Airport Capacity Runway Management with Digital Twin Technology

The approach to enable predictive decision-making, efficient resource use, and supports data-driven strategies for sustainable airport growth.

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Agenda

- About us

- What we talked about last summit

- Scenario – Adaptive Airport Systems: Integrating Safety and Operational Continuity

- The case – Airport Capacity Runway Management

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RESEARCH & DEVELOPMENT

Advanced Automation
MES Integration
Digital Twin, Simulation & Emulation
Advanced Analysis & AI

IIoT
Data Analytics Model
MES & Extended MES

OFFICES

Data-driven business
Production control
Forecast Predictions
Demand Simulations

WAREHOUSE

INTRALOGISTICS

PRODUCTION

What-If Analysis
Digital Transformation Roadmap
OT Security

We connect technologies, processes, and data to make business digitized and ready to anticipate and overcome any challenge.
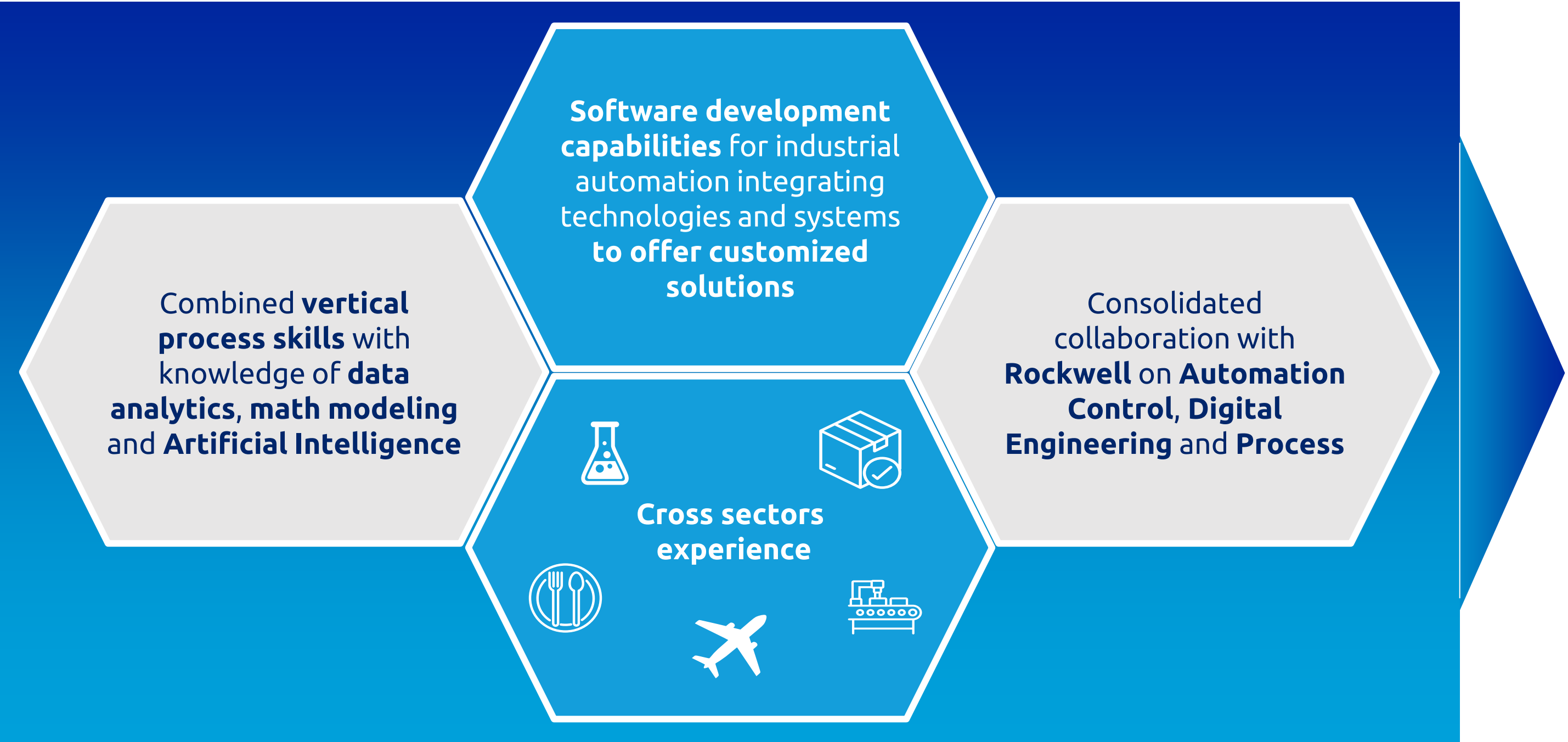
Group of leading Italian companies committed to enhance process automation through the creation of holistic and systemic solutions that enable efficient and sustainable operations management

