CARLO Company Introduction

Production innovation key in on-site

2025. 02.

CARLO

CARLO

CONTENT

CARLO

PART ONE

1. Company Introduction

1. Company Instruction

CARLO

Company name	CARLO
CEO	Dr. Ji-Woong Oh
Established	January 2017
Headquaters	7-2, Gwanggyojungang-ro 248beon-gil, A-902, Wonhee Castle, Yeongtong-gu, Suwon, South Korea
Product Development Research Lab	Ajou University M&S Research Lab

Core Business Areas

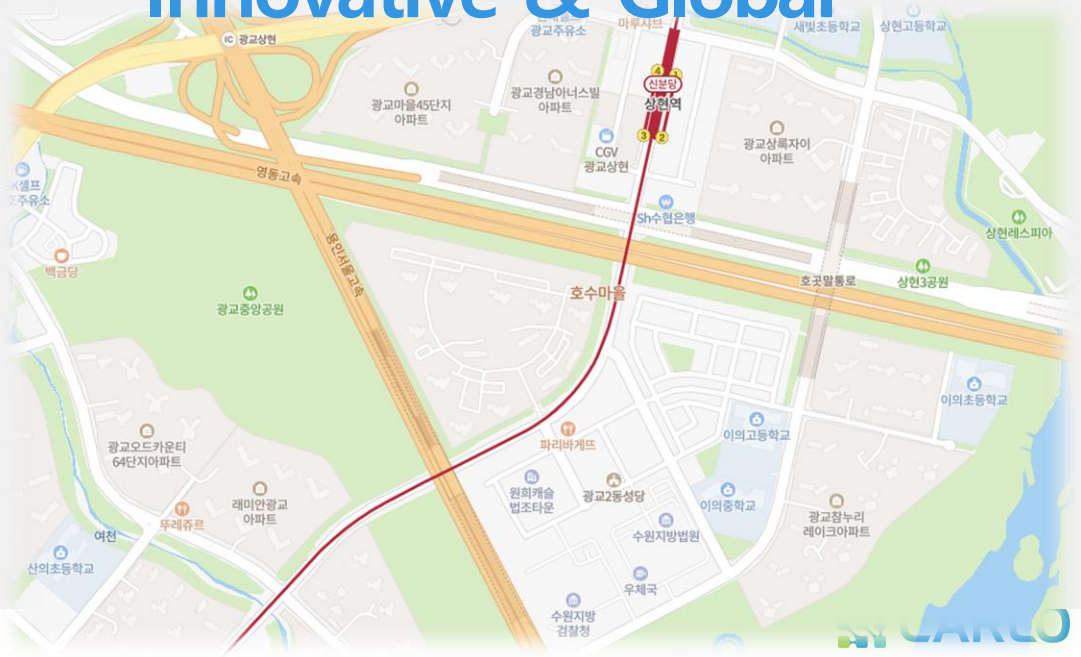
- Smart factory & digital twin implementation and operation
- Logistics optimization (OHT/AGV/Stocker/Conveyor)
- Logistics control system development (OCS, ACS, MCS)

Licenses & Certifications[1)]

- Discrete event modeling method for intelligent factories
- Selection of significant variables & regression analysis for discrete event models
- Automated deep learning program for artificial neural networks
- Cloud-based digital twin system for pipeline packages
- AI-based lifespan prediction program

1) Patent Numbers: C-2018-025458, C-2019-041048, C-2020-044040

Innovative & Global



1. Company Instruction

CARLO

Dr. Ji-Woong Oh

Total Workforce: 33

(CARLO 20, Research Lab 13)

R&D

Dr. Sang-Chul Park
& 12 members

- PINOKIO Engine
- PINOKIO-Sim
- PINOKIO-DT
- PINOKIO-Fairy
- LLM + DT
ChatGPT + PINOKIO

Degital Twin

Ji-Woong Oh &
5 members

- Synchronization
- Virtual Sensor
- Algorithm Opt.
- Industrial Protocol
- Interface

Logistics Optimization

Ji-Myoung Park,
Dong-Kyu Kim
& 5 members

- PINOKIO-OCS
- AGV / Conveyor
- Stocker / Lifter

On-site Implemantation & Stabilization

Kang-Hoon Cho,
Min-Su Ko & 5 members

- PLC / PC Control
- Equipment Dev
- On-Site Deployment
& & Stabilization

Partners

(Product Sales / Training / On-Site Deployment)

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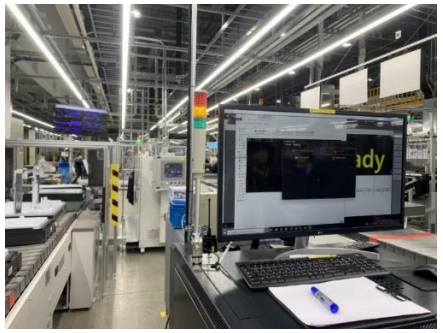
PART TWO

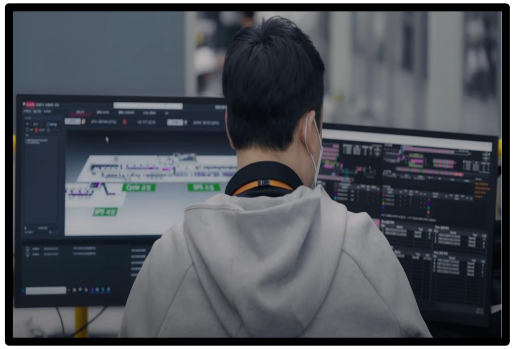
2. Major Achievements

2. Major Achievements

LG Electronics

- 2013–2014: Developed FLO 2.0 for work motion optimization.
- 2013–2017: Conducted simulation and optimization for various production lines (Refrigerator, Compressor, Semiconductor Packaging, etc.)
- 2016: Developed an Operator Assignment Program
- 2020–2022: Developed a Deadlock-Free AGV Control System (ACS)
- 2022: Developed an AI-driven real-time video analysis and forklift tracking system
- 2022: Established a Digital Twin for LG Smart Park in Changwon (MES communication & optical sensor integration)
- 2023: Built a Web-based Digital Twin for LG Smart Park (High-performance DT server & alarm system)
- 2023–2024: Developed a high-speed PLC signal data collection & analysis too
- 2024: Expanded Digital Twin coverage at Changwon LG Smart Park to track and monitor supplier component supply status
- 2025: Developing a Factory Modeler based on NVIDIA Omniverse





2. Major Achievements

삼성SDI 삼성디스플레이

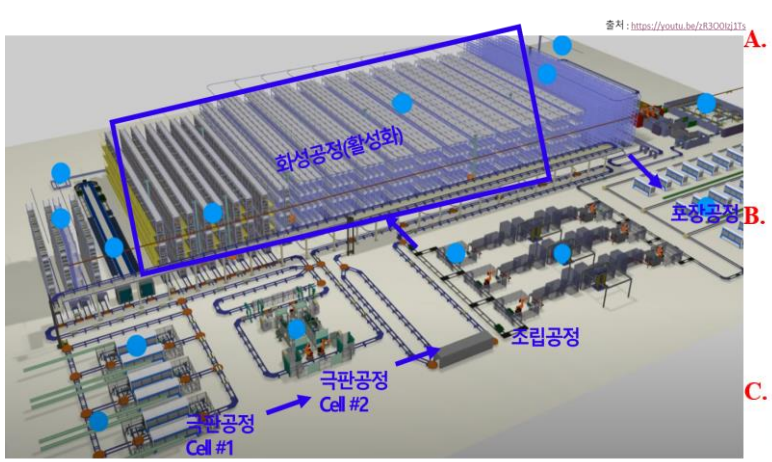
Samsung SDI / Samsung SDC

Samsung SDI

- 2023: Modeled PINOKIO for electrode manufacturing process at the Hungary plant
- 2023: Modeled PINOKIO for formation process at the Hungary plant
- 2024: Modeled PINOKIO for formation & electrode process at the Gamma plant
- 2024: Modeled PINOKIO for formation & electrode process at the Hungary 2-2 plant
- 2024: Developed AGV logistics volume forecasting software
- 2024: Established a Digital Twin for the formation process at the Hungary plant

Samsung SDC

- *2022: Conducted integrated simulation for production & logistics at large-scale fabs*
  (Performance comparison between PINOKIO and PlantSim)



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2. Major Achievements

SK Hynix / SEMES / Hyundai Kefico

SK Hynix

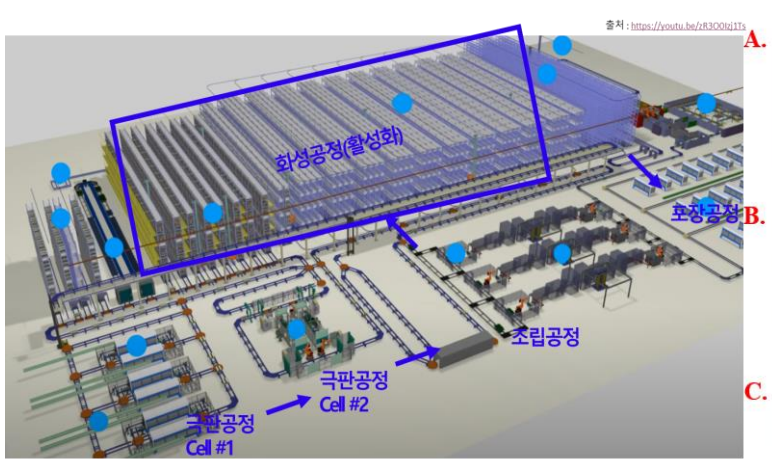
- 2020: Proof of Concept (PoC) for Fab AMHS Simulator
  (Performance comparison between PINOKIO and PlantSim)
- 2021: Developed Fab AMHS Simulator for Icheon M10
- 2022: Advanced Fab AMHS Simulator for various sites
  (Icheon M14, M16 HUB, M16A, P&T4 / Cheongju M11, M15 / Wuxi, China C2, C2F)
- 2023: Organized & supported the SK Group AI competition
- 2024: Conducted OSS Proof of Concept (PoC)

SEMES

- 2018: Designed a Digital Twin-based FAB OHT-Network
- 2019: Developed a virtual equipment simulation for OHT control logic

Hyundai Kefico

- 2017: Developed CP-Designer for automotive ECU
- 2018: Developed software modules and test scenarios for ECU-TCU



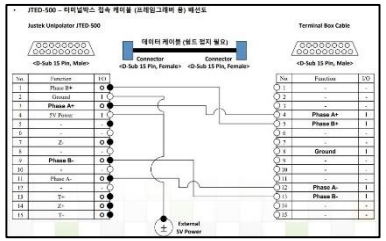
2. Major Achievements

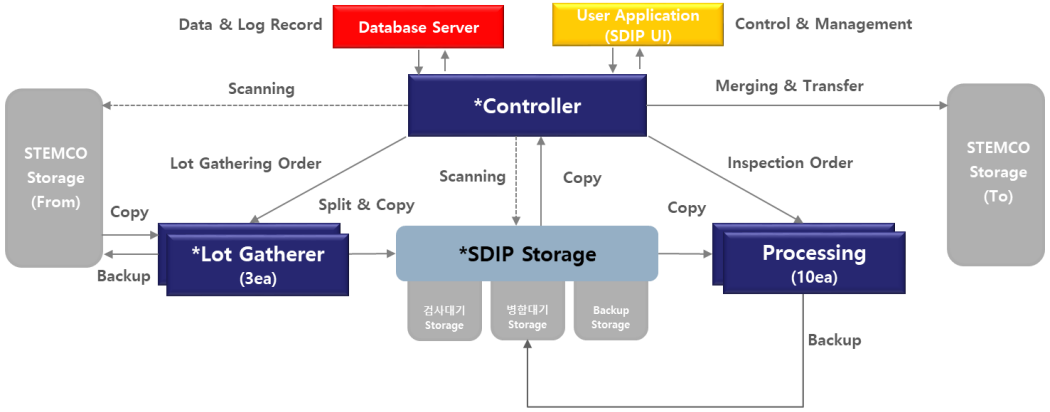
STEMCO
SAMSUNG & TORAY

STEMCO

STEMCO

- 2015: Reduced EAOI single-image noise
- 2016: Reduced EAOI image noise
- 2016: Reduced FVI image noise
- 2016: Implemented EAOI #1 equipment control
- 2017: Reduced EAOI #4 image noise using blueprint-based processing
- 2018: Developed a deep learning-based image noise reduction system for SOI equipment*(Configured with NAS 58TB, server, UPS, 8 server modules, and 1 rack)*
- 2019: Developed a deep learning-based defect detection system for inspection equipment*(Expanded with additional NAS 58TB, 16 additional server modules, and 2 racks)*
- 2021: Integrated deep learning-based process linkage for manufacturing equipment*(Added 12 server modules, configured with 1 rack)*
- 2022: Established a deep learning-based Digital Twin for manufacturing and inspection equipment





