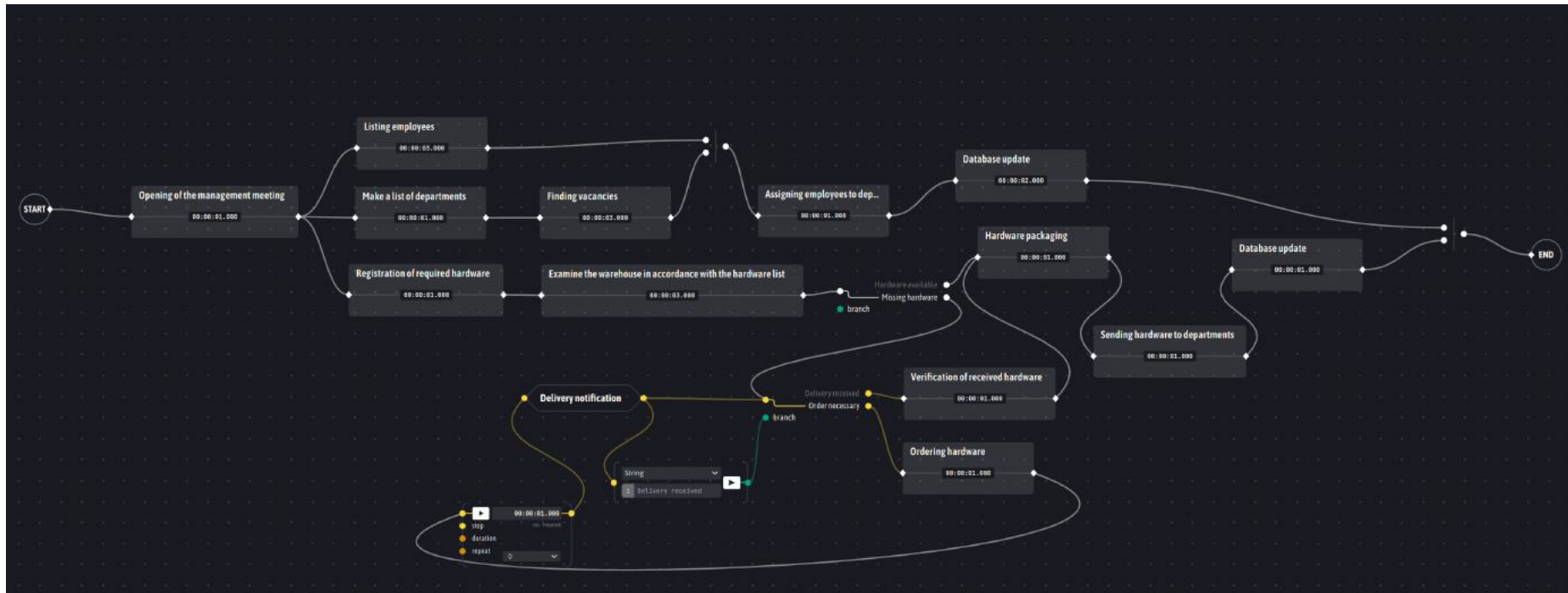


THALES

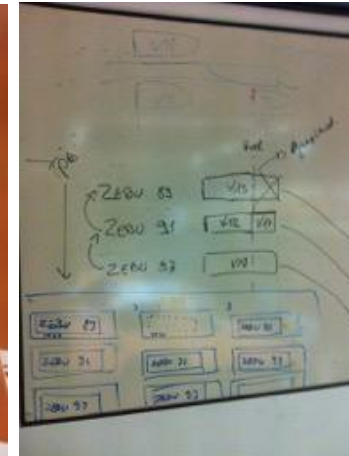


