TIER 0

Unified Namespace (UNS) Practice in Intelligent SMT Production

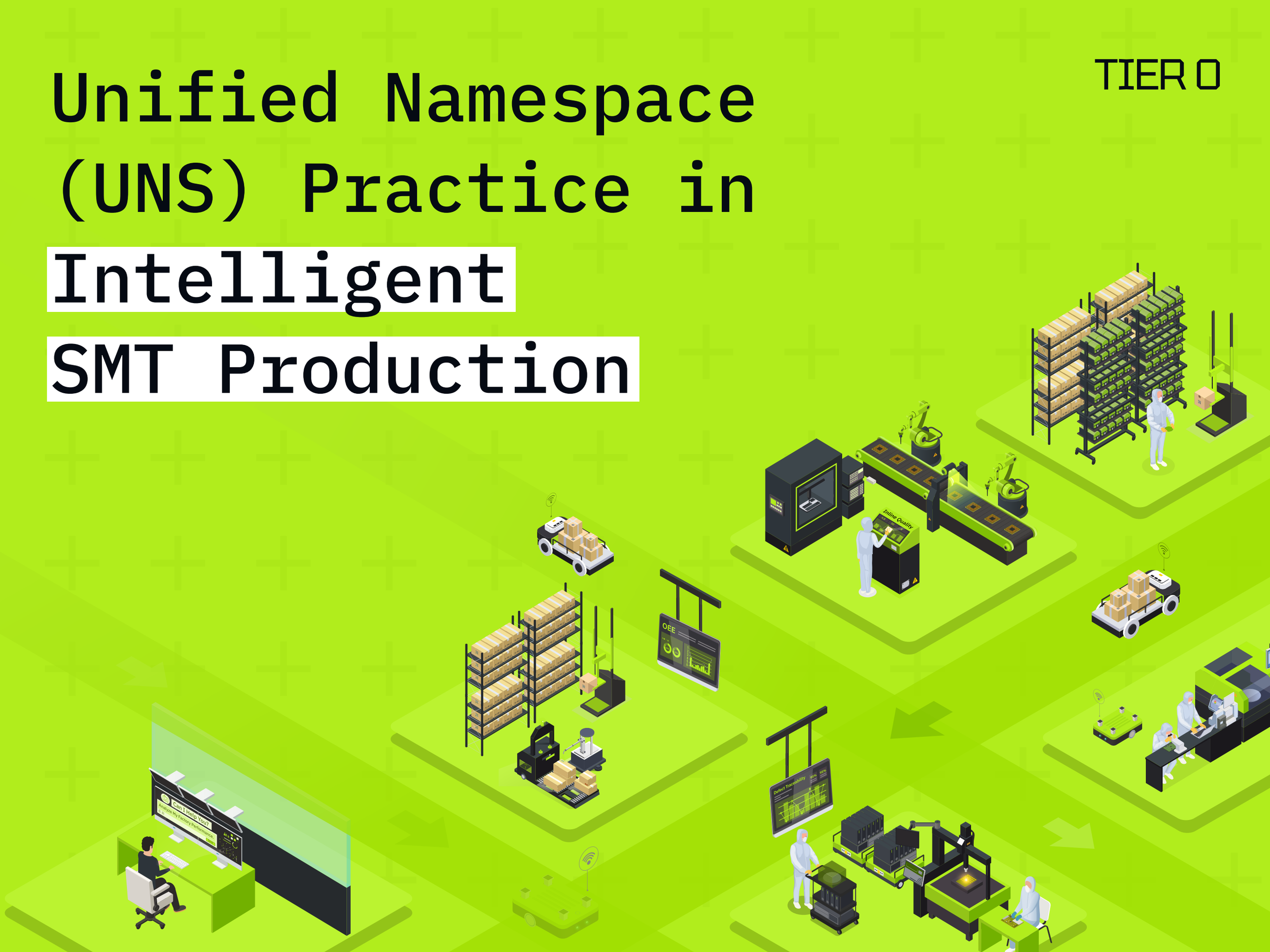


Table Of Contents

0 Introduction 00

◇ 0.1 Data Context Matters More Than Ever 01

◇ 0.2 The SMT Data Challenge: Fragmentation Behind Automation 02

1 Digital Transformation Across SMT Manufacturing 03

◇ 1.1 Unified Namespace: The Foundation Of Smart SMT Factories 04

◇ 1.2 From Polling To Event-Driven 07

◇ 1.3 Cloud-Native Lightweight Factory Data Lakehouse 08

◇ 1.4 Next-Generation Operation Apps For SMT Shop-Floors 09

◇ 1.5 Factory AI Agents 10

2 Agile Production 11

◇ 2.1 Reduce WIP Buffers With Full-Process JIT Orchestration 12

◇ 2.2 Minimize Downtime Through Real-Time Anomaly Monitoring 14

◇ 2.3 Synchronize Order Statuses Across MES, ERP, WMS, And SRM Systems 16

3 Operational Insights 18

◇ 3.1 Improve Asset Utilization With Automated OEE Dashboards 19

◇ 3.2 Detect And Resolve Quality Issues Faster With Inline Analytics 21

◇ 3.3 Optimize Energy Usage With Real-Time Consumption Analysis 23

4 AI-Enhanced Operations 24

◇ 4.1 Factory Agents Deliver Actionable Insights For Real-Time Decisions 25

◇ 4.2 Predict Equipment And Quality Issues Before They Occur 27

5 Rebuilding The Use Case Yourself: A Practical Tutorial 29

◇ 5.1 Step-By-Step Guide: Real-Time OEE Monitoring 30

◇ 5.2 Step-By-Step Guide: AGV Auto-Scheduling With Factory Agent 34

Conclusion 38

Reference 39

About Tier0 40

0.1

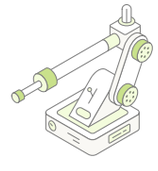
Data Context Matters More Than Ever?