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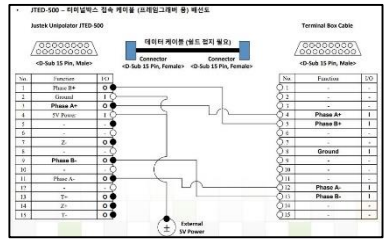
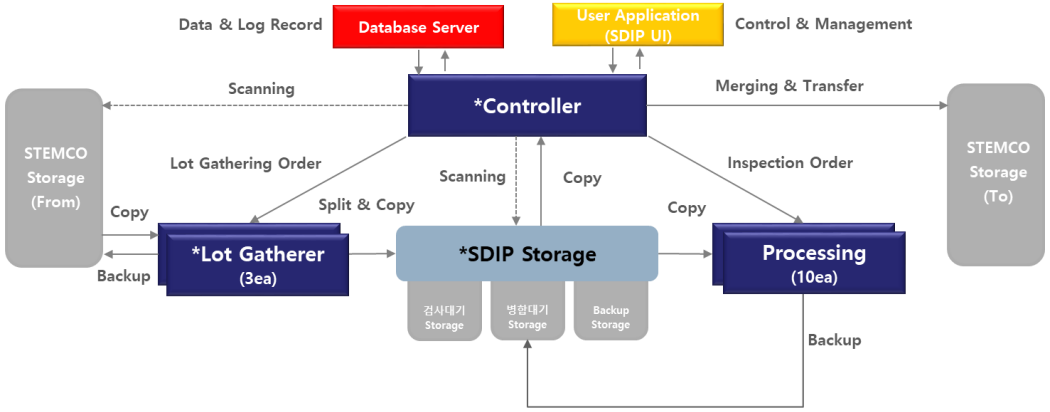
2. Major Achievements

Hankook Tire

Hankook Tire

- 2020: Built an AI-based ITT tire quality management system *(Applied to on-site equipment)*
- 2022: Conducted warehouse capacity validation simulation
- 2022: Developed a Simulation for Deriving Optimal Production Operating Conditions
- 2022: Developed a rubber block stacking pattern recognition system
- 2022: Developed an AI-based X-ray image inspection system
- 2023: Developed a Simulation for Optimal Operation of the Tire MBR Inspection Process

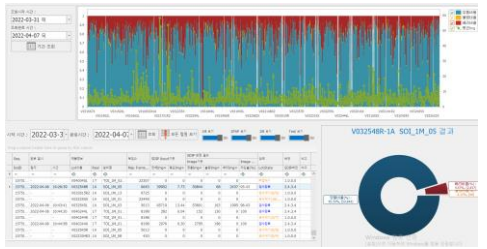




2. Major Achievement

POSCO / KITECH / KEPCO-KPS / Clad Korea / DAEJOO·KC / 오토텍 / Amorepacific

- POSCO 2018: Developed a Digital Twin-based online coke logistics system simulation
- POSCO 2018: Built an AI System with Digital Twin for deep learning-based equipment performance prediction and system redesign simulation



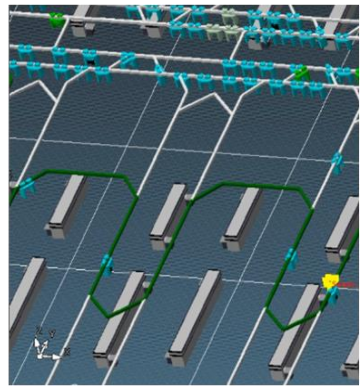
- KITECH 2020: Designed a Digital Twin-based manufacturing equipment diagnostics and maintenance service demonstration

- KEPCO-KPS, 2019: Developed an AI-based boiler quality management system
- Clad Korea 2021: Constructed a cloud-based Digital Twin synchronized with PLC signals
- Daejoo 2023: Developed a Digital Twin for PLC-controlled extrusion machines and optimized startup conditions
- MS Autotech 2023: Built and optimized a Digital Twin for robotic welding cells in automotive parts manufacturing
- Amorepacific, 2024: Optimized forklift picking operations for large-scale stocker systems
- Amorepacific, 2024: Developed an AI-driven color formulation algorithm
- Amorepacific, 2025: Established a Digital Twin for packaging lines

공장(Factory)

모사(Imitation)

통찰(Insight)



카를로 피노키오(PINOKIO)

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PART THREE

3. Product Overview

3. Product Overview

Product Lineup

- Five products designed to improve logistics and production-related issues in the design and operation stages

PINOKIO Simulator

Modeling & Simulation for Design and Analysis

SIMULATOR

Windows

PINOKIO Digital Twin

Monitoring & Simulation for Optimal Operations

DIGITAL TWIN

Windows Web

PINOKIO VCS

Vehicle Control System for Optimal Efficiency

VCS

Windows

FAIRY

Integration of PINOKIO with AI Models

Windows

JIMINY

PLC Analysis and Integration of PINOKIO with Equipment

JIMINY

Windows

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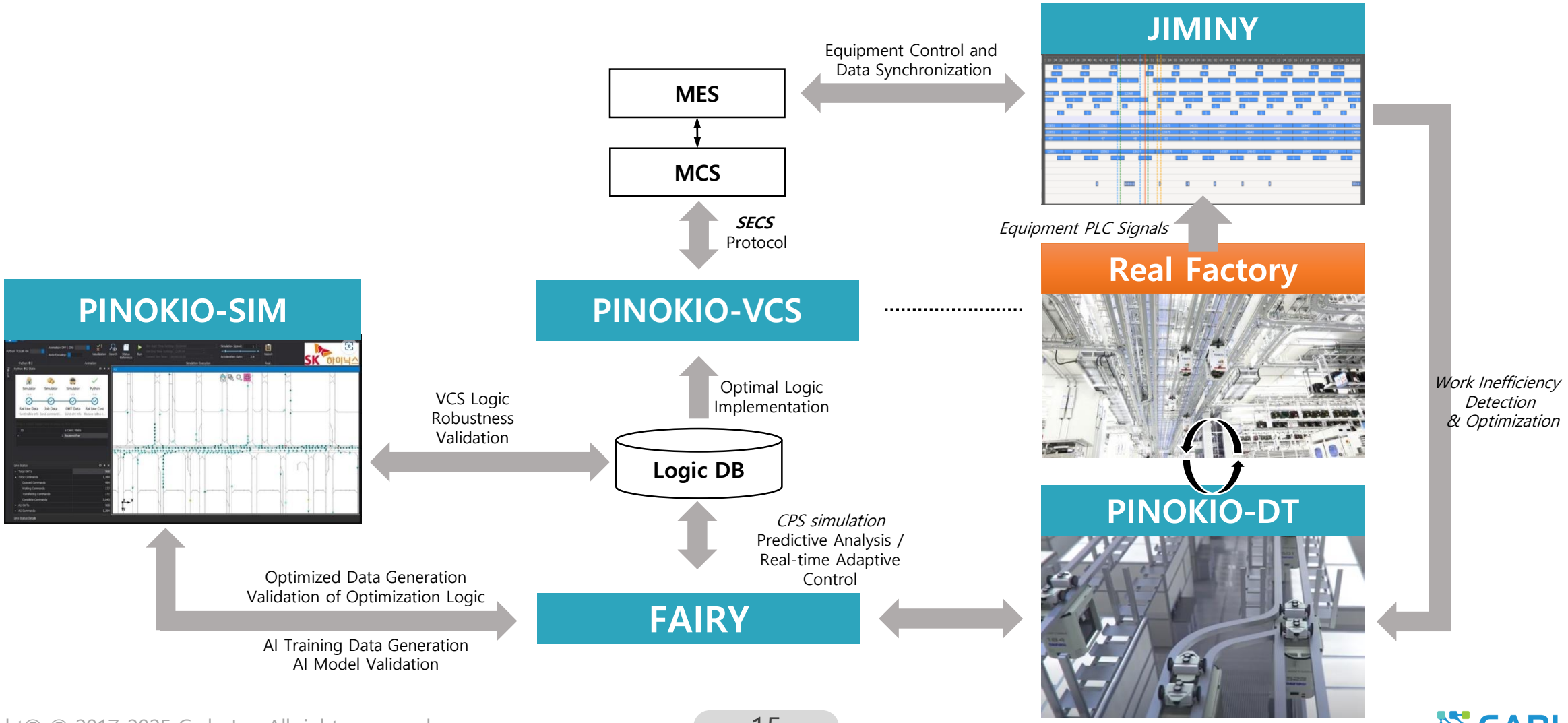
3. Product Overview

Product Lineup

- Five products designed to improve logistics and production-related issues in the design and operation stages



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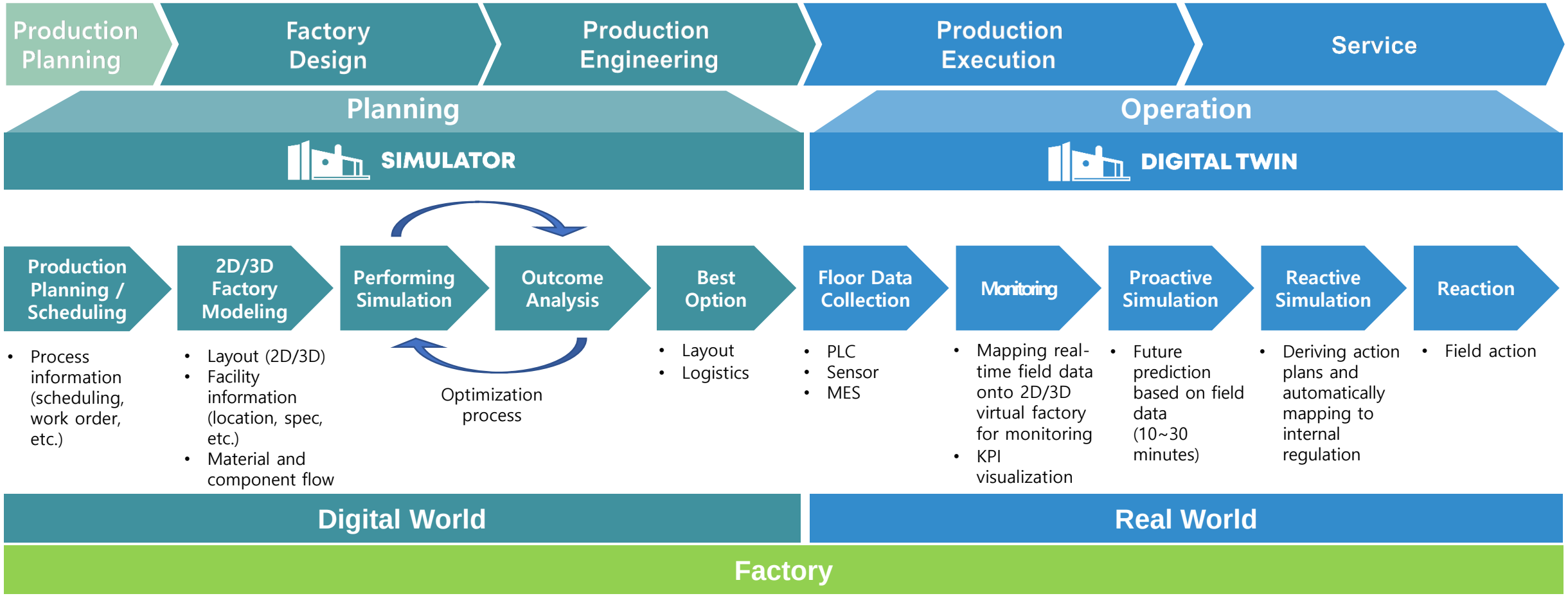
3. Product Overview

Flow of Digital Twin

PINOKIO Digital Twin covers both the production planning and production operation stages. In the production planning stage, it validates the facility layout and optimizes logistics through traditional simulations, while in the production operation stage, it enables predictive forecasting and proactive response through synchronization with MES and the Digital Twin.



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3. Product Overview

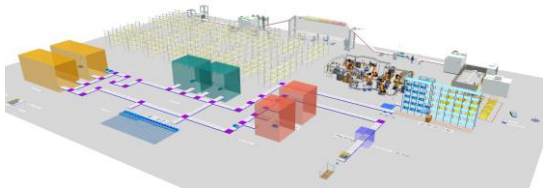
Process for Digital Twin Implementation

PINOKIDO has a 4-stage deployment process for Digital Twin, enabling Factory-Wide Digital Twin implementation through step-by-step expansion from small units like cells or units.

Phase 1

Abstract Digital Twin

- Utilized in the design phase. Create models, modify parameters, and validate KPIs (What-if Simulation)



Portions of the States

Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
Source	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SingleProc	99.98%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer	0.00%	0.00%	99.95%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	
SingleProc1	96.82%	0.00%	0.00%	0.00%	0.00%	3.18%	0.00%	0.00%	0.00%	
SingleProc2	31.34%	0.00%	0.00%	0.00%	1.38%	1.74%	0.00%	0.00%	65.54%	
Buffer1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SingleProc3	96.82%	0.00%	3.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer11	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SingleProc31	3.13%	0.00%	96.87%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Drain	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Drain1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	

Phase 2

Monitoring Digital Twin

- Perform Simulation w/ high consistency
- Build a Digital Twin based on manufacturing standards of the production system.
- Synchronize Digital Twin w/ the actual production system by acquiring production site info. (MES, sensors)

Phase 3

Proactive Digital Twin

- Set the Proactive Simulation execution cycle and Time Horizon based on the characteristics of production site.
- Execute Proactive Simulations according to the execution cycle.
- Warn operators in advance of potential issues within the Time Horizon. (So operators can take corrective action)

Phase 4

Autonomous Digital Twin

- Decision-making AI models to solve potential issues (Routing, Scheduling, Dispatching, etc.)
- Generate training data based on Digital Twin and train AI models.
- Establish a system for continuous evolution (Continuous Quality Improvement).