Annexes

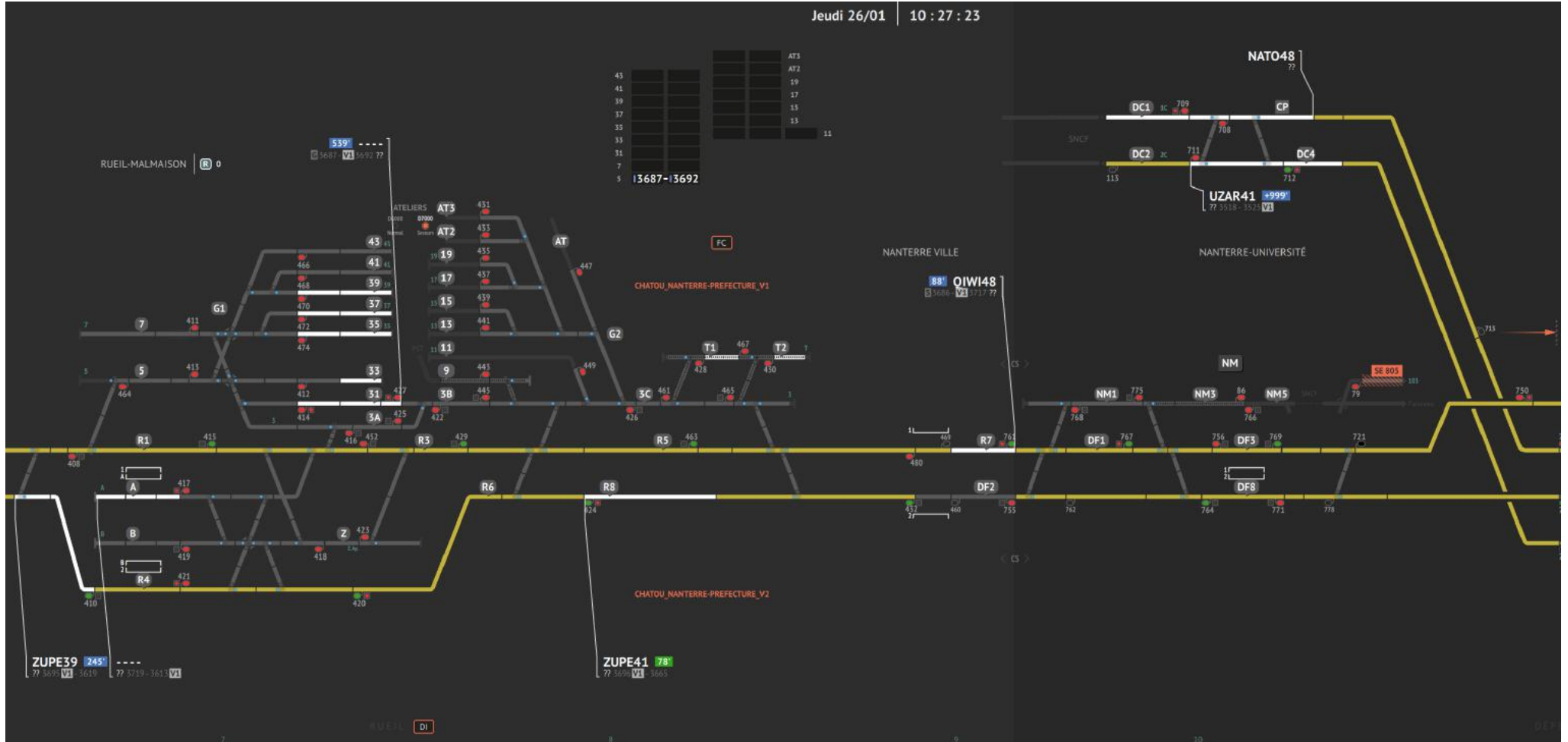
Scenarios, use cases & emerging functions