20+ Years of experience

850+ Projects Realized

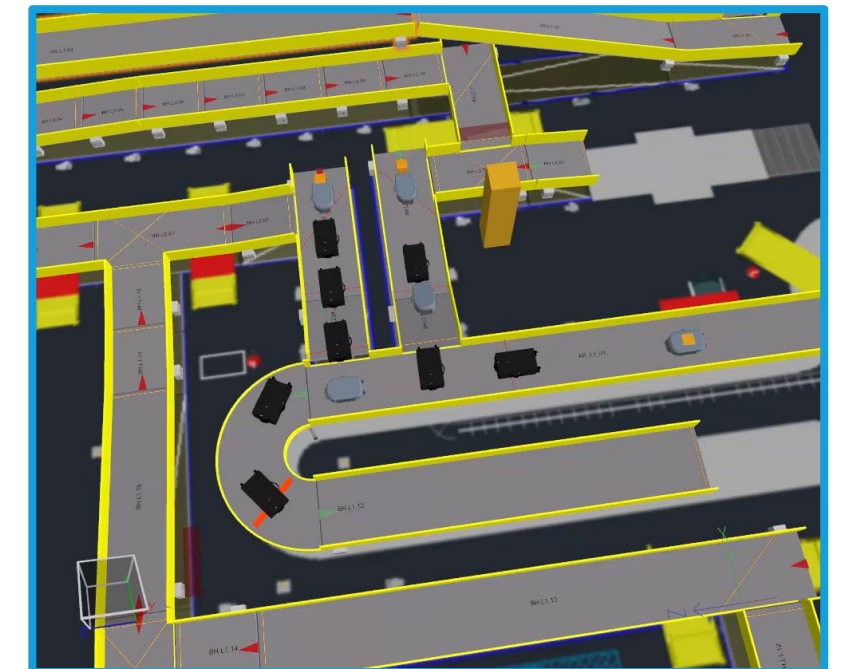**220+** Customers Satisfied

70+ Qualified Professionals

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automate
solutions builder

automate
consulting

bridger
industrial software

coelme
automation systems

(LATITUDO)
data intelligence

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www.automategroup.it

Our experiences

Combined vertical process skills with knowledge of **data analytics, math modeling** and **Artificial Intelligence**

Software development capabilities for industrial automation integrating technologies and systems **to offer customized solutions**

Cross sectors experience

Consolidated collaboration with **Rockwell** on **Automation Control, Digital Engineering** and **Process**