“Data isn’t the new oil—it’s far more valuable,” as the World Economic Forum puts it. Unlike finite resources, industrial data grows exponentially. Yet in manufacturing, it remains largely untapped. Every second, SMT lines generate megabyte of sensor readings, equipment logs, and quality reports—**much of which is locked in proprietary protocols, legacy systems, or unstructured formats.** This fragmentation makes it difficult to extract actionable insights.

At the core of this challenge is the **disconnect between OT and IT**: the machines, sensors, and controllers that generate data on the shop floor, and the MES, ERP, and analytics platforms that manage production. Without standardized semantics, manufacturers face **high integration costs**, **limited visibility**, and **brittle point-to-point connections**. Even analyzing basic KPIs—like equipment availability, energy usage, or quality trends—often requires significant manual effort.

This isn’t just a technical issue—it’s a strategic one. Without unified contextual data, factories can’t scale AI, predict maintenance needs, or streamline scheduling. Real-time, structured data pipelines are essential to enable automation, digital twins, and smarter decisions.

This whitepaper focuses on SMT—one of the most automation-intensive sectors in discrete manufacturing. With support from SUPCON’s Fuyang factory, we explore how **Tier0, an open-source industrial data platform based on Unified Namespace (UNS)**, addresses these challenges. Tier0 bridges OT and IT in real time, freeing data from silos and contextualizing it across assets, processes, and people. At Fuyang, this unified layer powers real-time OEE dashboards, predictive maintenance, and traceable quality graphs—proving that contextual data is not only valuable, but foundational to scalable smart manufacturing.



0.2

The SMT Data Challenge: Fragmentation Behind Automation

In the next section, we show how Tier0's platform capabilities resolves these roadblocks —unlocking scalable, data-driven operations.

Surface Mount Technology (SMT) lines are among the most automated in discrete manufacturing—yet many still rely on fragmented digital systems that hinder scalability. After two months of field research, our engineering team identified **5 recurring data challenges** in SMT operations:

Fragmented Protocols And Integrations

Vendors rely on file-based systems, Modbus, and proprietary protocols, leading to complex integrations and limited interoperability.

Unstructured And Inconsistent Data

Test logs and reports often lack standardization, arriving as plain text or nested JSONs, making analysis across systems difficult.

Product Complexity And Changeovers

With thousands of SKUs and frequent changeovers, static MES configurations fail to reflect real-time processes—hurting traceability and OEE accuracy.

Limited Machine-Level Visibility

Many machines don't expose detailed status, fault, or performance data, forcing engineers to rely on manual checks or incomplete MES records.

Data Infrastructure Lagging Behind AI Goals

While predictive maintenance and AI-driven quality control are priorities, siloed data often blocks progress.

LEARN MORE →

Chapter1

Digital Transformation Across SMT Manufacturing

◇ 1.1 Unified Namespace: The Foundation Of Smart SMT Factories

◇ 1.2 From Polling To Event-Driven

◇ 1.3 Cloud-Native Lightweight Factory Data Lakehouse

◇ 1.4 Next-Generation Operation Apps For SMT Shop-Floors

◇ 1.5 Factory AI Agents

1.1 Unified Namespace: The Foundation Of Smart SMT Factories

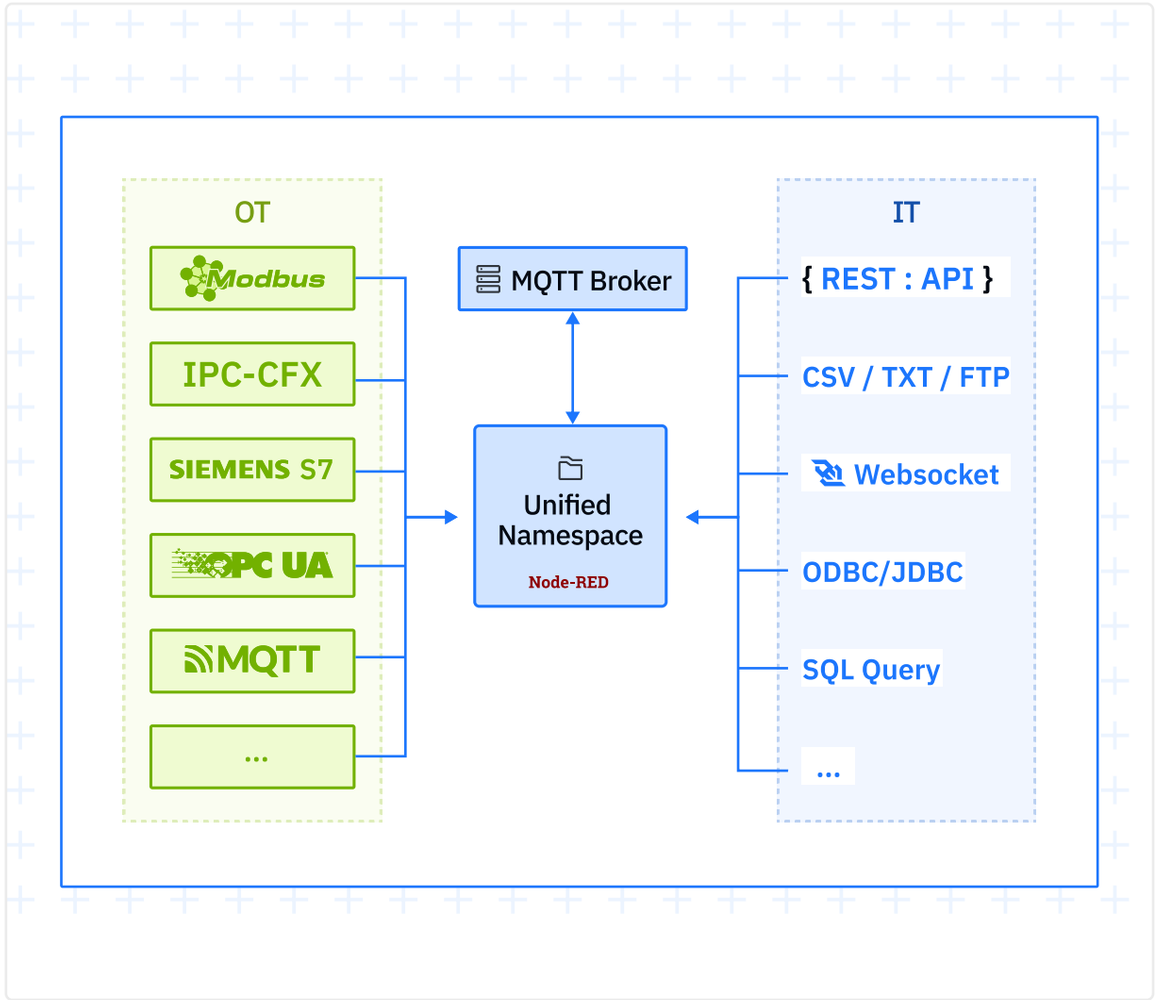
Unified Data Integration Across Standard Protocols, Custom Interfaces, And MES Systems