Participatory design on paper/cardboard mockups



Real-time line monitoring



Command & control

on the line, missions, drivers and trains



JOINVILLE LE PARC LA VARENNE SUCY BOISSY

1 Circulation 2 Manœuvres 3 Matériels & Missions

Vendredi 18/11 21:43:20

Traction Zones Cdt. Arg Rech. Arg Annulation P. Catégories Alarmes

JOINVILLE LE PARC LA VARENNE SUCY BOISSY

A 1413 J7 Z

B 1415 J7 M2 Z

F5 1409 A B **J5**

J2 1461 A B J4

J4 1417 J7 M2 Z

J5 1411 **J7** Z

J8 43 A B J4

J7 1503 L2 **M1**

M2 1531 M1

Nogent-Sur-Marne > Boissy-Saint-Leger | VOIE 1

R04 G	46R 49R	NELY98	20h36 ⁰⁰ > 20h51 ⁰⁰
B07 R G	29N	NEMO02	20h45 ⁰⁰ > 21h01 ⁰⁰
B06 G	44R	NEMO06	20h56 ⁰⁰ > 21h12 ⁰⁰
H03 B	43V	WNWS08	21h05 ⁰⁰ > 21h14 ⁰⁰ +G Boissy 1.1-V2T
V02 G B	48R	NEMO08	21h10 ⁰⁰ > 21h26 ⁰⁰ DECOUPLE Boissy Q2 +G Boissy B 1-V10
B02 B R	44V 43R	NEMO10	21h25 ⁰⁰ > 21h44 ⁰⁰ DECOUPLE Boissy Q4 +G Boissy A 1-V10 02
B04 B	48V 47V	NEMO14	21h44 ⁰⁰ > 22h00 ⁰⁰ DECOUPLE Boissy Q7 +G Boissy A 3-V18 04
G03 B V	51V	NEMO16	21h57 ⁰⁰ > 22h13 ⁰⁰ DECOUPLE Boissy Q1 02
G04 V	49V	NEMO20	22h15 ⁰⁰ > 22h31 ⁰⁰ 04
V01 B	46V	NEMO22	22h25 ⁰⁰ > 22h41 ⁰⁰ DECOUPLE Germain Q4 +G Boissy 1-V16
V01 V	52V 41R	NEMO26	22h40 ⁰⁰ > 22h55 ⁰⁰ DECOUPLE Germain Q4
V04 R	45V 43R	NEMO28	22h55 ⁰⁰ > 23h11 ⁰⁰ DECOUPLE Germain Q2

VOIE 2 | Nogent-Sur-Marne < Boissy-Saint-Leger

R			
G01 G	41R 43V	ZEMA11	20h41 ⁰⁰ > 20h59 ⁰⁰ +G Germain 1.1-V7
V04 R	42R	ZEMA13	20h52 ⁰⁰ > 21h09 ⁰⁰ DECOUPLE Germain Q2
R04 G	49R 46R	ZEMA15	21h04 ⁰⁰ > 21h21 ⁰⁰ +G Germain 1.1-V9 10
B07 R G	29N	ZEMA19	21h18 ⁰⁰ > 21h35 ⁰⁰ DECOUPLE Germain Q1
B06 G	44R	ZEMA21	21h39 ⁰⁰ > 21h56 ⁰⁰ +G Germain 1.1-V5 05
V02 G	45R 47R	ZEMA25	21h50 ⁰⁰ > 22h06 ⁰⁰ DECOUPLE Boissy Q1
B02 R	48R 40R	ZEMA27	22h04 ⁰⁰ > 22h21 ⁰⁰ DECOUPLE Boissy Q4
B04 B	45R 48V	ZEMA31	22h20 ⁰⁰ > 22h36 ⁰⁰ DECOUPLE Boissy Q3
G05 V	47V	ZEMA33	22h34 ⁰⁰ > 22h51 ⁰⁰ DECOUPLE Boissy Q1
G04 V	49V	WRWN33	22h40 ⁰⁰ > 22h44 ⁰⁰ +G La Varenne 1.1-VF
G05 B	51V 50V	ZEMA37	22h50 ⁰⁰ > 23h06 ⁰⁰ DECOUPLE Boissy Q1
V01 R	41R	ZEMA39	23h05 ⁰⁰ > 23h21 ⁰⁰