Digital Engineering projects to enrich customers' operational benefits

ADR
AEROPORTI DI ROMA

GENOVA CITY AIRPORT

REGGIO CALABRIA airport

LEONARDO

fives

cassioli
AUTOMATIC MATERIAL HANDLING

ELEMASTER

LAVAZZA
TORINO.ITALIA.1895

Mozarc
medical

DANIELI AUTOMATION
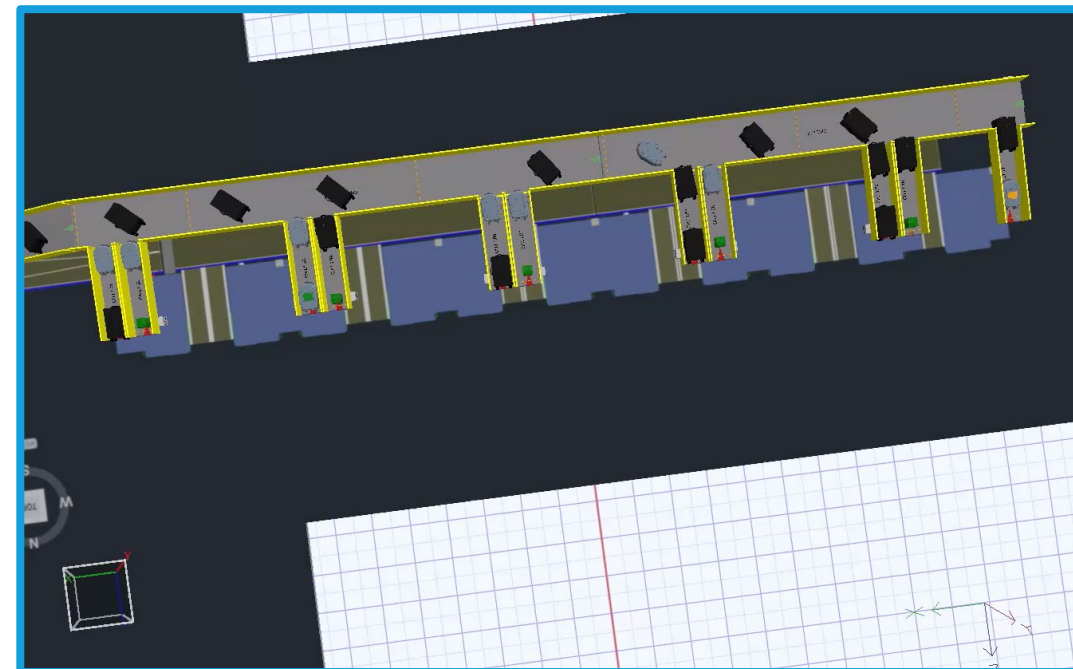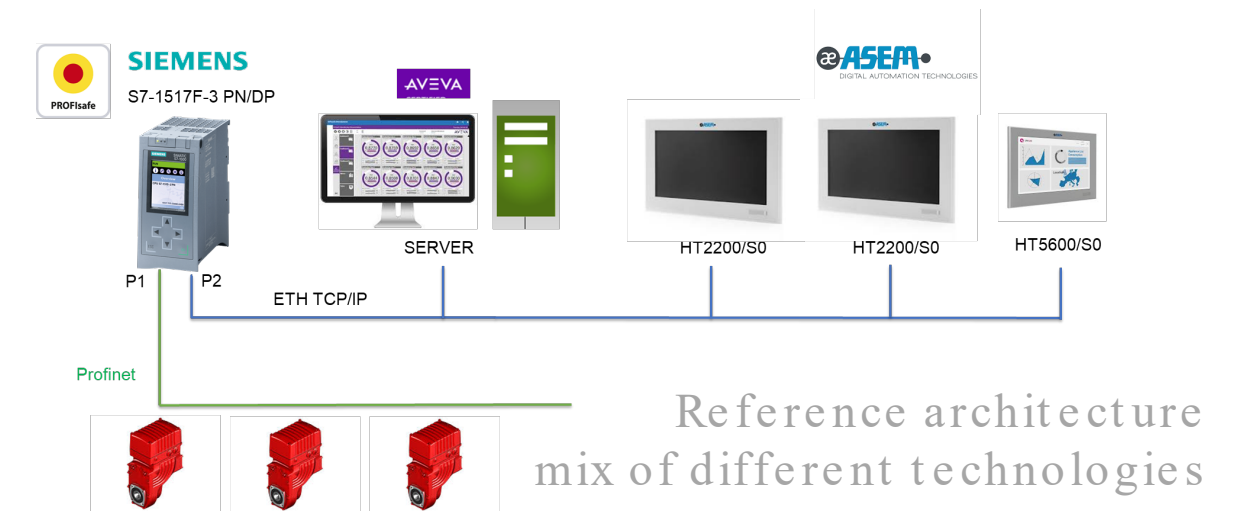
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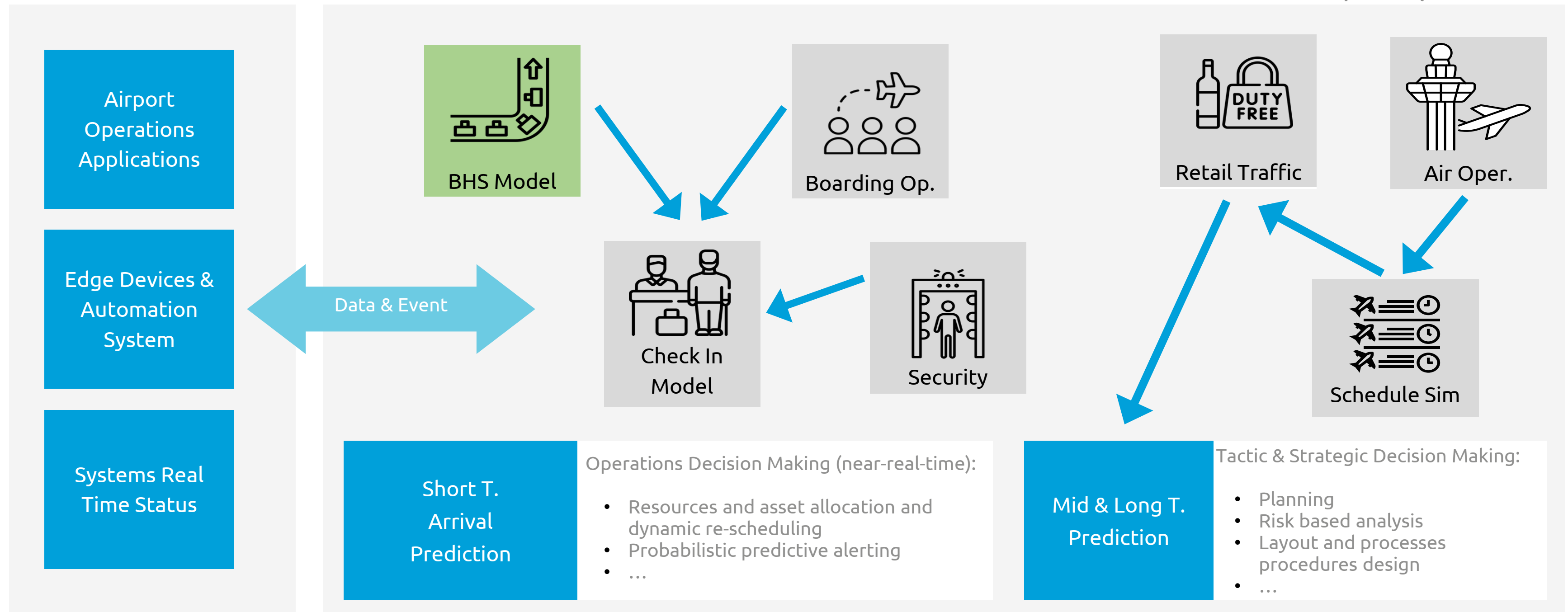
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We've Started Focusing on BHS Simulation...