Seamless Integration Of IT And OT Systems

Modern SMT shop floors operate as complex ecosystems, yet often suffer from fragmented, vendor-specific systems that hinder end-to-end visibility and coordination. SMT lines, inspection systems, warehouse control systems (WCS), and robot control systems (RCS) frequently operate in isolation.

To address these challenges, Tier0 adopts a real-time Unified Namespace (UNS) architecture that enables:

- Seamless data integration across standard and non-standard SMT equipment and IT systems (MES, WMS, ERP), reducing interface redundancy and simplifying maintenance.
- Flexible protocol connectivity via a built-in Node-RED toolkit supporting Modbus, OPC UA, Siemens S7, MQTT, and SMT file formats, with extensibility for custom nodes such as IPC-CFX.
- Real-time semantic modeling and distribution powered by a lightweight MQTT broker, facilitating cross-layer collaboration and intelligent, data-driven operations.



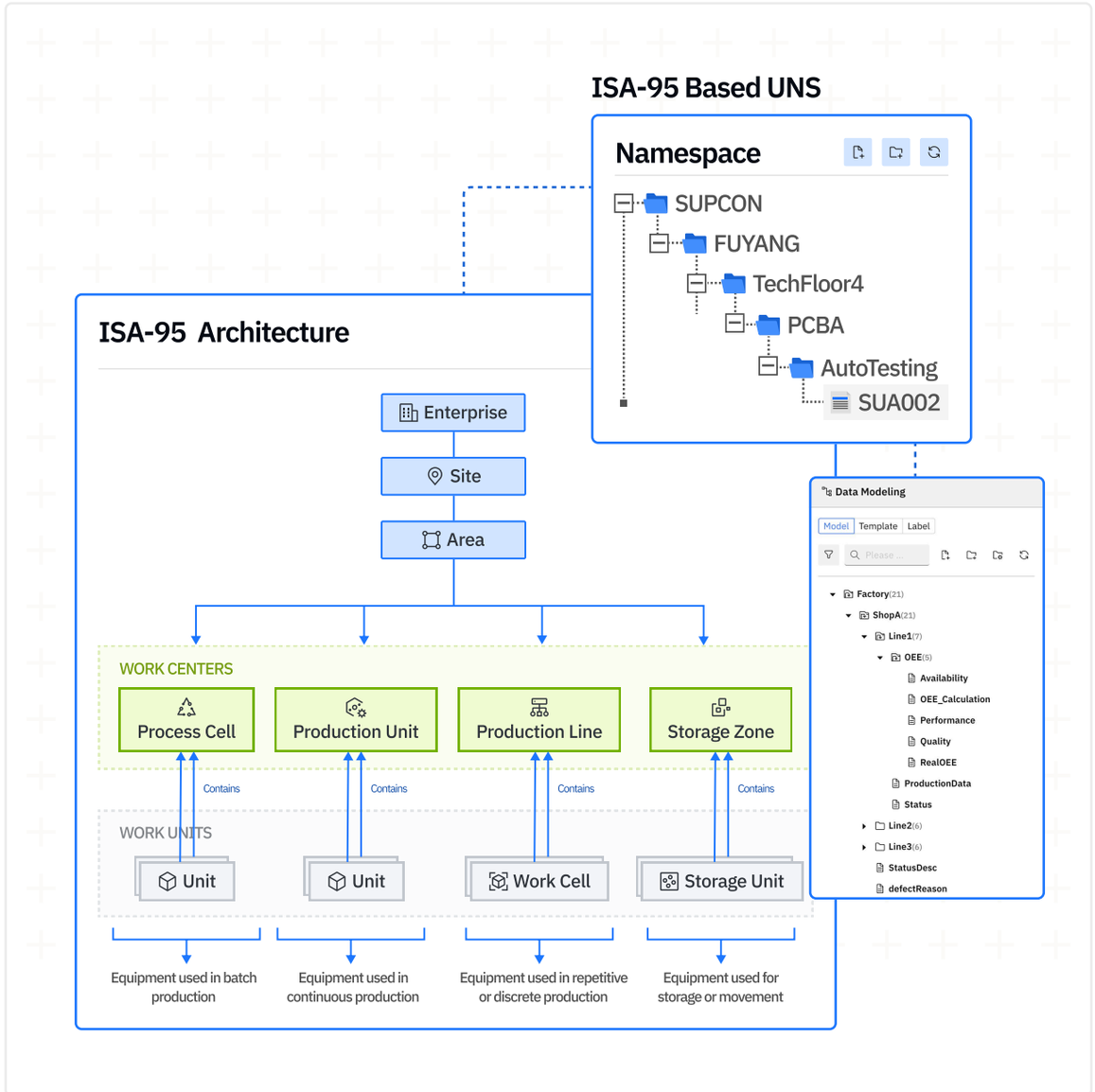
1.1 Unified Namespace: The Foundation Of Smart SMT Factories