J8 J2 **F5** **A** 1416 **J7**

J8 J2 **F5** **B** 1414 **J7**

J8 **J2** **J4** 1412 **J7**

B **A** **J7** 1412 **J7**

J4 **B** **M2** 1400 **J7**

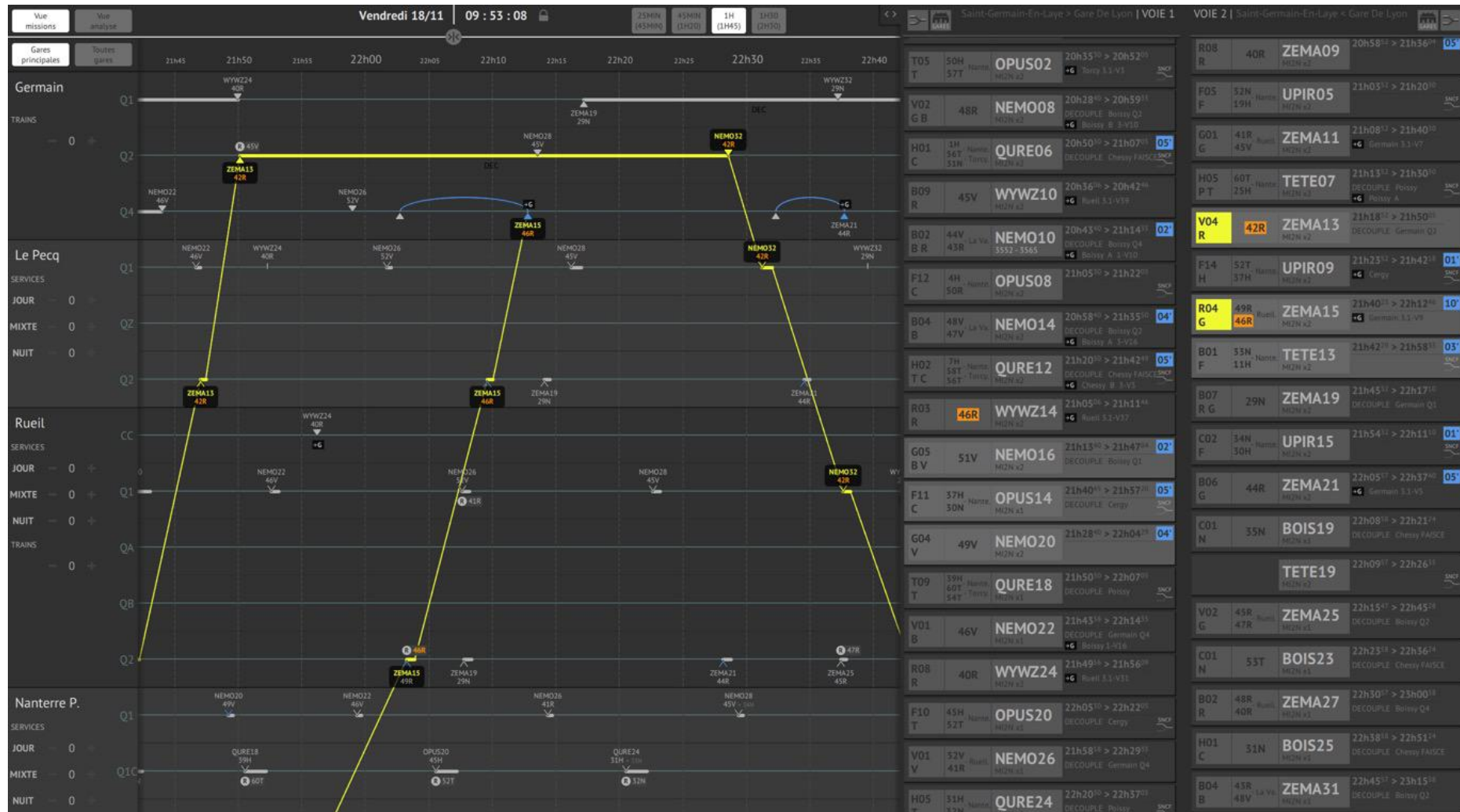
J4 **B** **A** **Z** 1418 **J7**

Joinville Le Parc

M2 **J7** **L2** 1534 **J7**

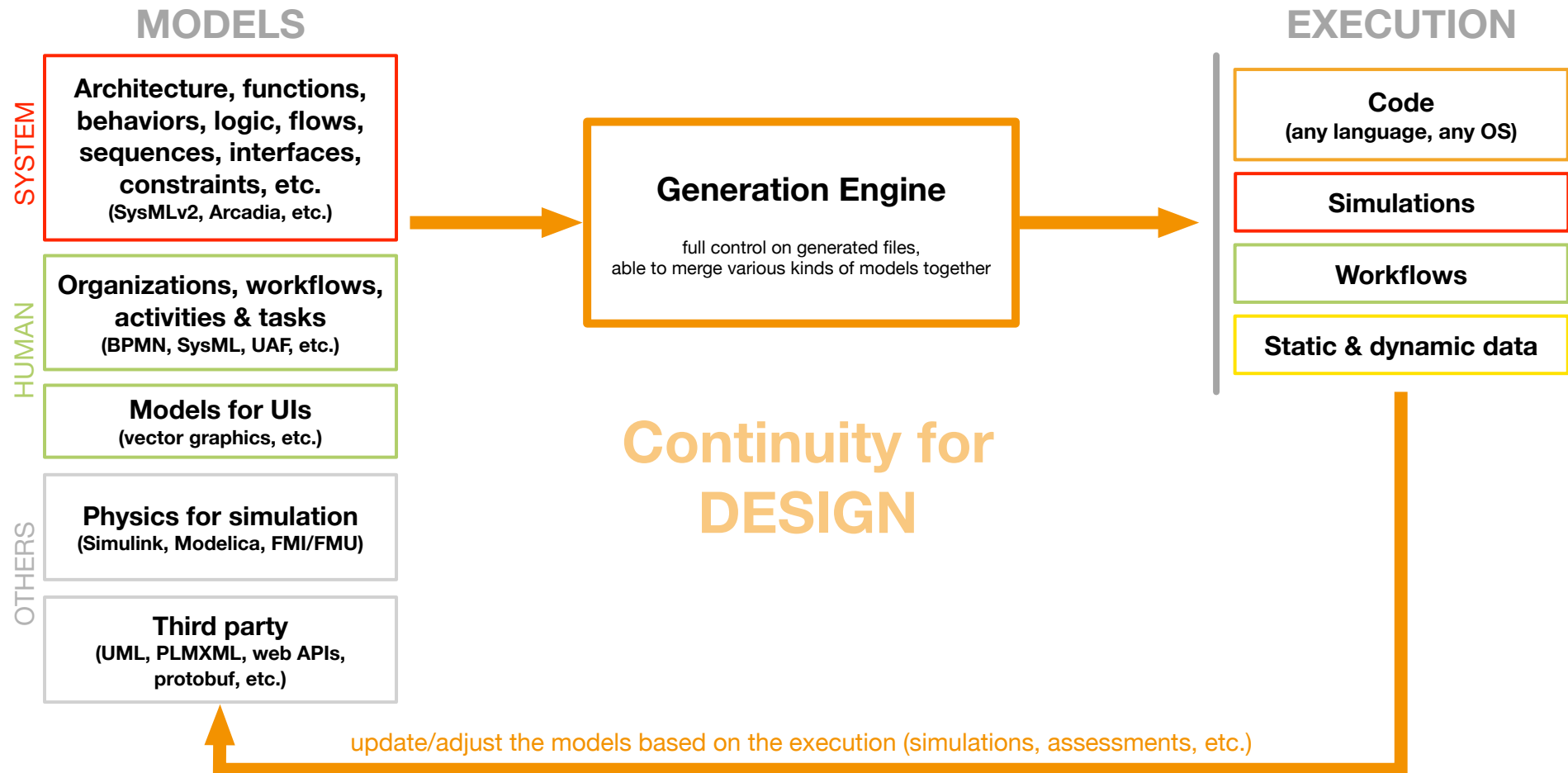
M2 **M1** 1532 **J7**

Real-time strategic management with decision support



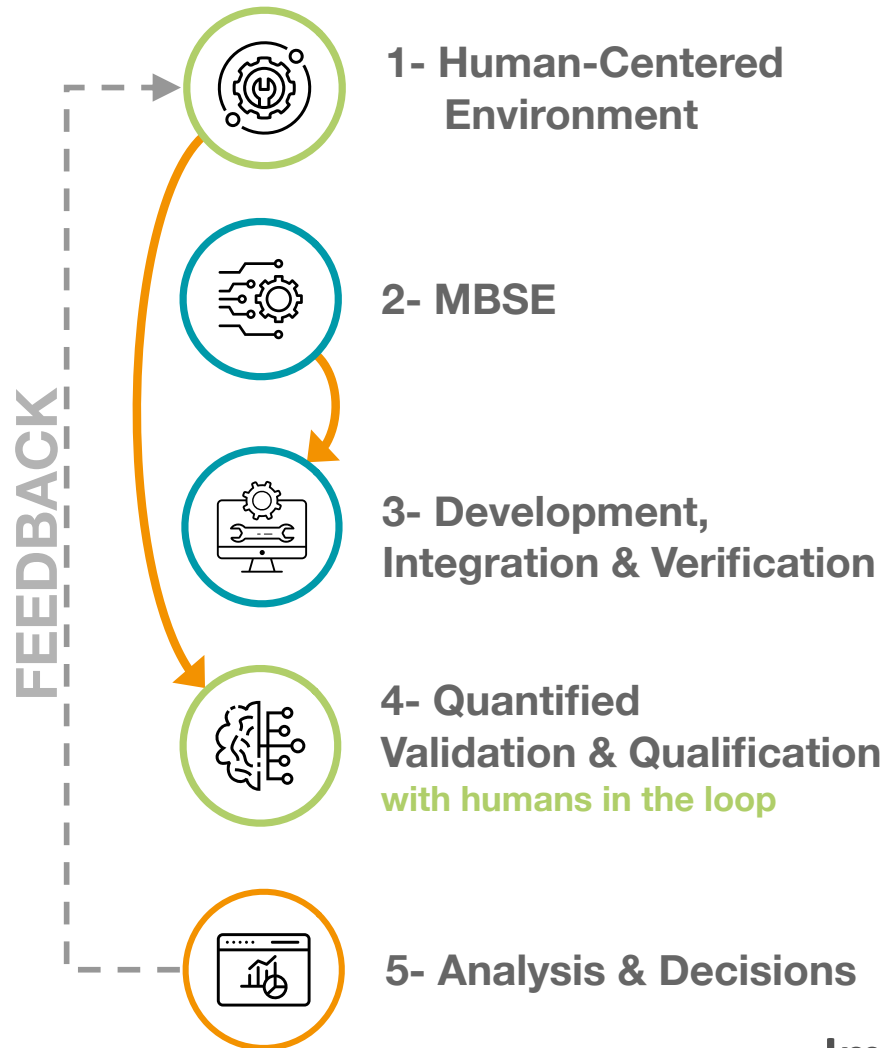
Iterate on the models

using feedbacks from the system and its environment



A multidisciplinary & iterative PROCESS for System of Systems Engineering