High-fidelity simulation, from check-in to bay

Check-in

Main transport

X-Ray

Bays

Operators management

Bays allocation

PLC & logic parameters settings

HIGH LEVEL ANALYSIS

LOW LEVEL ANALYSIS

Peak flow management

Check-in desks allocation

Alarms/failures management

...
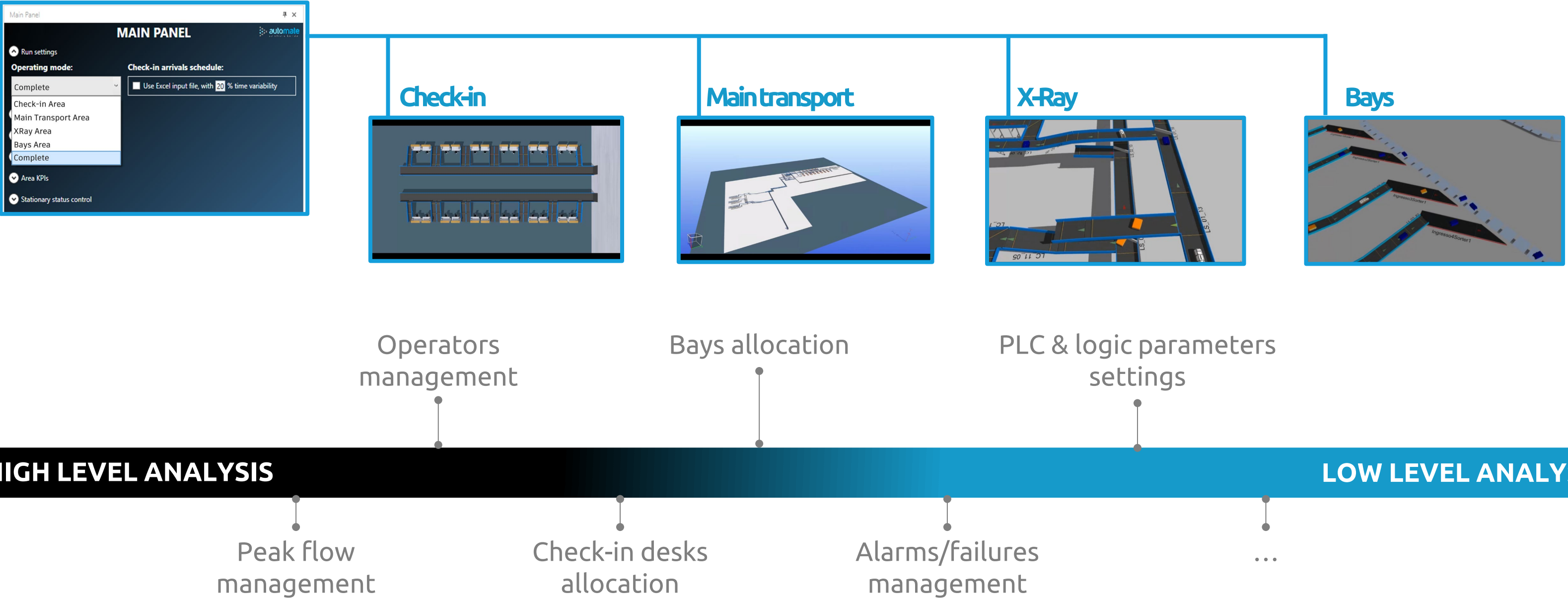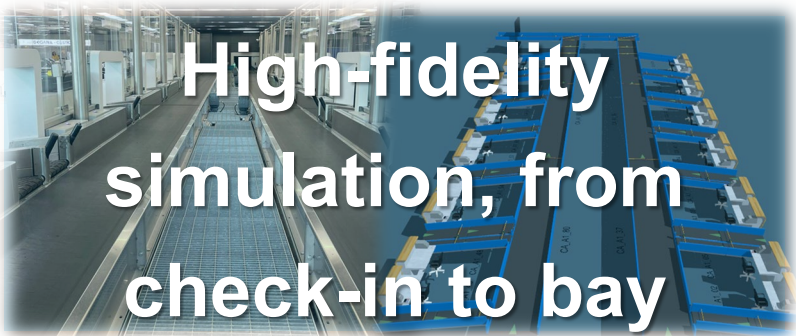
...Progressing Toward Seamless BHS Integration via Smart Virtual Testing

Reference architecture
mix of different technologies

- **Overcome critical factors** during pre/virtual - commissioning
  - **Interoperability** among various technology components
  - **synchronization** with civil and electromechanical part
  - **Integration** of third party machines (e.g. x-ray machines)
  - Difficulty **test on throughput** due to logistic/regulation/timing requirements

- Nowadays this is how we implement all complex projects
  - extended libraries to accelerate the realization
  - enhanced algorithms to assure challenges of automation logic

...Beyond BHS: Shaping the Future of Adaptive Airport Operations

Airport Operations Applications

Edge Devices & Automation System

Systems Real Time Status

BHS Model

Boarding Op.

Data & Event

Check In Model

Security

Retail Traffic

Air Oper.