Unified Data Integration Across Standard Protocols, Custom Interfaces, And MES Systems

Structured Semantic Modeling For SMT

Effective data integration requires clear business contexts. Tier0 introduces structured semantic modeling that transforms complex factory data into intuitive, real-time operational models:

- Utilizes familiar file, folder, and tree structures to simplify data management.
- Supports both ISA-95 modeling for professional and general applicability, and customizable modeling to precisely match specific production process, management and analytical requirements.
- Typically employs ISA-95 to build hierarchical physical-spatial structures (folders) representing enterprises, sites, areas, work cells, or production lines. Each device or line is associated with real-time State and Action data files/folders or analytical files/folders (e.g., OEE), linked within hierarchical ISA-95 structures, facilitating easy navigation and check.



1.1 Unified Namespace: The Foundation Of Smart SMT Factories

Unified Data Integration Across Standard Protocols, Custom Interfaces, And MES Systems

Real-Time Data Perception And Query On The Shop Floor

The Unified Namespace (UNS) makes all factory data instantly accessible as structured topic-payload pairs, organized hierarchically for clarity and usability:

- Navigate real-time data using hierarchical namespaces to explore metadata, key-value pairs, and time-series metrics.
- Offers an end-to-end data flow topology, covering Connection, Modeling, Persistence (Sink), Visualization, and Distribution, enabling agile, data-driven decisions.



1.2 From Polling To Event-Driven

Real-Time Event Processing With Event-Flow

Modern SMT and 3C factories require real-time collaboration across maintenance, quality control, logistics, and production execution. To meet these demands, Tier0 introduces Event-Flow—a visual event processing engine designed to bridge the gap between raw industrial data and actionable applications:

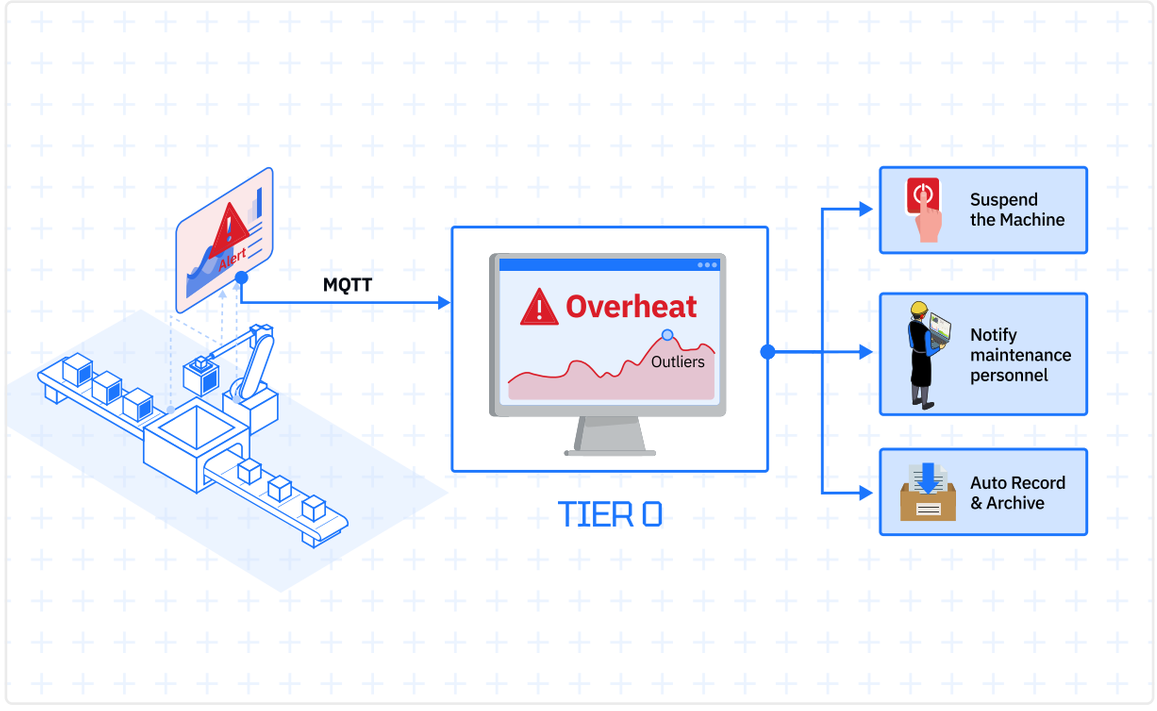
- A low-code, visual interface for configuring event-state logic, with support for advanced JavaScript-based custom processing.
- MQTT-native communication for low-latency, reliable event subscriptions and message dispatching.
- Deep integration with UNS data structures, enabling conditional logic based on real-time semantic topics, and facilitating downstream tasks such as notifications, alarms, or inter-system coordination.

Representative use cases:

Capturing real-time quality anomalies and instantly notifying QC teams or triggering containment actions.

Monitoring AGV/AMR location and health status to support proactive maintenance or fault response.

Enabling dynamic Just-in-Time (JIT) logistics scheduling, minimizing material wait times and bottlenecks across the line.