SIMULATOR

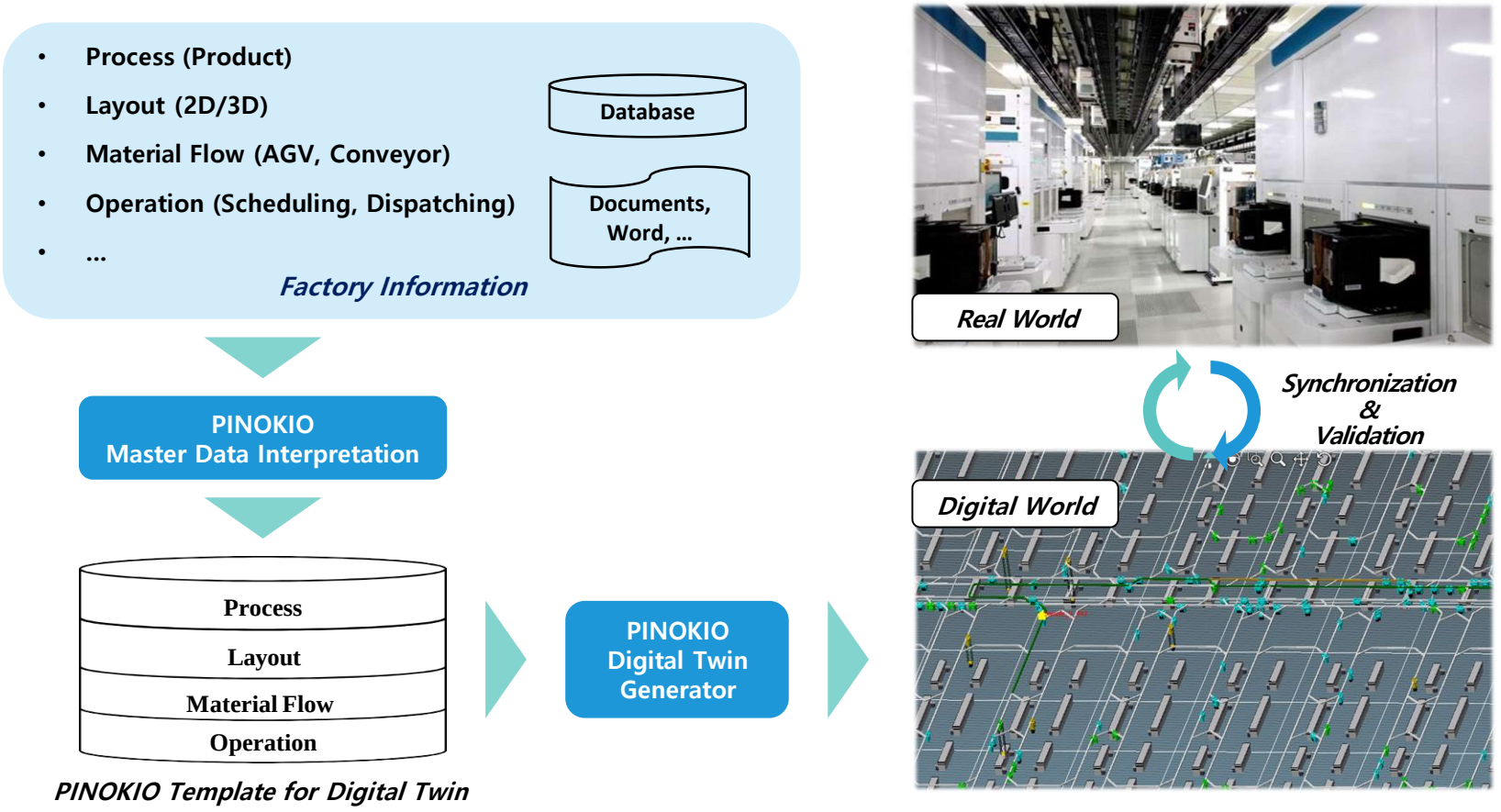
DIGITAL TWIN

CARLO

3. Product Overview

PINOKIO Introduction

CARLO's Digital Twin enables real-time monitoring based on field data and AI-driven future predictions.
It offers high-speed simulations, processing data 60 to 700 times faster, providing an optimized solution for large-scale factories with the capability to handle massive data volumes.



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3. Product Overview

PINOKIO Workflow

A real-time monitoring system can be built based on various data generated in the production site (MES, PLC, sensors, etc.), enabling visual tracking of product flow, production volume, and work-in-process (WIP) stock. Additionally, an AI-based accelerated simulator, specifically designed for manufacturing environments, continuously runs predictive simulations to anticipate future conditions and anomalies at specific time intervals. This system supports the formulation of appropriate response strategies tailored to the predicted scenarios.

Real-world Site

Sensor Data Collection

On-site Data Collection

- Manufacturing Reference Information (Processes, Layout, Logistics Operations, etc.)
- Sensor Data (Location, Detection Time, Product Information, etc.)

Virtual Factory Conditions

Real-time Monitoring

- **2D/3D Visualization**
- Real-time Visualization
- Display of Various Metrics (Logistics Supply Status, Buffer Loading Status, Total Production Status, etc.)
- KPI Configuration

Future Scenarios

AI-based Future Prediction

- Future prediction at each time interval (1–10 seconds) within the time horizon (10–60 minutes)
- Alerts (e.g., notifications, alarms) triggered when issues arise within the future prediction period

Rapid On-site Response, Downtime Minimization, First Time Fix, Optimal Equipment Lifecycle Management

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3. Product Overview

Why PINOKIO Digital Twin?

High Model Flexibility & Development Support Feature – Provides developer-level custom modeling environment

High Speed Simulation – Optimized simulation events and algorithms

Monitoring and Prognosis – Real-time synchronization and predictive simulations through Digital Twin

AI Platform – Integration with AI libraries

PINOKIO Introduction Video: https://www.youtube.com/watch?v=a4eJpv_eTho

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3. Product Overview - PINOKIO Digital Twin Specifications

Simulation for Design

High Performance

- Perform a 70x speed simulation of a factory with a 53,000- square meter site and over 1,000 vehicles.

High Resolution

- Achieve high consistency at the level where hardware sensors are modeled (supports 1x speed).

  98.8% of Consistency Rate based on Command Delivery Time (Total Time).

Applications

- All SK Hynix fabs; LG Electronics' new refrigerator factory in Changwon; Samsung SDI Hungary/Gamma plants

Acceleration performance can exceed 300x depending on the simulation adjustments for acceleration/deceleration and tracking control.

Target Factory	Throughput Ratio	Factory Scale
Single Fab(M14A)	70x	1,000 OHT units, 53,000㎡
Multi Fab(M14A, M14B)	30x	1,800 OHT units, multiple inter-floor Lifters, 106,000㎡

SK Hynix
Semicondector Fab

Samsung SDI Stellantis Battery Plant

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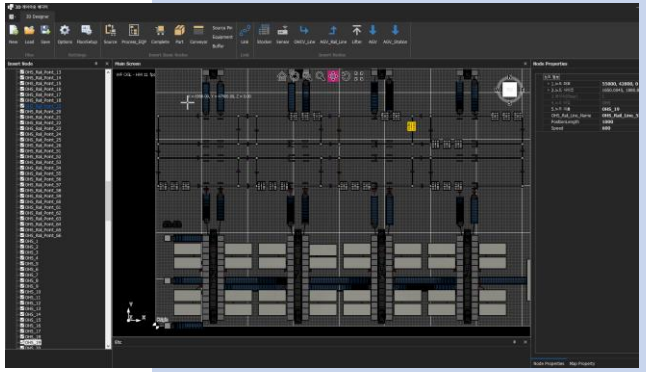
3. Product Overview - PINOKIO Digital Twin

Simulation for Production & Logistics

Production/Logistics Modeling

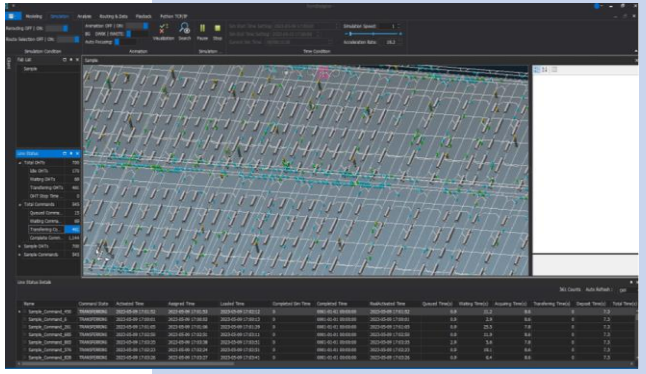
- Modeling layout/operation information related to production and logistics.
- Provides all components necessary for the factory production/logistics design through the UI.
- AGV/OHT/Conveyor Network, Buffer Equipment (Stocker, Lifter, STBs, etc.)



VMS modeling

Production/Logistics Simulation

- Review the productivity and logistics feasibility of the layout created in the Layout Modeler
- Evaluate throughput, operation rate, delivery time, congestion occurrence, etc.
- Perform cross-validation with commercial software (Automod, PlantSim, etc.) upon customer request.



VMS simulation

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3. Product Overview - PINOKIO Digital Twin Specifications

Vehicle Control System

Vehicle Modeling(AMHS)

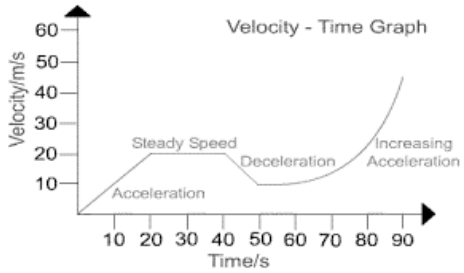
- Reflect the specifications (HW, SW) of factory-specific vehicles in ultra-high resolution, including size, minimum inter-vehicle distance, acceleration/deceleration capability, speed limits by follow control level, route change distance, junction control, and idle vehicle management.

Lifter/Stocker Modeling

- Reflect the operations of conveyors, buffers, and RM related to lifters/stockers in ultra-high resolution, including in/out ports, conveyor capacity/speed, lifter parallel transfer, and lifter multi-floor transporters.

Dispatching Logic

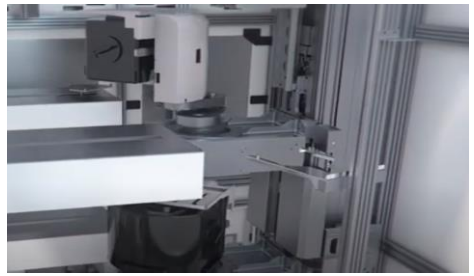
- Simultaneously simulate command scheduling and dispatching, including vehicle allocation, reservation allocation, reallocation, route updates, and destination updates.
- Support logic optimization using statistical techniques (regression analysis/design of experiments), neural networks, and reinforcement learning.



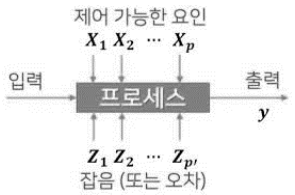
Acceleration/Deceleration & Following Control

Junction Control/Idle Vehicle Control

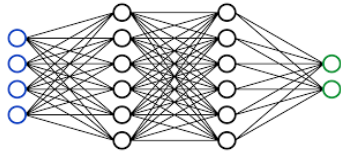
Lifter Conveyor System



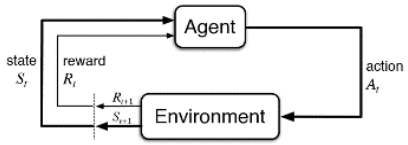
2 Lots Parallel Transfer



Statistical methods



Neural Network



Reinforcement Learning

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3. Product Overview

PINOKIO Developer License

PINOKIO provides a developer-level custom modeling environment for advanced equipment and system modeling.
By leveraging a common integrated development environment (IDE) such as Visual Studio and a 3D modeling environment, PINOKIO offers significantly greater flexibility in simulating events and logic compared to other commercial simulators that rely on predefined UIs and restricted scripting.