Schedule Sim

Short T. Arrival Prediction

Operations Decision Making (near-real-time):

- Resources and asset allocation and dynamic re-scheduling
- Probabilistic predictive alerting
- …

Mid & Long T. Prediction

Tactic & Strategic Decision Making:

- Planning
- Risk based analysis
- Layout and processes procedures design
- …

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Scenario - overall

The Evolving Challenges in Airport Operations

- **Growing** passenger traffic and aircraft movements
- **Pressure** on infrastructure and environmental constraints
- **Complexity** of real-time coordination between ground and airside
- **Need for predictive**, not reactive, decision-making

Critical Pain Points in Airport Operations

- **Lack of visibility and synchronization** across zones
- **Inefficient** turnaround processes
- **Limited** ability to test **"what-if" scenarios**
- **Reactive response** to congestion or incidents

Capacity vs. Efficiency a Delicate Balance

Physical limitations (runways, gates, taxiways)

Operational disruptions (weather, delays, maintenance)

Balancing safety, performance, and sustainability

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Scenario - Focus on Runway Management

Runway Operations – The Bottleneck of Capacity

- **Limited number** of runways vs. growing demand

- **Intervals between arrivals/departures**

- **Coordination** with ground handling and ATC

- **Delay propagation** from runway inefficiencies

Runway Management – Key Needs

- **Accurate forecasting** of demand

- Real-time **tracking of operations and performance**

- Simulation of **contingency scenarios** (e.g. closure, surge)

- Data-driven **allocation of slots and sequencing**

Key benefits and strategic values

- **Improved on-time performance**

- **Faster response to disruptions**

- **More efficient use of runway capacity**

- **Data-driven planning and collaboration**

- **Supports capacity planning and investment decisions**

- **Enhances passenger experience via reduced delays**

- **Aligns with sustainability goal**

- **Enables long-term innovation in airport management**

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The Case

- **Objective:** Evaluate operational capacity of single-runway airports using a hybrid simulation model.

- **Methodology:** Integration of **System Dynamics (SD)** and **Discrete Event Simulation (DES)** for dynamic and stochastic modeling.

- **Case Study:** Applied to **Venice Marco Polo Airport (VCE)** – a high-traffic single-runway configuration.

- **Model Features:**
  - Models arrival/departure flows, taxiways, gates, and holding queues.
  - Incorporates **Poisson arrival processes** and **exponential service times**.
  - Dynamically prioritizes runway usage to minimize delays.

- **Simulation Output:**
  - Construction of a **capacity envelope** aligned with Gilbo's theoretical framework.
  - Identification of **operational bottlenecks** and runway saturation thresholds.

Airport Capacity Runway Management

Power of coupling

Airport Capacity Runway Management
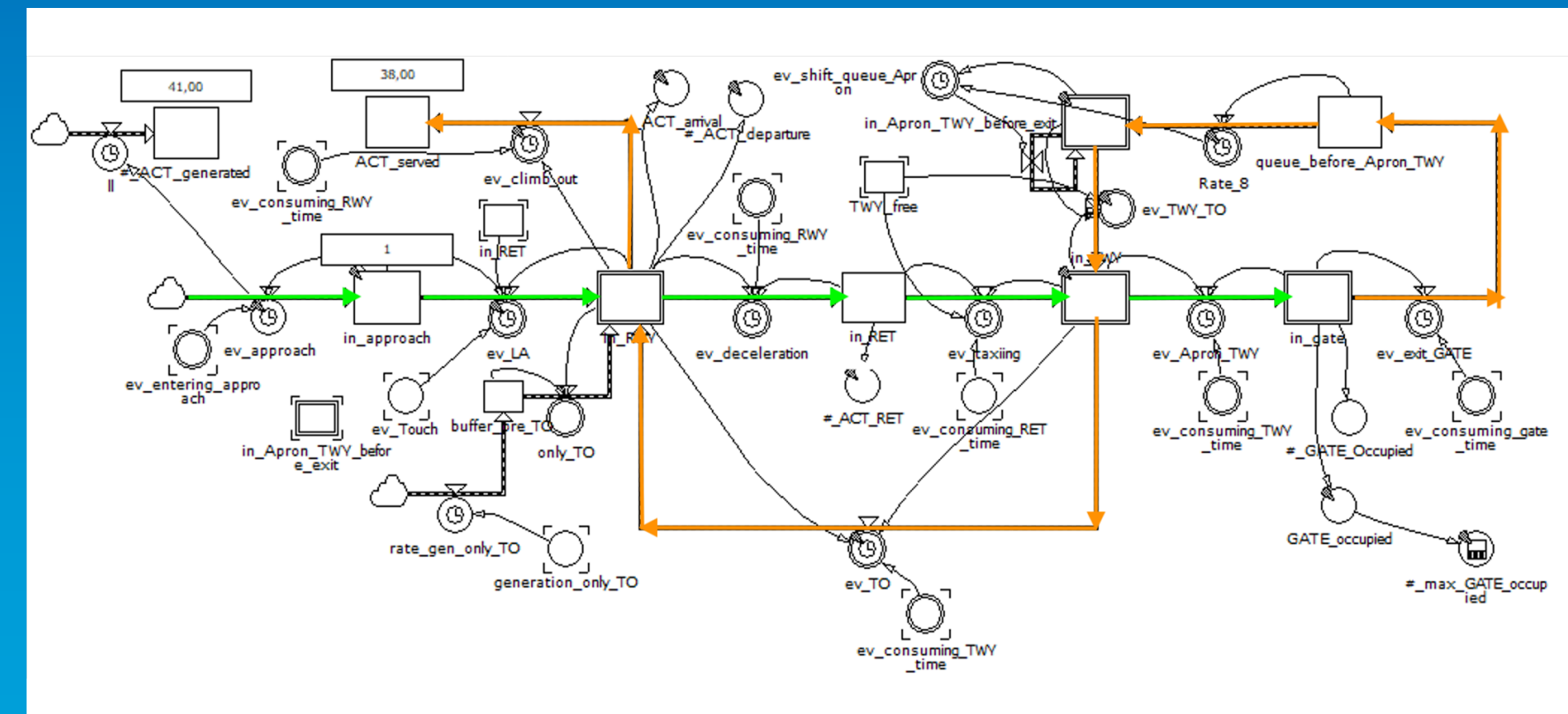
- **Real-time visualization** of aircraft movements and resource allocation (runway, taxiway, gates)