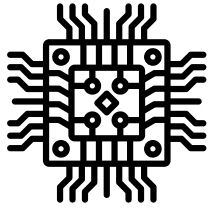
DEFINITION



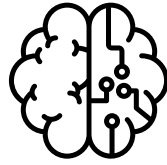
- Progressively refine problems & solutions
 - Leverage standards and models from all relevant disciplines
 - Make things quantified & concrete
- Flexibly mix mock-ups, digital twins, prototypes, co-simulations, and system components at various levels of maturity
- Collect actionable data
 - orchestrated by the scenarios,
 - with realistic and repeatable context,
 - traced with the metrics & requirements.

Improve the models progressively, keep them useful & up-to-date for all and at all times, contribute to a Single Source of Truth.

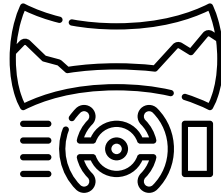
Unified platforms for Simulations + Integration + Operations



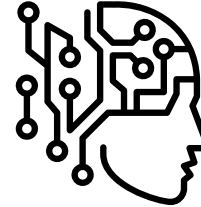
Hardware & test benches



Simulations & algorithms
(Matlab, etc.)



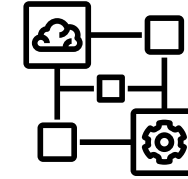
Environments & simulators



A.I. & automation engines



Human operators



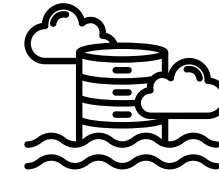
System-wide logic & services

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