Visual Studio

- Add/Modify Model
- Add/Modify Event
- Add/Modify Logic
- Add/Modify UI
- Add/Modify KPI & Report

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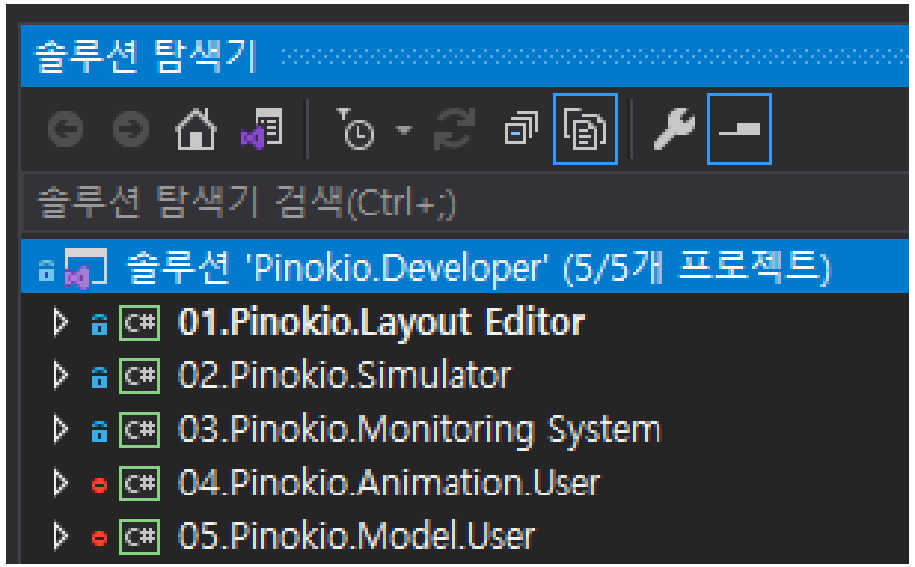
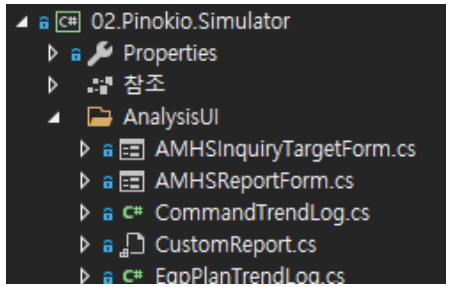
3. Product Overview

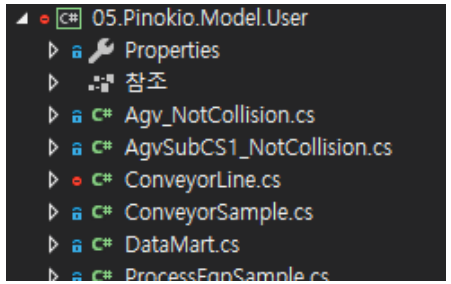
PINOKIO Developer License



[Developer Solution Screen in Visual Studio]



[Example of UI-related Projects]



[Example of Model-related Projects]

No	project	Role
01	Layout Editor	Add/Modify UI for placing shapes and defining simulation models
02	Simulator	Execute simulations and add/modify KPI UI
03	Monitoring System	Execute monitoring and add/modify Dashboard UI
04	Animation.User	Add shapes for equipment and components
05	Model.User	Add models for equipment, components, logic, and systems

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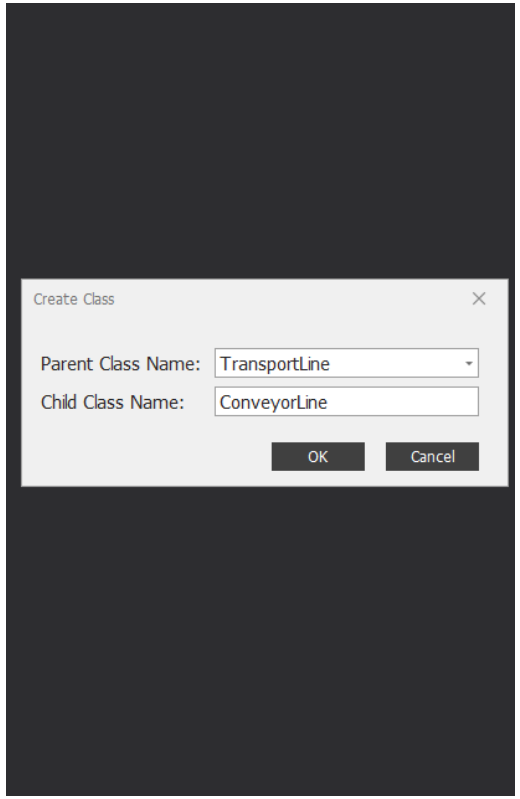
3. Product Overview

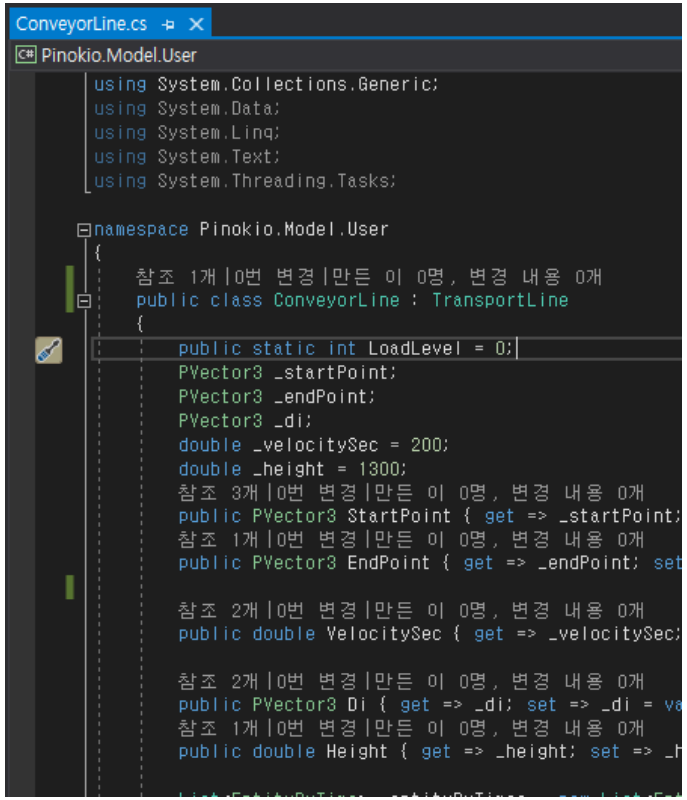
PINOKIO Developer License

Model Addition/Modification Process

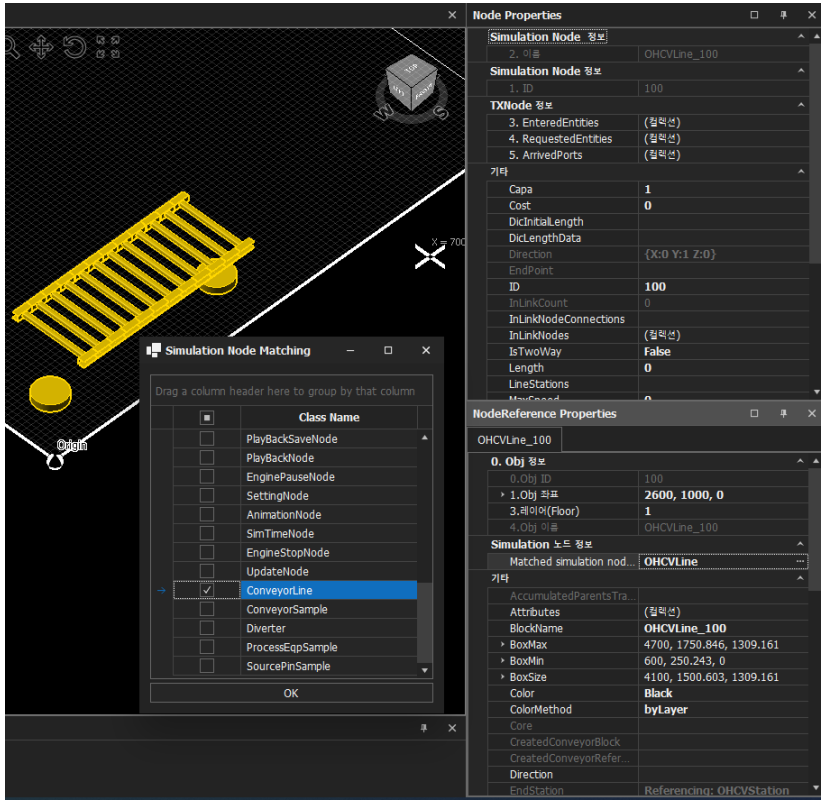
1. Inherit an existing model to create a new model



2. Add and modify variables/functions within the new model



3. Match the new model to an existing shape for use

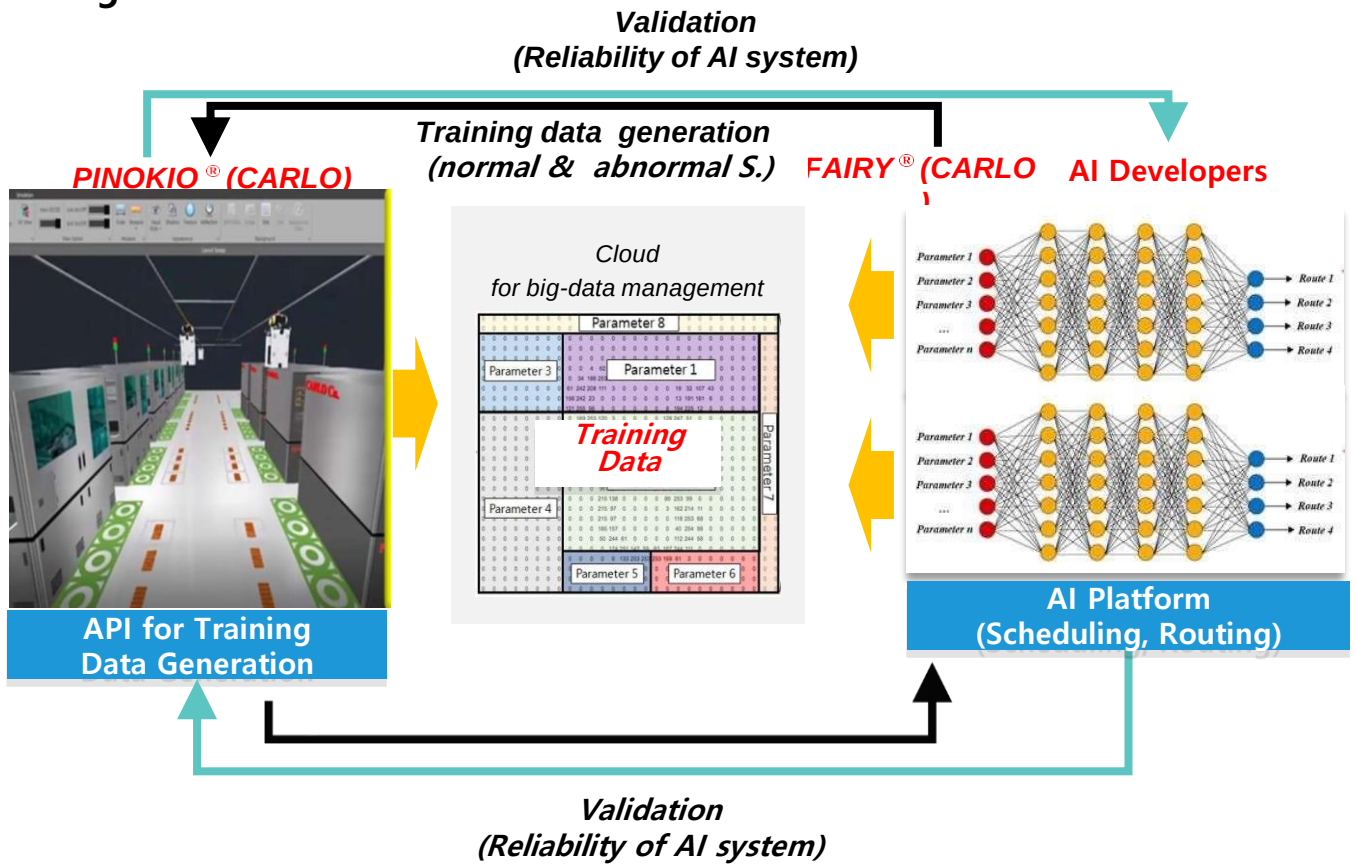


CARLO

3. Product Overview

CARLO AI Platform : FAIRY

FAIRY® is an AI platform specialized for manufacturing sites, capable of accurately generating rare abnormal situations (e.g. jams, defects) with high fidelity. This enables the creation of training data for reinforcement learning and supervised learning.



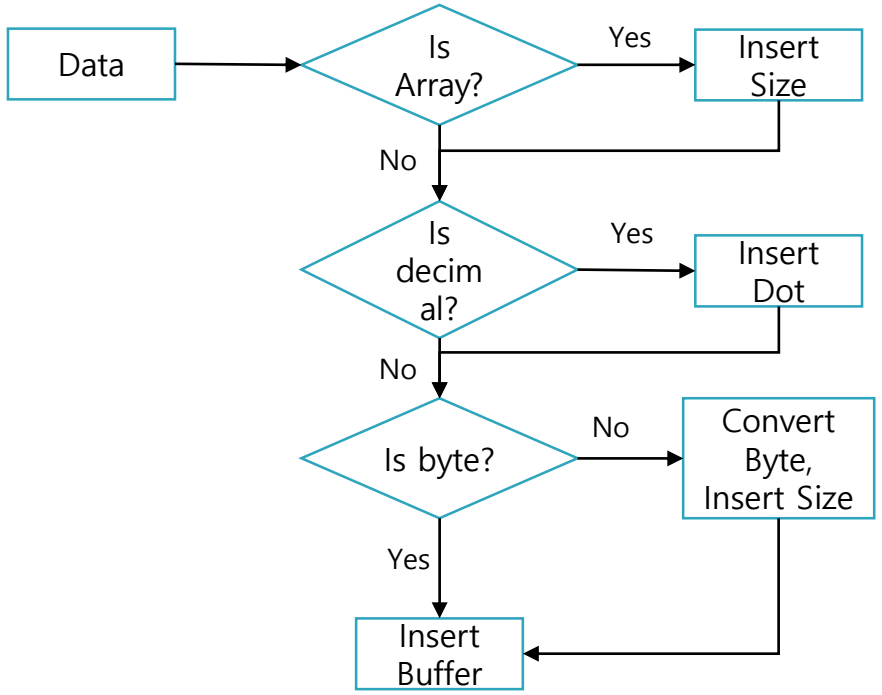
PINOKIO Digital Twin

- ✓ Provides an environment for training data generation and reinforcement learning (state space, action space, reliability adjustment).
- ✓ Supports real-time communication with Python programs.
- ✓ Validates AI applications (scheduling, routing, dispatching, etc.) and facilitates their implementation in factories.