- **Validation and testing** of the simulation logic under realistic physical constraints and operational rules

- Enhanced stakeholder engagement through **immersive visual scenarios**

- The possibility to test **"what-if" scenarios** and operational strategies in a near-realistic environment, with feedback loops into the SD–DES model.

Aeroporto di Venezia

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The case - Architecture
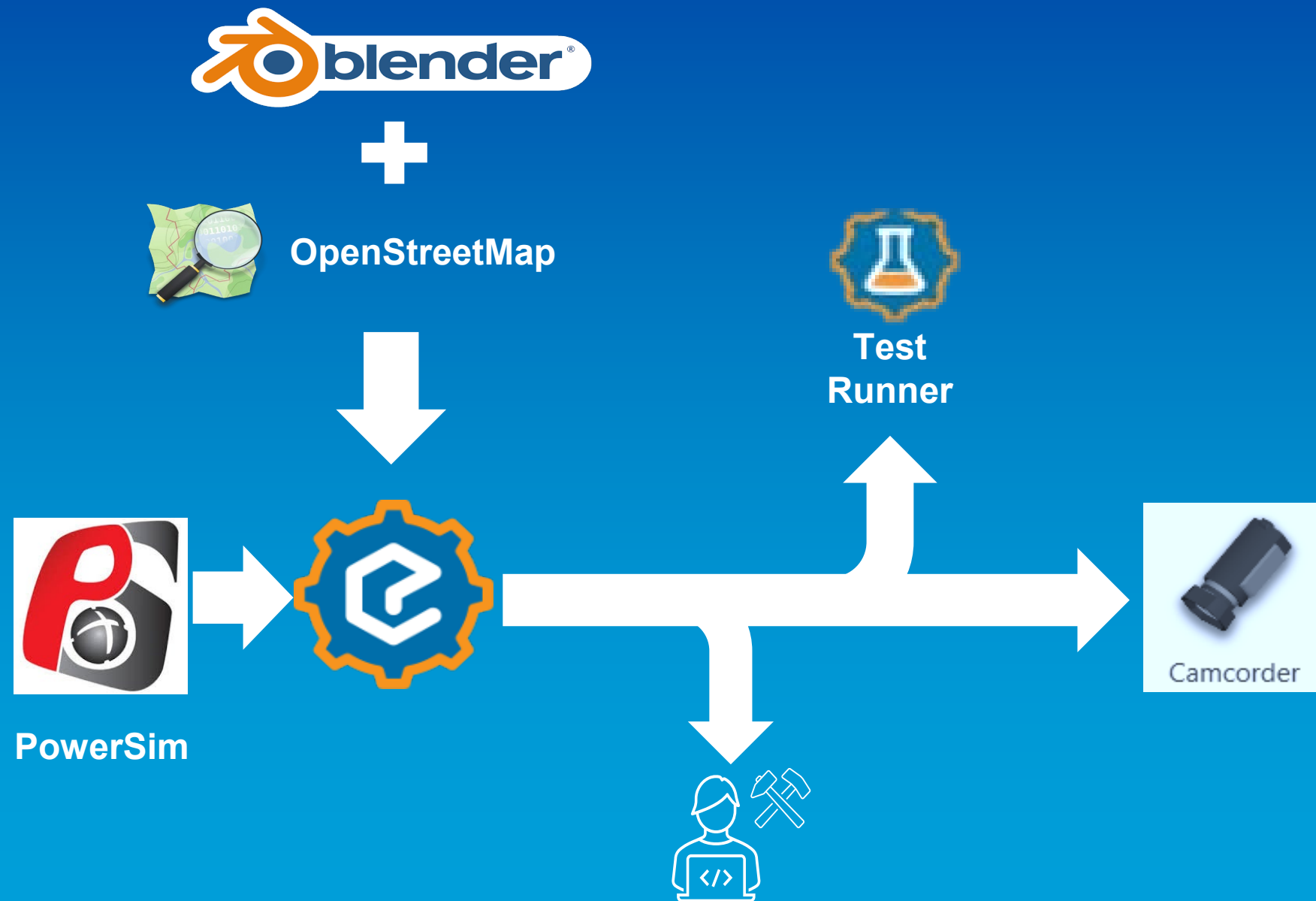
- **Automatic mesh generation** of Venice Airport (buildings, main terminal, satellite image)

- **Manual Model Creation** of high-detail elements (e.g. landing strip texture, aircrafts, gates, etc.)