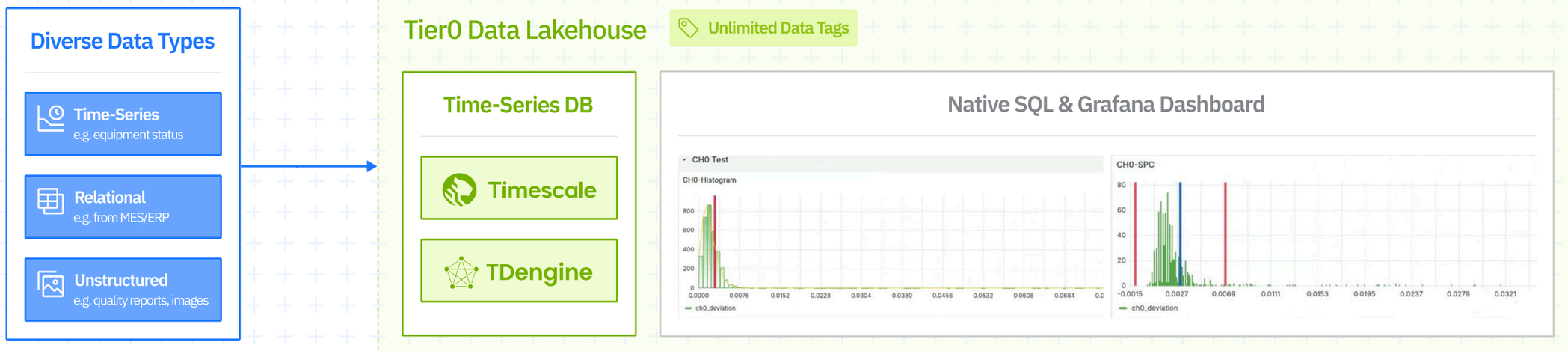


1.3 Cloud-Native Lightweight Factory Data Lakehouse

For Time-Series, Relational, And Unstructured Data

SMT operations generate vast volumes of heterogeneous data—including time-series sensor signals, relational production records, and unstructured logs or quality reports. To effectively harness these sources, Tier0 provides a **cloud-native, lightweight data lakehouse** tailored for manufacturing.

- High-performance time-series storage with streaming computation via TimeScaleDB or TDengine, ideal for metrics such as OEE, MTBF.
- Flexible persistence/sink directly from UNS, enabling fast, structured queries.
- Built-in SQL compatibility and Grafana-based visualization, allowing engineers to explore actionable insights.
- No tag count limitations, supporting scalable and flexible data modeling beyond traditional historians or commercial IIoT solutions.

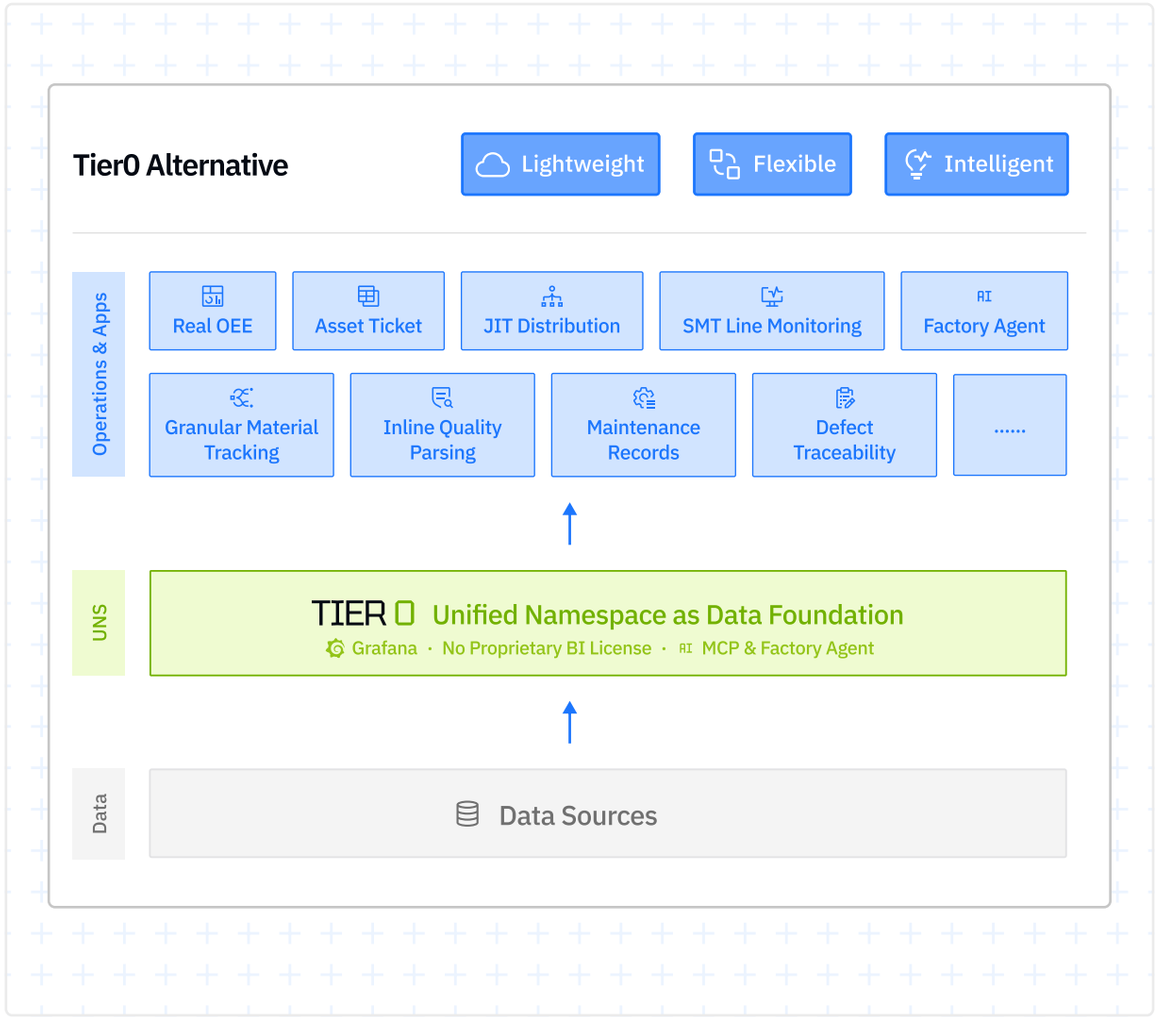


1.4 Next-Generation Operation Apps For SMT Shop-Floors

Ready-To-Use Industrial Apps

As SMT factories become more dynamic, traditional business intelligence (BI) tools often fall short—limited by rigid data schemas, high licensing costs, or poor support for real-time analytics. Tier0 offers a lightweight, flexible, and intelligent alternative:

- Embedded Grafana engine with native support for multiple data sources (TimeScaleDB, PostgreSQL, etc.), enabling trend monitoring, quality tracking, and yield analysis.
- No reliance on proprietary BI licenses, significantly reducing deployment and maintenance overhead.
- Fully compatible with MCP and factory Agent for real-time monitoring and insights.

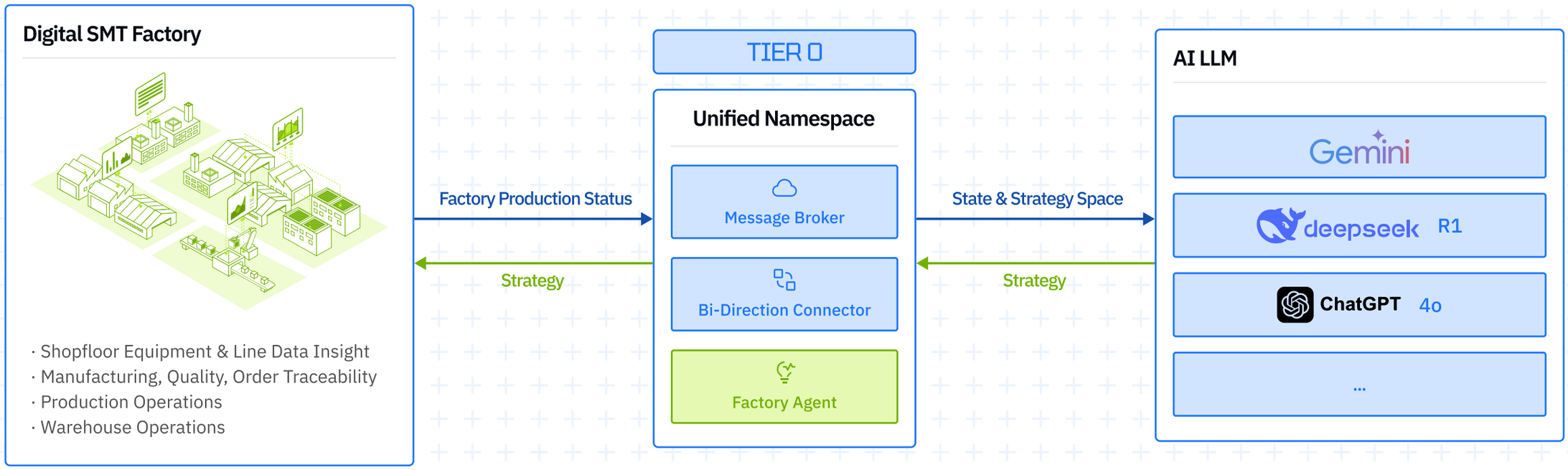


1.5 Factory AI Agents

Build Factory-Wide AI Assistant

Factory Agents, developed by FREEZONEX, is an AI-powered assistant designed for factory-wide analytics and decision support—leveraging Large Language Models (LLMs) to interpret and reason over data from equipment, production lines, quality, inventory, and orders:

- Real-time data fusion from the Unified Namespace (UNS), ensuring that insights are always grounded in accurate, contextual factory data.
- Natural language interaction and reasoning, transforming complex operational data into interactive Q&A, KPI metric lookup, cross-system analysis, and strategy recommendation for operation optimization.



LEARN MORE →

Chapter2

Agile Production

◇ 2.1 Reduce WIP Buffers With Full-Process JIT Orchestration

◇ 2.2 Minimize Downtime Through Real-Time Anomaly Monitoring

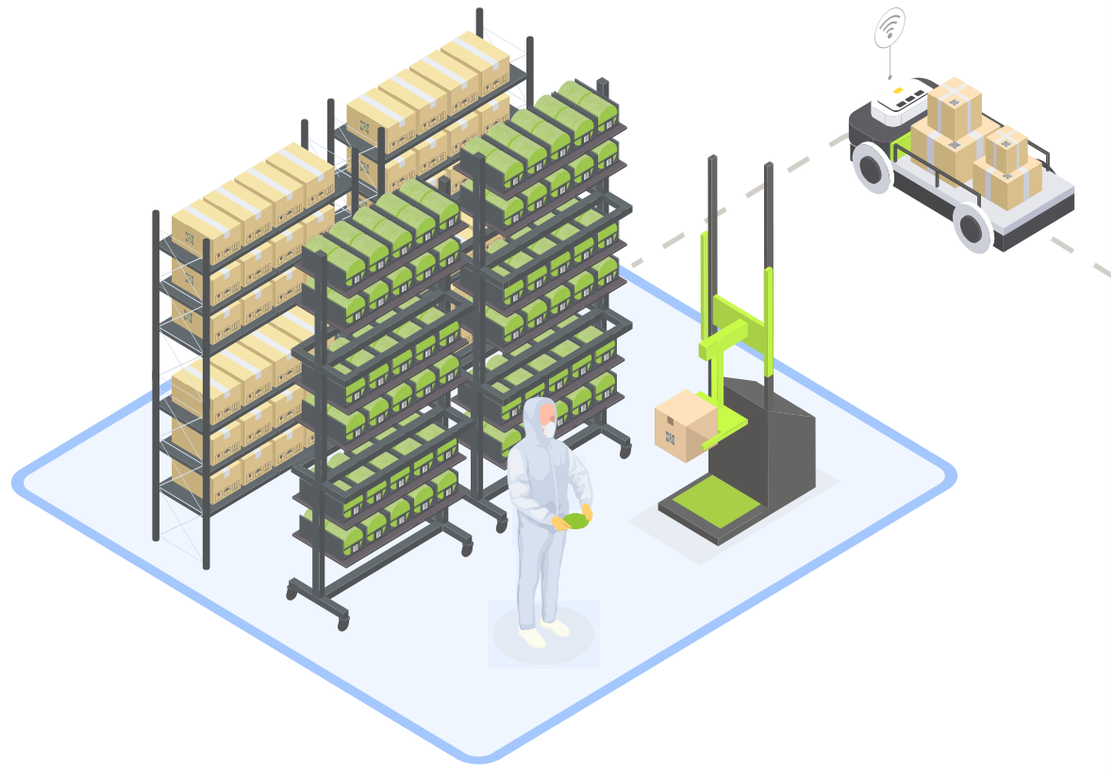
◇ 2.3 Synchronize Order Statuses Across MES, ERP, WMS, And SRM Systems