3. Product Overview

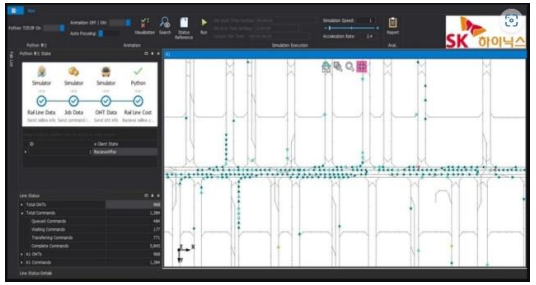
CARLO AI Platform : FAIRY

CARLO AI Platform is a specialized for manufacturing sites, capable of accurately generating rare abnormal situations (e.g. jams, defects) with high fidelity. This enables the creation of training data for reinforcement learning and supervised learning.



Communication Data Optimization Process

PINOKIO Simulator



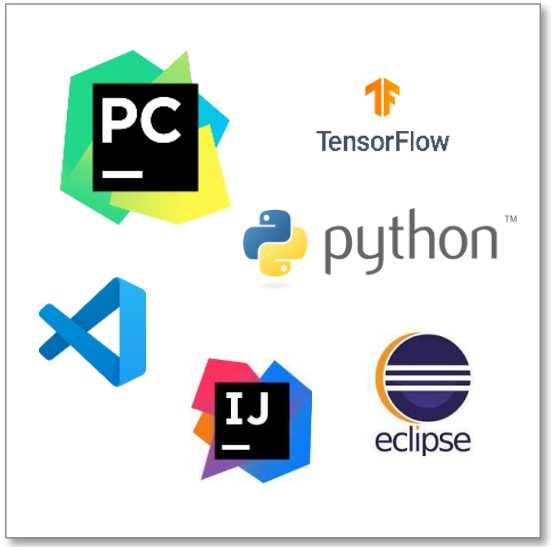
PINOKIO Digital Twin

Data

TCP/IP Communication s

Reflection of Prediction Results

Support of AI Models (Reinforcement Learning/ Neural Network)



CARLO

3. Product Overview

Distinctiveness from Competitors

PINOKIO Digital Twin has a more flexible structure for the Digital Twin environment compared to traditional general-purpose simulators. Its unique technology optimizes and minimizes the number of simulation events, providing superior performance in acceleration and other aspects.

	PINOKIO SIM®/DT® (CARLO)	Conventional Simulator (Company S)	Conventional Simulator (Company A)
Digital Twin Modeling	High (Automative Model Generation) - **Supports automatic generation of DT models based on manufacturing standard information** - **High reusability of models** - **Supports automatic conversion of ACS and OCS inputs** - **Supports modeling based on DWG drawings** - **Enables the rapid generation of various alternatives**	Low (Manual Modeling) - Each modeling is refined into a simulator-specific data format through collaboration between industry experts and simulation specialist. - Low reusability of models - Manual data entry for modeling required - No custom import functionality for on-site systems.	Low (Manual Modeling) - Each modeling is refined into a simulator-specific data format through collaboration between industry experts and simulation specialist. - Low reusability of models - Manual data entry for modeling required - No custom import functionality for on-site systems.
Simulation Acceleration Performance for Digital Twin Future Prediction	**Large-scale (1,000 units of logistics equipment) : 20x acceleration**	**Large-scale (1,000 units of logistics equipment): 1x acceleration**	**Comparative Test was not possible**
	Small-scale (60,000 delivery cases): 54,000x acceleration	**Small-scale (60,000 AGV delivery cases): 2,000x acceleration**	**Small-scale (60,000 AGV delivery cases) : 2,500x acceleration**
In-House Development (Adding new equipment, modifications, logic changes)	High - Supports user development based on C# - **Supports UI/Script in the form requested by user**	Medium - Simulation is only possible within the scope that simulator allows. - **Outside the scope, need further development.**	Low - Only possible within the scope provided by the simulator. - Limitation in further development.
Responsiveness to User Requirements (Speed of Response)	High - Customization for Reflecting User Requirements (Dedication)	Medium - Simulation is only possible within the scope that simulator allows. - **Outside the scope, need further development.**	Low - Only possible within the scope provided by the simulator. - Limitation in further development.

1) S사 반도체 Mega FAB 최고
2) L사 소형라인 AGV 기준

CARLO

CARLO

PART FOUR

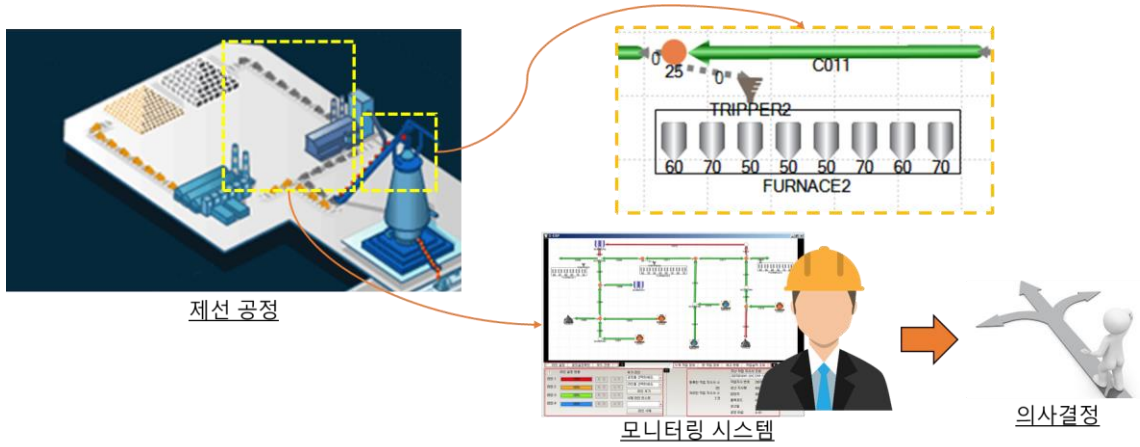
4. Case Studies

4. Case Studies

[Steelmaking] Coke Logistics Simulation

AS-IS

In the ironmaking process, the buffer level (the empty level of the blast furnace) is managed to control the production volume and quality of molten iron.
A monitoring system is in place to support the decision-making of facility operation engineers who oversee this buffer level.

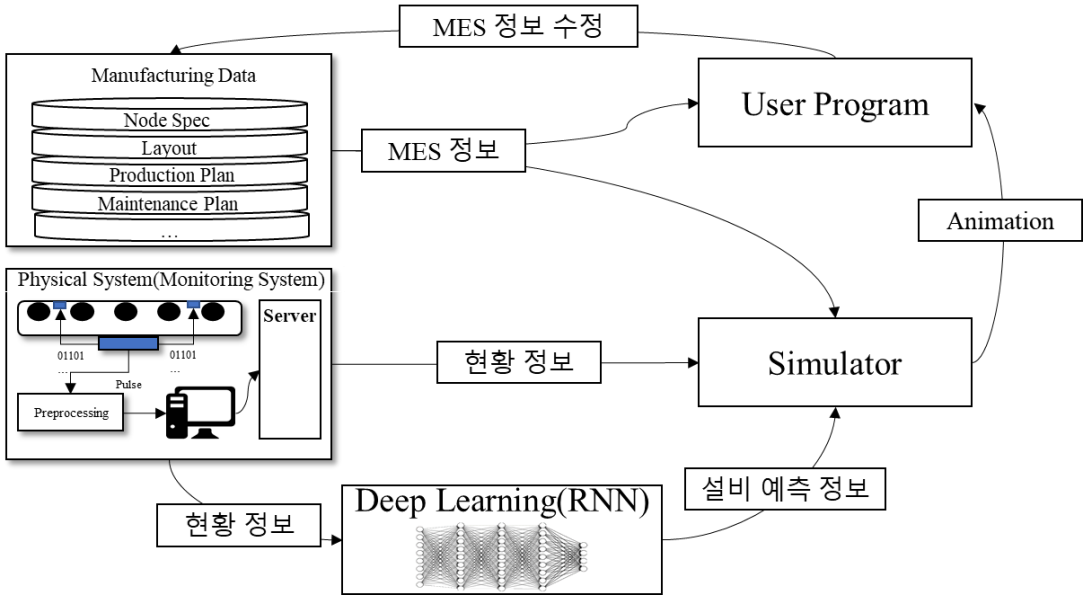


Objective

- By running predictive simulations based on equipment operation rules set by engineers, generate a logistics facility operation schedule and corresponding results (alarms).
- These simulations operate on an hourly cycle with a four-hour forecast window.

Implementation Details

- Development of a “What-If” simulator integrating with the MES and real-time status information.
- Construction of a Digital Twin (operational simulation) system.
- Custom development of graphical features on a WinForm basis for compatibility with low-spec PCs.



Scope

Covers the entire ironmaking process at POSCO Pohang Works.

4. Case Studies

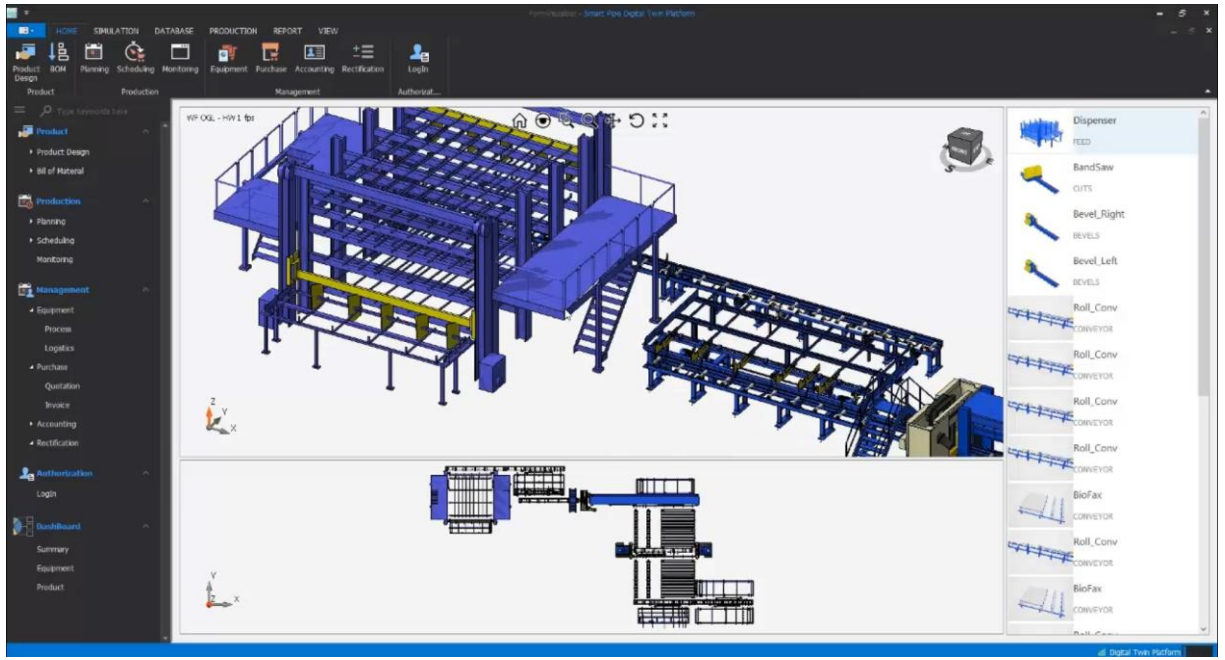
[Shipbuilding Piping] Cloud-based Digital Twin Implementation on Site

AS-IS

The piping plant currently manages its daily tasks manually, relying on handwritten or paper-based methods.

Objective

Transform the plant into a facility capable of organization-wide task scheduling and real-time progress monitoring.



Implementation Details

- Deploy an MES (Manufacturing Execution System) and monitoring system
- Develop an optimized scheduling system specifically for piping operations

Scope

Clad Korea Pohang Plant

CARLO

4. Case Studies

[Semiconductor] AMHS Simulation of Mega FAB

Objective

Simulate 1,000 to 5,000 OHT/Lifters and improve the routing and scheduling logic.

Implementation Details

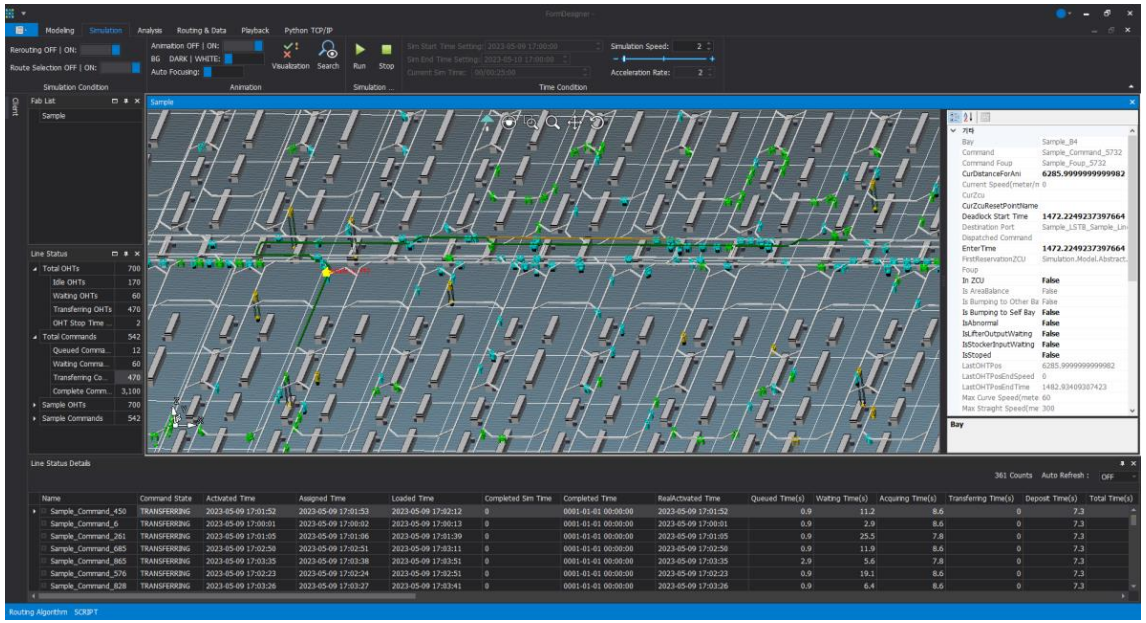
Use AI for scheduling, controlling, and routing of OHT movement paths.