- Model **Logic Calibration**

- Experiments & Versioning **Validation**

- **High quality** video

Test Runner
Quick, Custom & Reusable Model Validation

■ **Experimental input:**

Aircrafts arrival rate, Total Aircract capacity, Gate Service Time

■ **Two- stage approach using Test Groups:**

Individual input testing ➡ Combined testing based on initial results

■ **Test Runner Benefits:**

- Definition of a standalone test list

- Headless (fast) simulations

- Configuration feasibility check (e.g. Passed, failed)

- Actions (assertion, set input, record output) or Scripts (fully customizable)

Optimizer
Effortless Optimal weights based on scientific techniques

- **Tunable Priority** Score to balance arrivals and departures

$$\mathcal{P}_{arr} = \alpha \cdot Q_{arr} + \beta \cdot T_{wait}^{arr}, \quad \mathcal{P}_{dep} = \gamma \cdot Q_{dep} + \delta \cdot T_{wait}^{dep}$$

Traditional approach : define "ok" weights based on experts ' opinion or quick analytical calculation

- **Built -in strategies** for automatic optimization :

  - Brute force (full factorial), simple but exponentially slower

  - Particle Swarm (density -based), simple and fast

  - Genetic Algorithm (Fitness score, generations, mutations), the slightly complex middle -ground

Priority Rule Tuner

RUN STOP

Select Model
Venice_Airport_V1.demo3d

Model Duration Per Iteration
120

Iterations
40

Algorithm Options

| Brute Force |
| Particle Swarm |
| Genetic |

Velocity Fraction
0,25

Personal Factor
0,50

Social Factor
0,50

Scripted Scenarios
Test Scenarios
+ NEW TEST GROUP
Arrival Rate
ACT Capacity
Gate Service Time
Combined Tests
Optimizers (Beta)
+ NEW OPTIMIZER
Priority Rule Tuner
Models
Model Actions

Description	Type	Minimum Value	Maximum Value	Optimum Value			
DataCollection1.Alpha	Float	0	3	1,03594782			
DataCollection1.Beta	Float	0	3	0,556719			
DataCollection1.Gamma	Float	0	3	0,89945319			
DataCollection1.Delta	Float	0	3	0,37503957			

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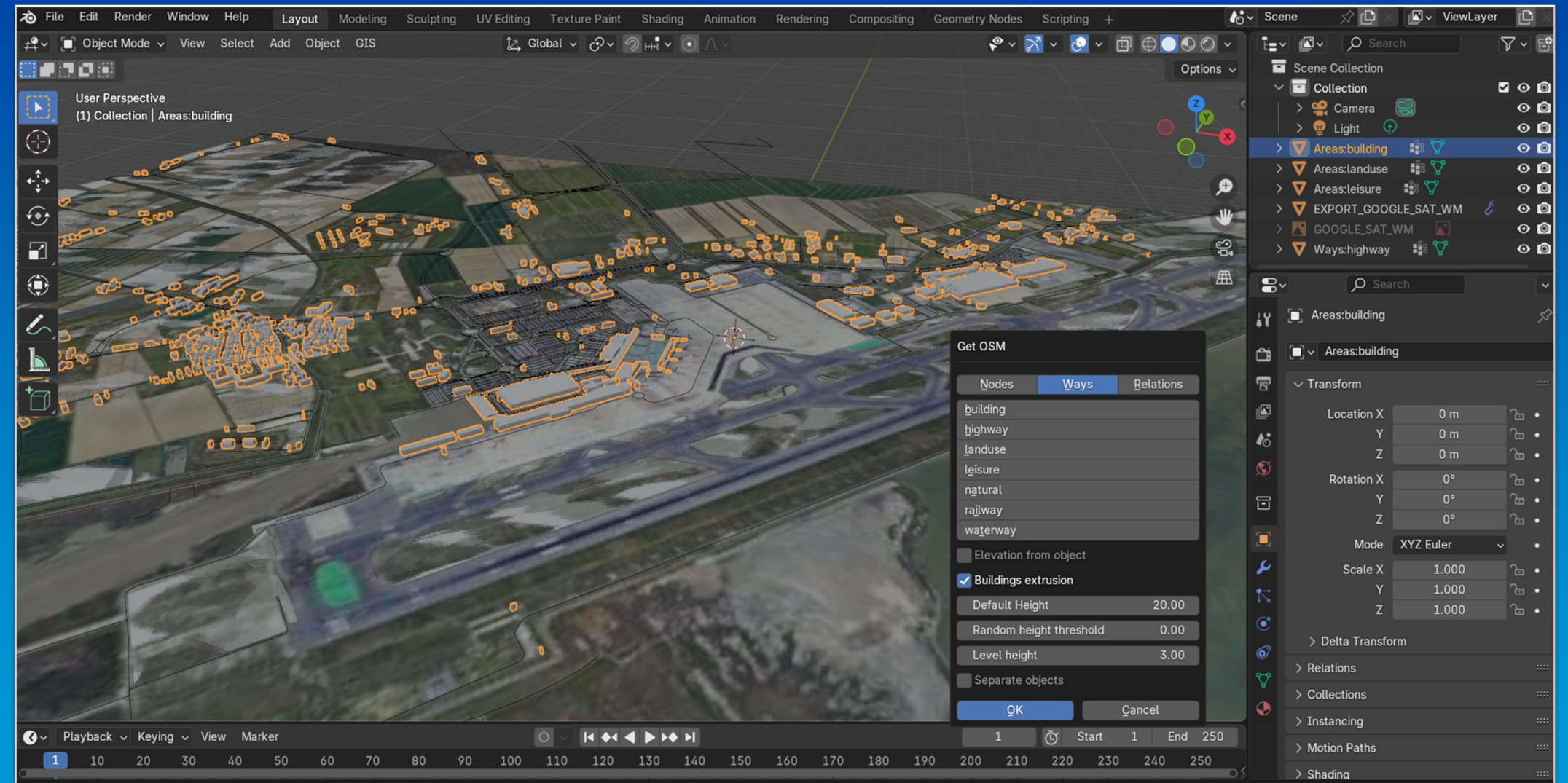# Camcorder
For smooth , high quality videos