2.1 Agile Production

Reduce WIP Buffers With Full-Process JIT Orchestration

Fragmented Logistics: A Bottleneck To True Lean Execution

In high-throughput SMT factories, the disconnect between production systems and internal logistics remains a major obstacle to lean manufacturing. While MES and AGVs are commonly deployed, their coordination is often disjointed. At SUPCON Fuyang, for example, operators must manually dispatch AGVs via PDA after each cycle. When AGVs are unavailable, finished units accumulate in buffer zones—disrupting flow, occupying space, and introducing delays.



The Hidden Cost Of Excessive Buffers

Excess WIP buffers are more than spatial inefficiencies. According to Little's Law, higher WIP levels increase lead times and degrade throughput responsiveness [1] . Real-world lean transformations, such as Hewlett-Packard's, have shown that reducing WIP from weeks to a single day can significantly boost agility and throughput [2] .

2.1 Agile Production

Reduce WIP Buffers With Full-Process JIT Orchestration

Lack Of Context Slows Decisions

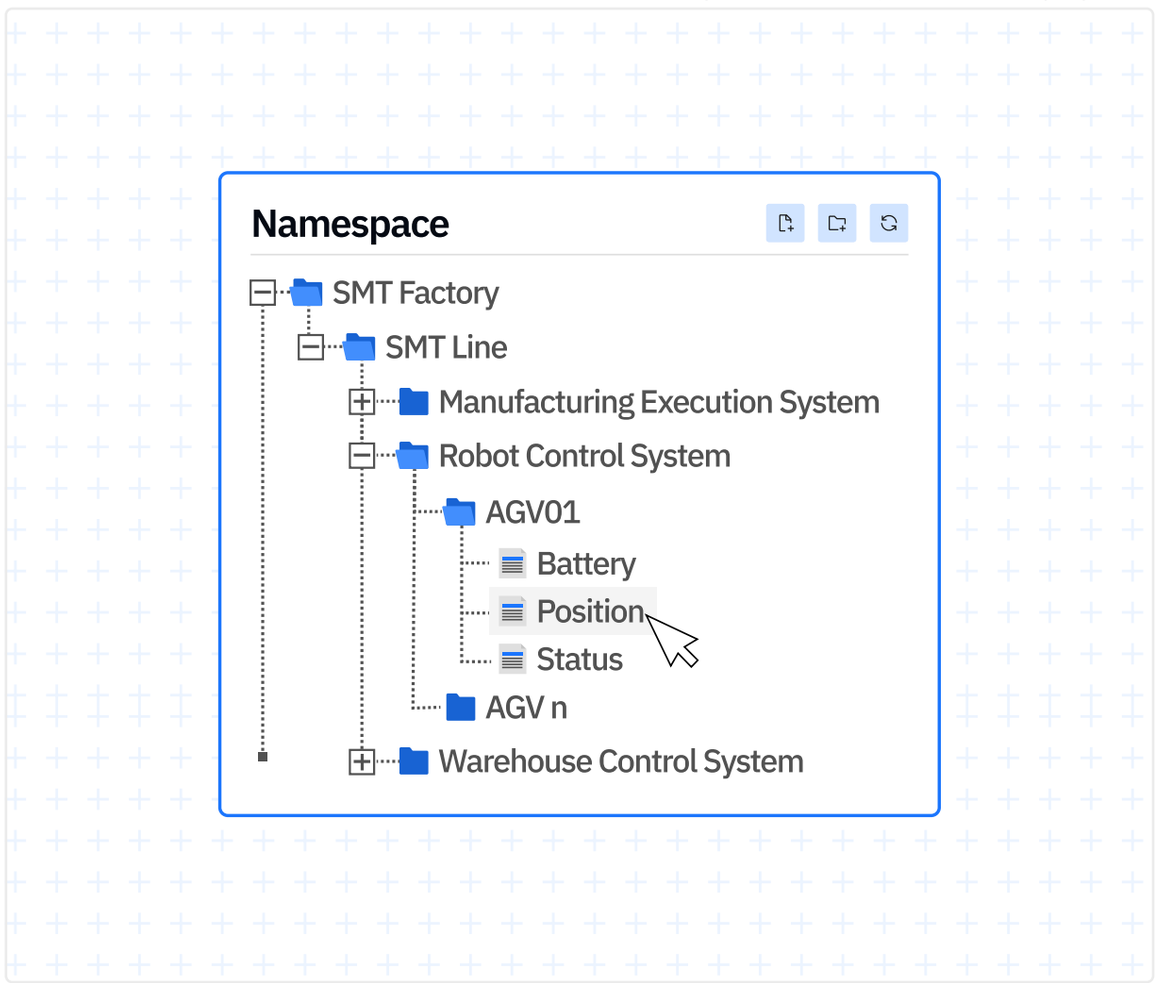
Without contextual integration between MES, WMS, and AGV control systems, handling exceptions—like rush orders or rework—requires manual, cross-system coordination. This slows response times and increases the risk of errors. Industry research shows that over 60% of automation projects underperform due to fragmented systems and lack of shared context [3] .