Results/Benefits

- 14% reduction in OHT delivery time
- Achieved high accuracy in simulation, with a 98.8% match to the SK Hynix Fab simulation and 99.1% match to the Daihatsu Emulator.

Scope of Application

All SK Hynix fabs (Icheon, Cheongju, Wuxi, China)



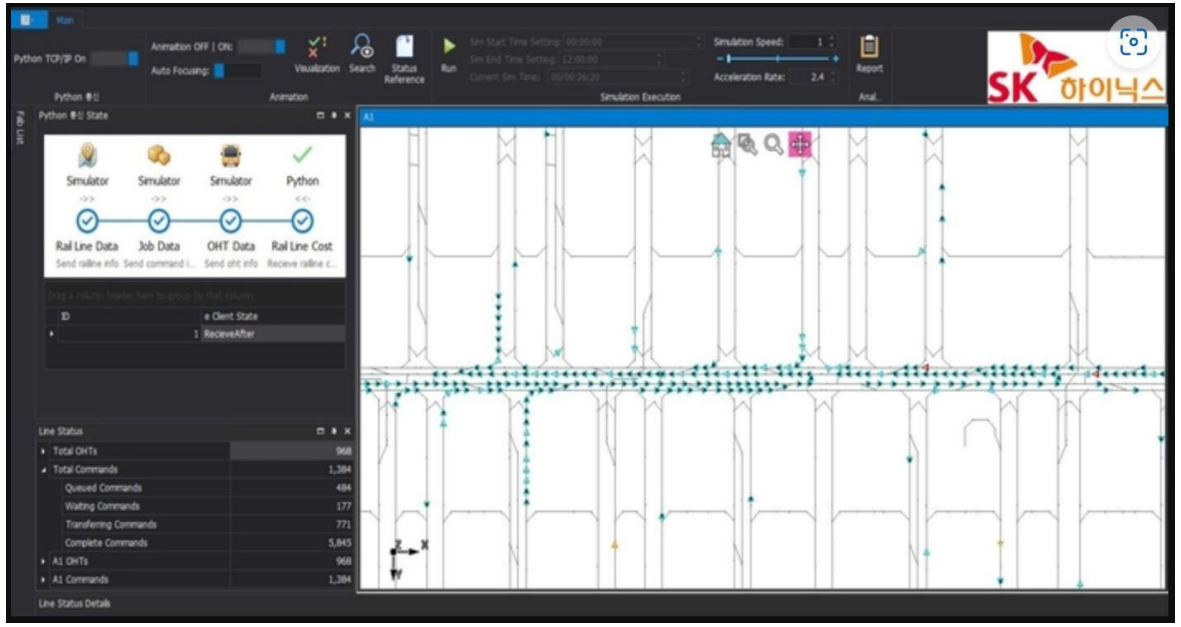
Hynix Icheon Fab

SK Hynix Wuxi Fab, China

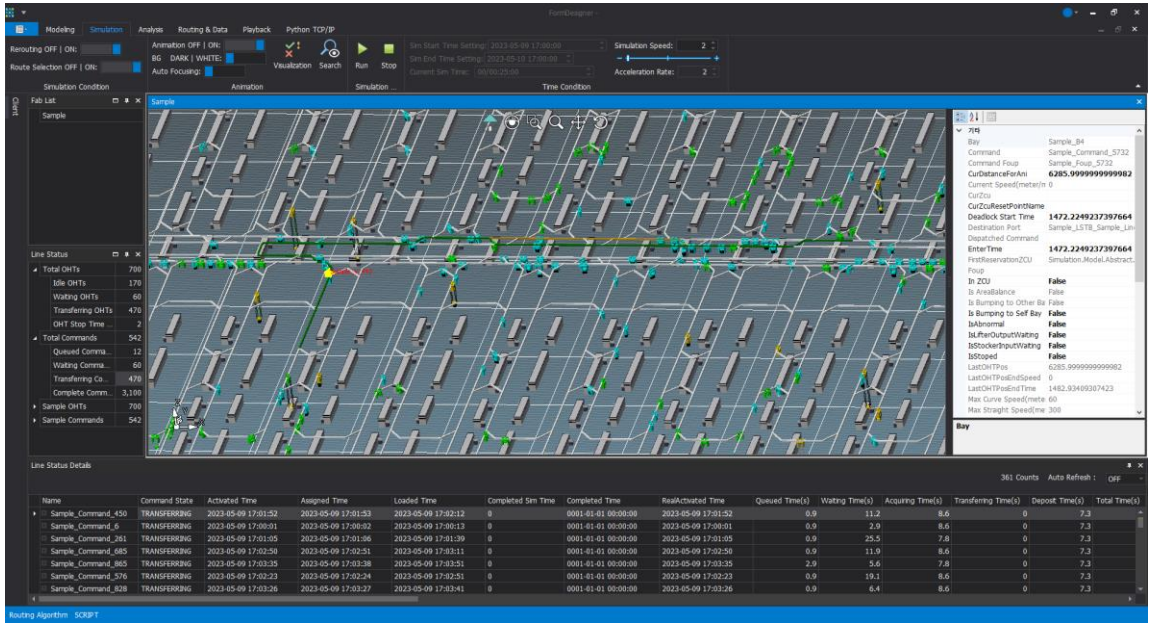
CARLO

4. Case Studies

[Semiconductor] AMHS Simulation of Mega FAB



2D Animation



3D Animation

CARLO

4. Case Studies

[Semiconductor] SK Group AI Competition 2023

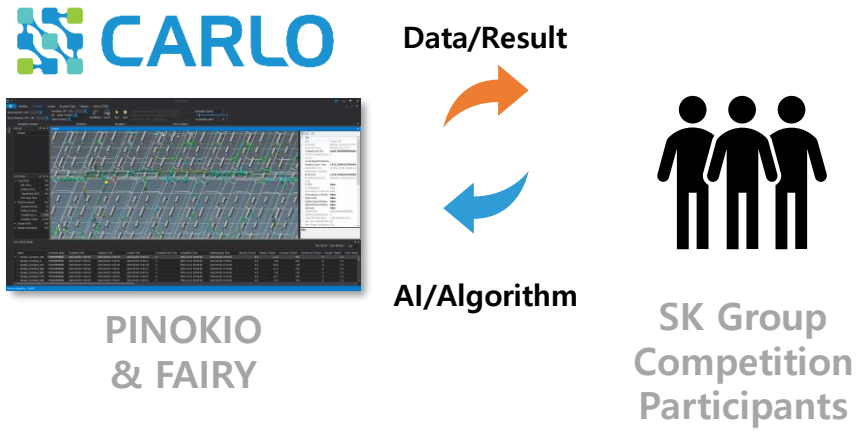
Organized by: SK Hynix, SK C&C, mySUNI

Participants: Employees of the SK Group

Awards Presented by: CEO of SK Hynix

AI Training Data Generation and Application:

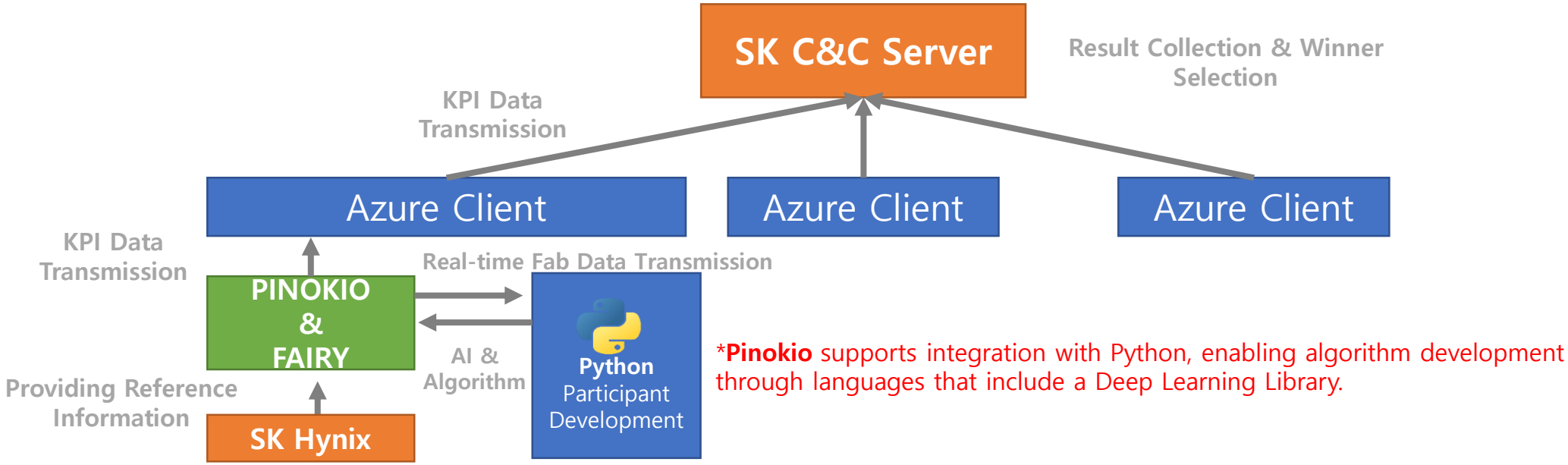
PINOKIO & CAP



4. Case Studies

[Semiconductor] SK Group AI Competition 2023

- The AI competition was based on Microsoft's Azure platform and focused on optimizing the FAB OHT (Overhead Transport) routing at SK Hynix. The goal was to derive the most optimized algorithm. Participants developed algorithms using Python, and the results were automatically collected through system integration between Pinokio and SK C&C.
- Through this AI competition, SK Hynix acquired an effective solution, and the SK Group was able to build a platform for nurturing deep learning talent and solving challenges across the group.



4. Case Studies

[Semiconductor] SK Group AI Competition 2023

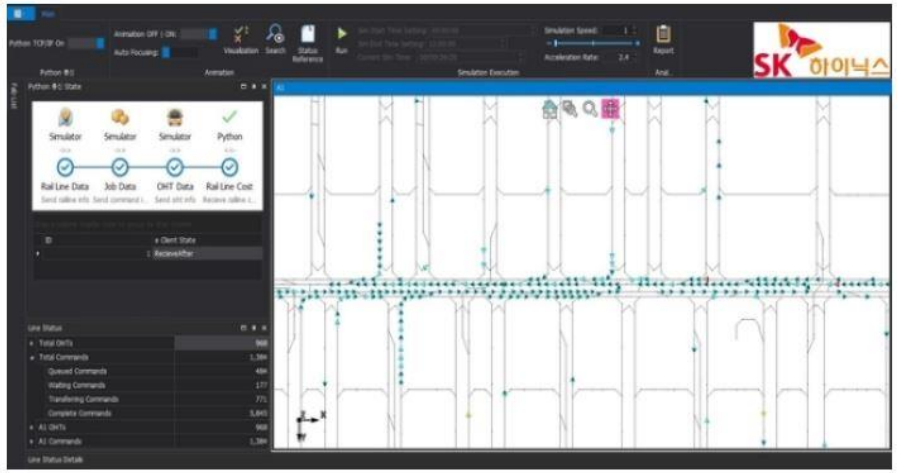
전자신문 PICK

SK하이닉스, AI로 웨이퍼 옮긴다 '용인 공장 전체 적용'

입력 2023.11.26. 오전 10:02 기사원문

박종진 기자

16 12



SK하이닉스 웨이퍼 이송시스템 예시.

SK하이닉스가 반도체 공장(팹) 내 웨이퍼 이송 시스템을 인공지능(AI) 기반으로 구축한다. 기계학습 등 AI 기술로 웨이퍼 이송 지연을 최소화, 생산성을 극대화한다. 2027년 가동에 들어갈 용인 반도체 클러스터는 웨이퍼 이송 환경을 완전 AI화한다.

웨이퍼 이송 시스템은 반도체 팹 천장에 설치된 레일을 따라 움직이는 웨이퍼이송장치(OHT) 등으로 구성된다. 웨이퍼가 담긴 통(FOUP)을 순차적으로 다음 공정 장비로 옮기는 작업으로, 이동 경로 계산과 적용은 소프트웨어(SW) 기술력에 좌우된다.