- **Easy scene setup** via camera PoV

- **Frame-level detail**

- **Full control of camera trajectory** (red line)
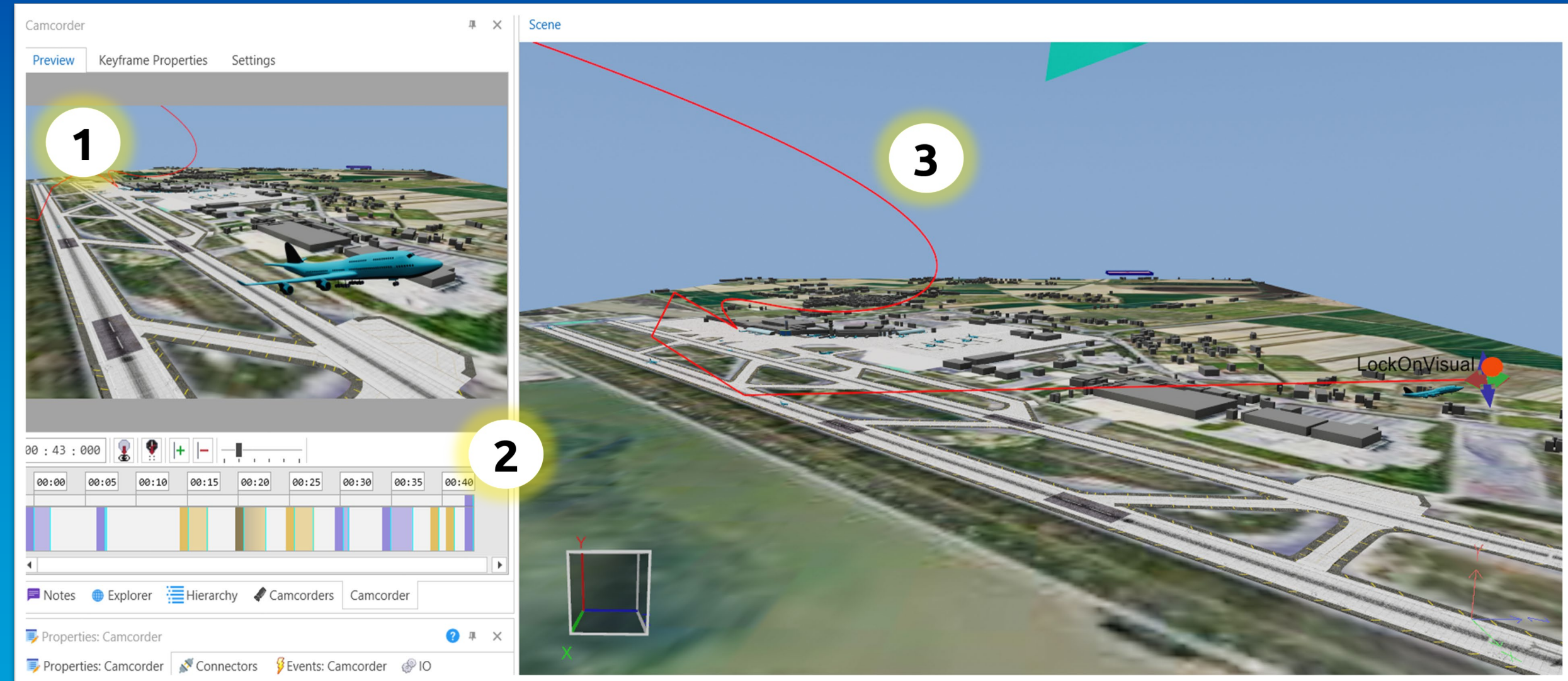
TIP: Ensures video plays 1x when model does not !

Blender + GIS

- **Goal:** Generating mesh of very large areas to be importe into E3D

- **Unique integration :**

  - Blender, a free 3D animation software

  - Geographical Information System (GIS) add-on for automatic mesh generation from imported data

  - OpenStreetMap, a crowdsourced geographical information database

- **Optional imports:**

  buildings, land use, road network, railways, waterways, 3D terrain altitude, satellite images, ...

OpenStreetMap

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Thank you !

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automate solutions builder

automate consulting

bridger industrial software

coelme automation systems

(LATITUDO data intelligence)

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