SK하이닉스는 최근 웨이퍼 이송시스템 SW를 효율화할 수 있는 AI 알고리즘을 확보했다. 웨이퍼 이송 구간 혼잡도 해소방안, 효율적인 레일 가동 주기, 신속한 이송방법 등을 개선하기 위해서다. AI 알고리즘은 SK하이닉스 이천 팹 웨이퍼 이송 과정에서 축적한 빅데이터를 활용했다. 이천 팹은 약 30km 길이의 상하층 구조 웨이퍼 이송 시스템을 가동 중이다.

AI 웨이퍼 이송 시스템은 특정 구간 또는 예기치 않게 OHT가 정체되는 문제를 해소할 수 있다. 웨이퍼를 지연 없이 신속히 다음 공정으로 옮겨야 반도체 제조 전체 생산성이 높아진다. 기존에는 반도체 팹 내 최적화된 경로를 설정해도 생산계획·이송량 변화나 신규 장비 도입 등 각종 변수로 웨이퍼 이송 과정에 지연과 정체가 발생했다는 게 회사측 설명이다.

SK하이닉스는 웨이퍼 이송 지연 원인 파악과 문제 해결을 SK그룹 'AI 경연' 과제로 제시했다. 사내 152팀 349명이 34일간 경쟁한 결과, 웨이퍼 이송 경로 최적화 모델을 개발했다. OHT 정체 시 다른 장치와 겹치지 않게 새로운 경로로 우회하거나 공정별 지연시간·대기시간을 최소화할 수 있는 AI 알고리즘을 구현했다.

SK하이닉스는 신규 확보한 AI 알고리즘과 기존 SW를 결합, 이천·청주 등 팹에 우선 적용할 계획이다. 연말까지 시뮬레이션 등 내부 검증을 거쳐 내년 시스템 투자를 시작한다. 이후 용인 팹 전체에 AI 기반 웨이퍼 이송 환경을 조성할 방침이다.

이번 시도는 외산 의존도가 높은 웨이퍼 이송 시스템 시장에서 SK하이닉스의 SW 기술 내재화라는 의미도 담고 있다. OHT 등 웨이퍼 이송 시스템 시장은 일본 다이후쿠가 시장 대부분을 점유한 상태다. 이송 시스템 SW도 다이후쿠가 직접 개발해 왔던 것으로 알려졌다. SK하이닉스가 독자 개발한 AI 기술을 웨이퍼 이송 시스템에 적용하면 국산화 효과도 기대된다.

SK하이닉스 관계자는 "하루 약 1000대의 OHT가 수십만회의 웨이퍼를 이송하는데 정체나 지연이 발생하는 상황을 최소화하기 위해 AI 알고리즘을 활용하기로 한 것"이라며 "용인 반도체 클러스터 구축 전에 개선된 시스템을 실제 팹에 적용해 효과를 확인할 계획"이라고 말했다.

CARLO

4. Case Studies

[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing

Objective

The need for a monitoring system for the automated refrigerator production line, along with a proactive alert system for abnormal situations through simulation

Implementation Details

Built a monitoring system based on real-world data and integrated it with an AI-based proactive simulation for detecting abnormal situations

Results/Benefits

- Detection and alerting of abnormal situations (warning messages, SMS)
- Listed as one of the top 10 smart factories globally by McKinsey

Scope of Application

New refrigerator line at **LG Electronics Changwon Smart Park**

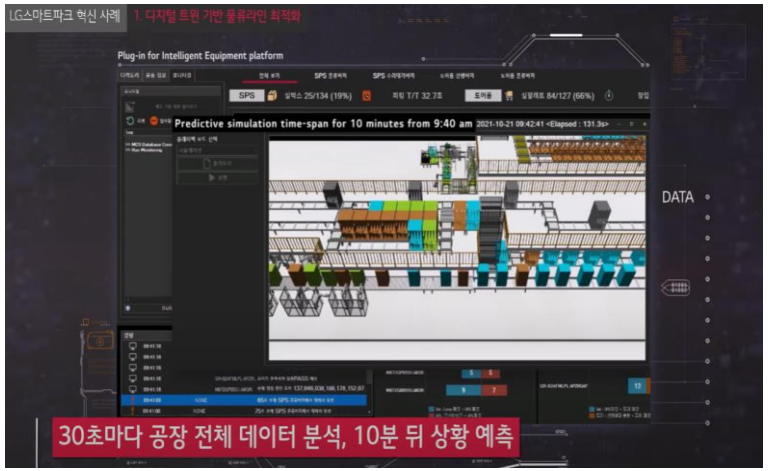
LG전자, 창원 '스마트파크' 가동...가전 '세계 1위' 굳힌다

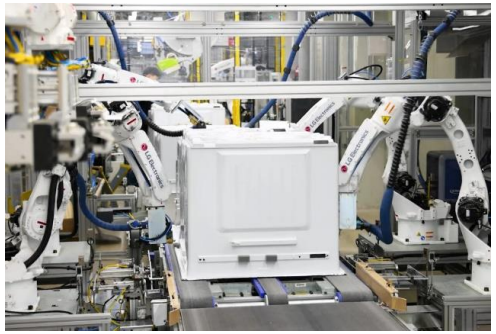
발행일 : 2021.09.16 13:30

LG전자, 창원 'LG스마트파크' 통합생산동 1차 준공

4800억 투입... 3개 생산라인 가동
세계 최고 수준 '지능형 자율공장' 구축 눈길
통합생산동 완성 시 연간 생산능력 '50%' 이상 증가
협력사 일자리 창출 기여... 주요 협력사 직원 10% 늘어

신축 통합생산동은 조립, 검사, 포장 등 주방가전 전체 생산공정의 자동화율을 크게 높였다. 설비, 부품, 제품 등 생산 프로세스 관련 빅데이터를 기반으로 한 통합 모니터링 시스템을 도입해 생산 효율성과 품질 경쟁력을 동시에 향상시켰다. 또 딥러닝



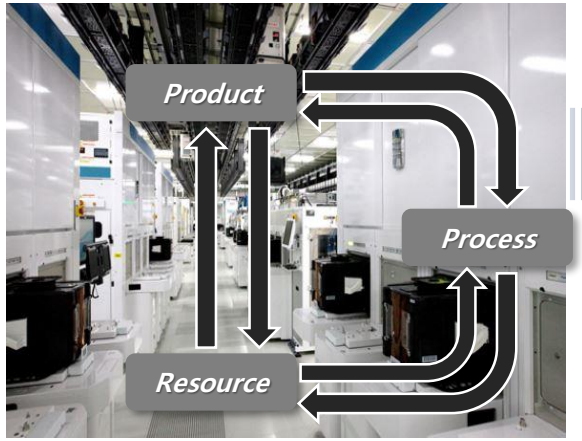


CARLO

4. Case Studies

[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing

Real Plant



Sensor Info

Digital Twin

Virtual Sensor Framework

Provided Information (WIP) | Equipment Status | Production Status | ETC..

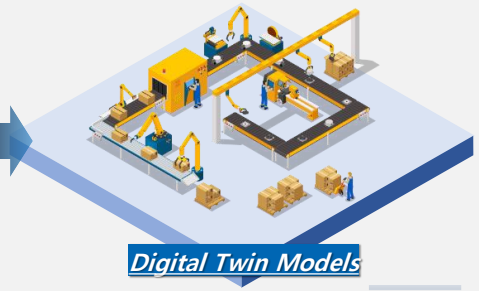
Real-time Process Information

[Time, Sensor Id, Info.]
$[t_1,\ s_1,\ Info.]$
$[t_{1.5},\ vs_2,\ Info.]$
$[t_2,\ s_2,\ Info.]$
$[t_{2.7},\ vs_3,\ Info.]$
...

High Resolution Models

- Product Model
- Resource Model
- Process Model

A model with over 98% accuracy compared to the actual factory



Digital Twin Models

Utilizing **virtual sensor** technology to monitor **real-time factory conditions**. Based on this data, **online simulations** are conducted, enabling the prediction of potential future issue

Predictive Simulation

- Initialize the model based on real-time factory conditions and conduct high-resolution simulations
- Determine the Time Horizon based on simulation acceleration performance (Overclocking)

Production System Abnormality Warning

- Congetion Warning
- Plan-Execution Discrepancy Warning
- Line Stop Warning
- Bottleneck Warning

Response Simulation (Proactive)

- Perform simulations to determine response strategies for abnormal situations

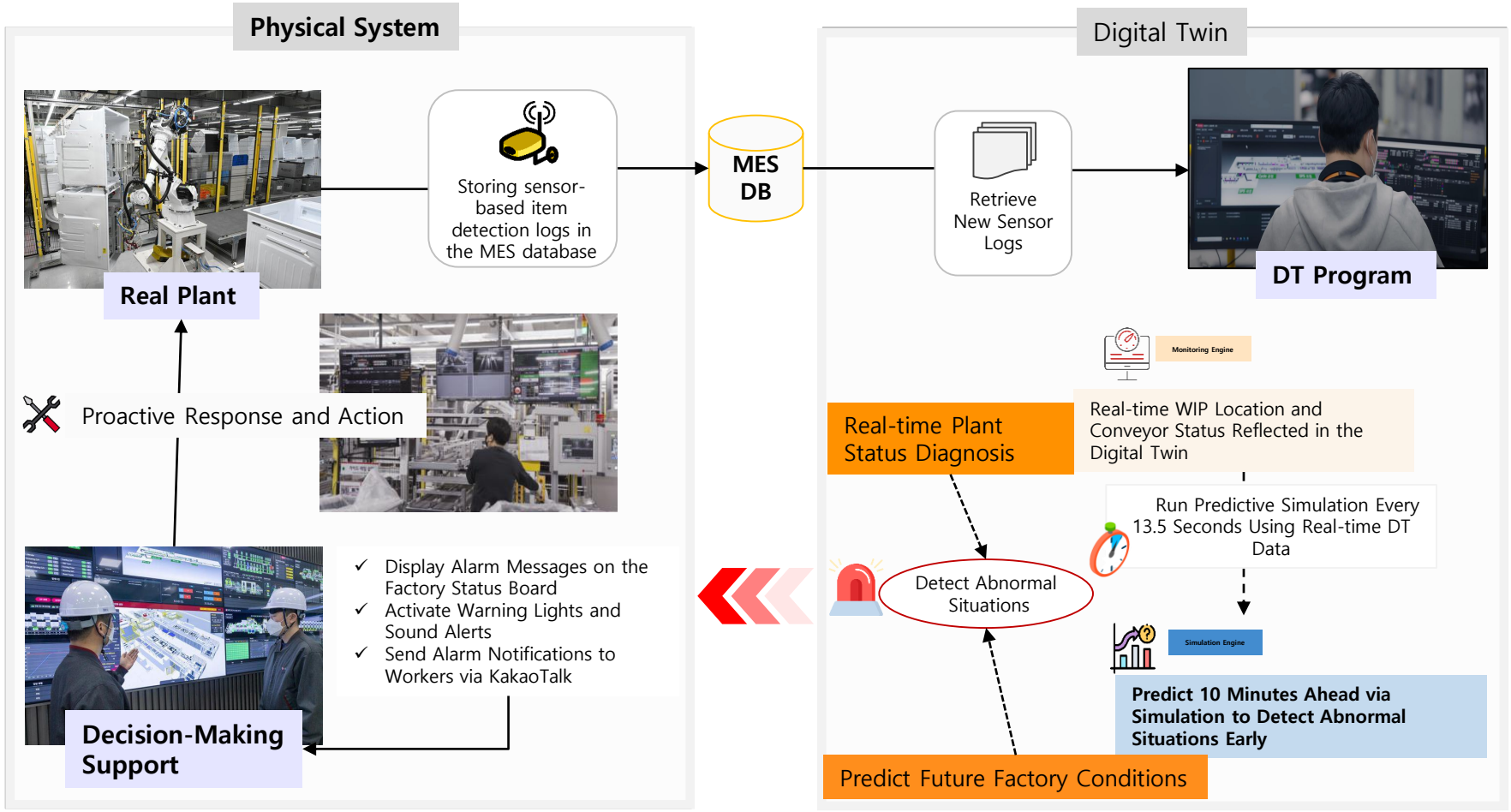
Ex1) Change product priority
Ex2) Modify input planning
Ex3) Adjust buffer operation logic
...

Establish **a reverse control** cycle for the production system by applying response strategies derived from the Digital Twin for **predicted abnormal situations**
➔ **Proactive Digital Twin (Autonomous Digital Twin)**

CARLO

4. Case Studies

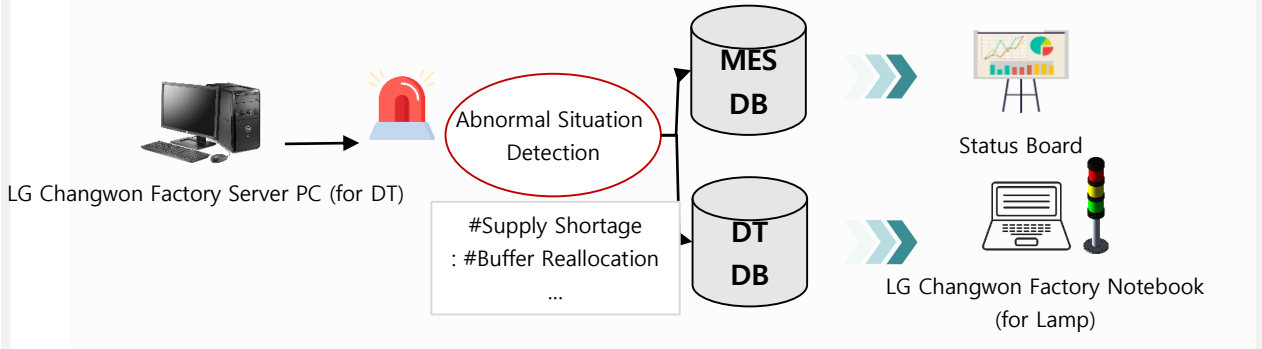
[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing



CARLO

4. Case Studies

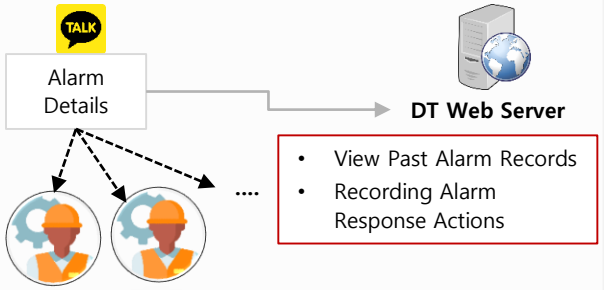
[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing



- Regularly check the DB through MES and display alerts on the status board
- A program running on the field notebook automatically controls the lamp after querying the DB

Display alert on the status board

Warning light alarm



- Send KakaoTalk alert message when an abnormal situation is detected in DT
- Provide DT 3D View and Chart at the time of alarm occurrence

KakaoTalk Alert / Mobile Web

CARLO

4. Case Studies

[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing

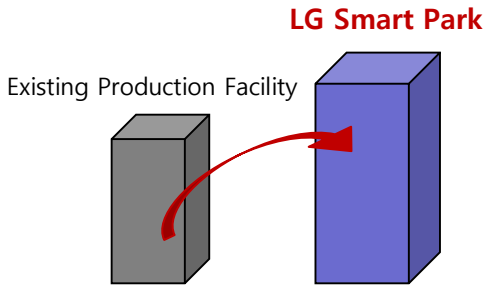
Logistics Line Optimization Based on Digital Twin

☐ Production Line Simulation Analysis

- ▶ Improvement in Material Stockouts through Pre-forecasting(Monitoring Accuracy **100%**, Prediction Simulation Accuracy **95.34%**)
- ▶ Just-in-time Supply of Parts and Materials for Mixed Production Processes
- ▶ Playback Function to Reproduce Past Factory Conditions → Reduced Defect Cause Analysis Time by 50%

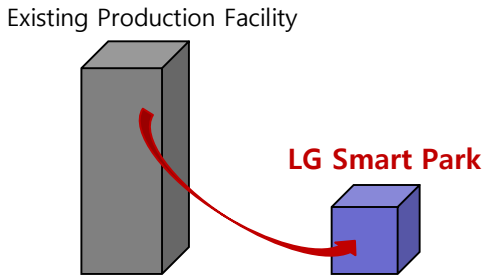
Enhancing Manufacturing Competitiveness

17% Improvement in Productivity



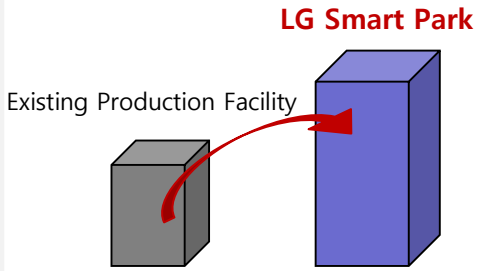
Units Produced Per Hour Compared to Existing Production Facility

70% Reduction in Quality Costs



Annual In-house Quality Costs Compared to Existing Production Facility

30% Improvement in Energy Efficiency



Energy Consumption Per Unit Produced Compared to Existing Production Facility

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4. Case Studies

[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing

LG Smart Park was selected as a **'Lighthouse Factory'** by the World Economic Forum (WEF) in March 2022, an annual recognition for leading global manufacturers.

서울신문

[르포]LG냉장고 13초에 1대 생산… 창원 스마트파크의 시간은 10분 빨리 흐른다

스마트파크 현장 취재는 시설 보안 유지를 위해 스마트폰 카메라에 보안스티커를 부착한 이후 입장이 가능했다.

조선일보

'K가전의 메카' 창원 LG스마트파크, 제조업 미래를 밝힌다 - 조선일보

지난 3월 세계경제포럼(WEF)은 LG전자 프리미엄 가전의 중심 생산기지인 경남 창원 'LG스마트파크'를 '등대공장(Lighthouse Factory)'에 선정했다.

Real Plant

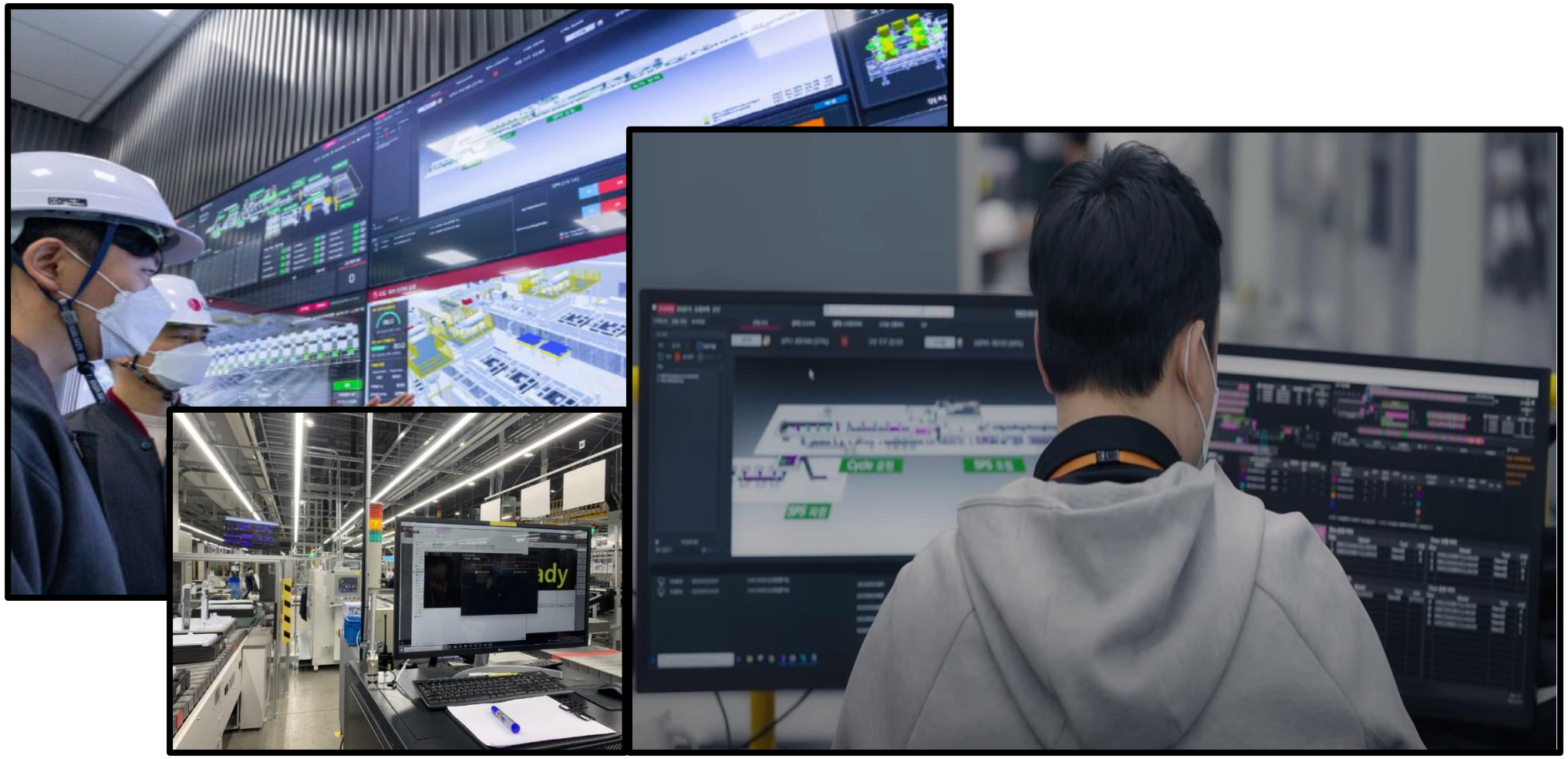
CARLO PINOKIO®

Digital Twin

CARLO

4. Case Studies

[Consumer Electronics] Digital Twin for Smart Refrigerator Manufacturing



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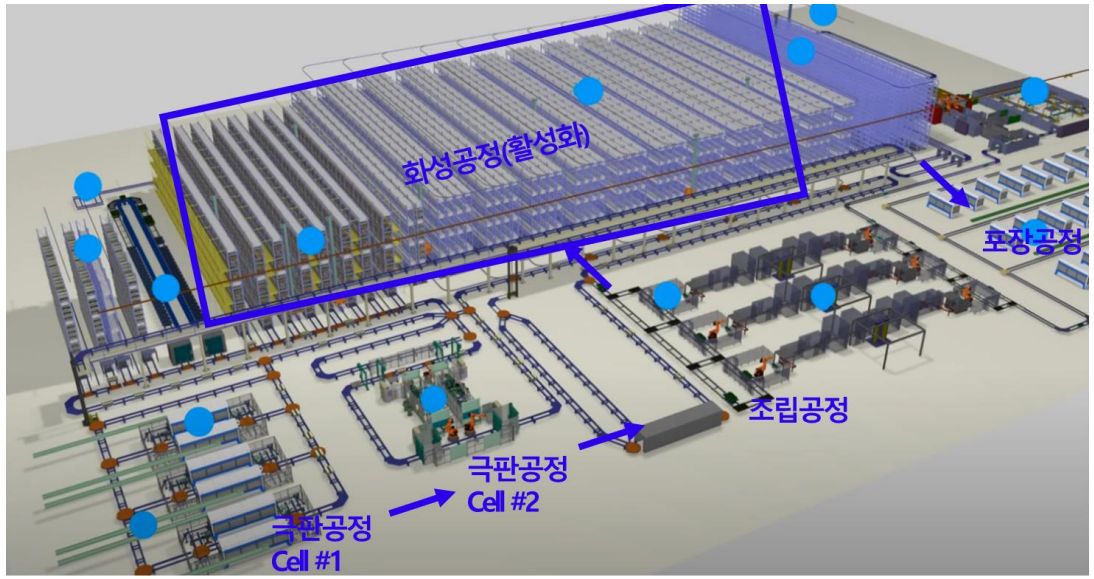
4. Case Studies

[Secondary Battery] Battery Line Production/Logistics Simulation

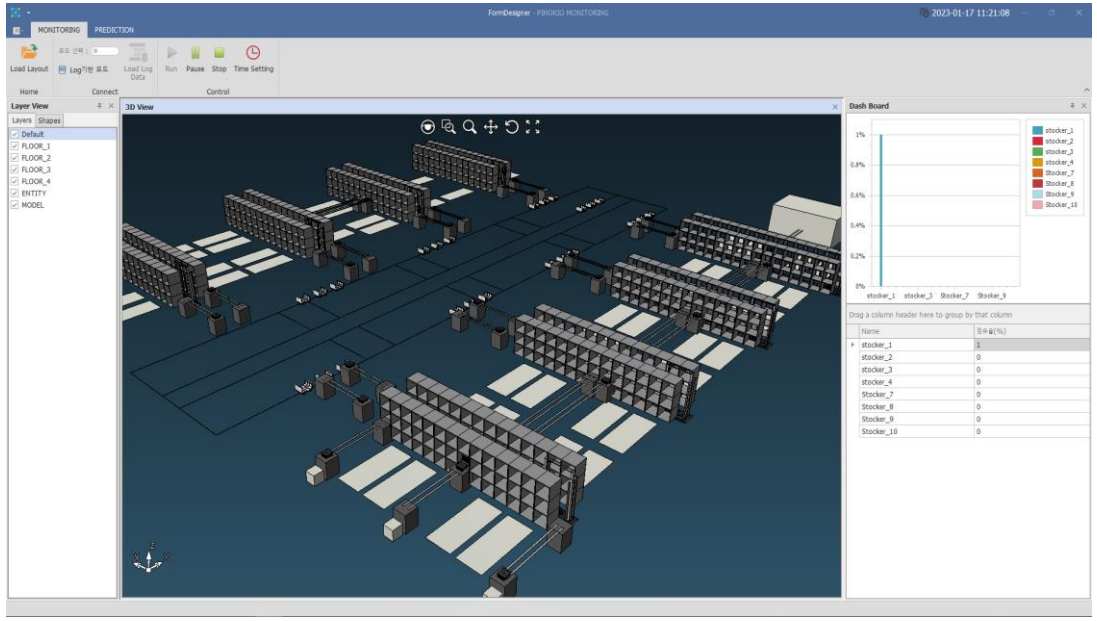


AS-IS

The factory line designers at Samsung SDI currently use Automod for layout modeling and simulation, which takes about one month for a single alternative.

Objective

To reduce the layout modeling and simulation time (from 1 month to 1 week) and create models for future Digital Twin development and validation.



Implementation Details

Automated layout modeling based on MES/design drawings (1 month → 1 week)
Ensured the accuracy of the integrated simulation for production and logistics (Process, AGV, STK, OHT)

Scope of Application

- Samsung SDI Hungary Plant: Anode/Cathode Line
- Samsung SDI Gamma Plant: Anode/Cathode Line

Thank you for listening

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