Full-Process JIT Orchestration By Tier0

Tier0 addresses this through an event-driven orchestration model based on a Unified Namespace (UNS). By integrating MES, RCS, and WCS into a unified structure, production events —such as task completion or machine state changes— automatically trigger AGV assignments. Tasks, feedback, and exception handling are managed via a publish-subscribe mechanism, removing the need for manual intervention.

This approach turns logistics into an intelligent, active part of production. It minimizes buffer reliance, enables just-in-time material flow, and improves cross-department transparency. As a result, SMT factories can optimize space, reduce working capital, and build adaptive, resilient production systems—laying the groundwork for AI-driven JIT scheduling.

*UNS architecture developed in this case, for reference purposes.



2.2 Agile Production

Minimize Downtime Through Real-Time Anomaly Monitoring

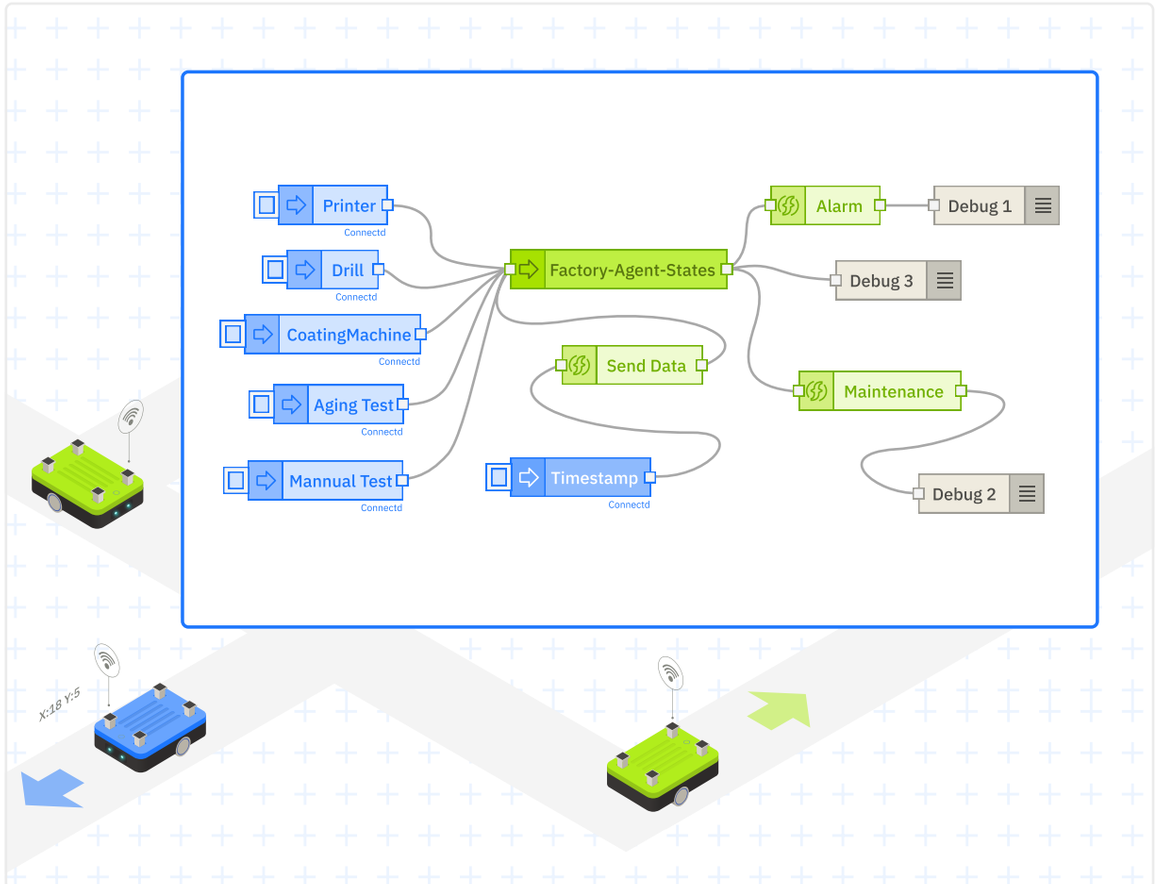
Why Downtime Hurts SMT So Deeply

SMT production is highly sensitive to disruptions due to fast takt times, frequent changeovers, and tightly integrated equipment. A single fault—whether in a printer, pick-and-place machine, or SPI/AOI station—can cascade into broader delays. Yet many factories still rely on manual anomaly detection. At SUPCON Fuyang, for example, AGV or sensor failures are spotted by operators and reported through disconnected systems, delaying responses and increasing quality risks.

The cost of unplanned downtime is staggering—ranging from $50,000 to over $260,000 per hour depending on production scale and product complexity [4] . Without real-time coordination across MES, logistics, and maintenance systems, root causes go unresolved and long-term reliability suffers.

From Reactive To Real-Time Response With Tier0

Tier0 offers a unified, real-time framework for anomaly detection and automated response. Edge-level issues—like AGV disconnections or SMT alarms—are captured instantly and routed through the Event-Flow module. This triggers digital maintenance workflows: alerts are sent to relevant staff, and work orders are automatically generated with full context (timestamp, asset ID, fault type, location). Operators no longer need to report issues manually. Maintenance teams can act immediately with full traceability and visibility.

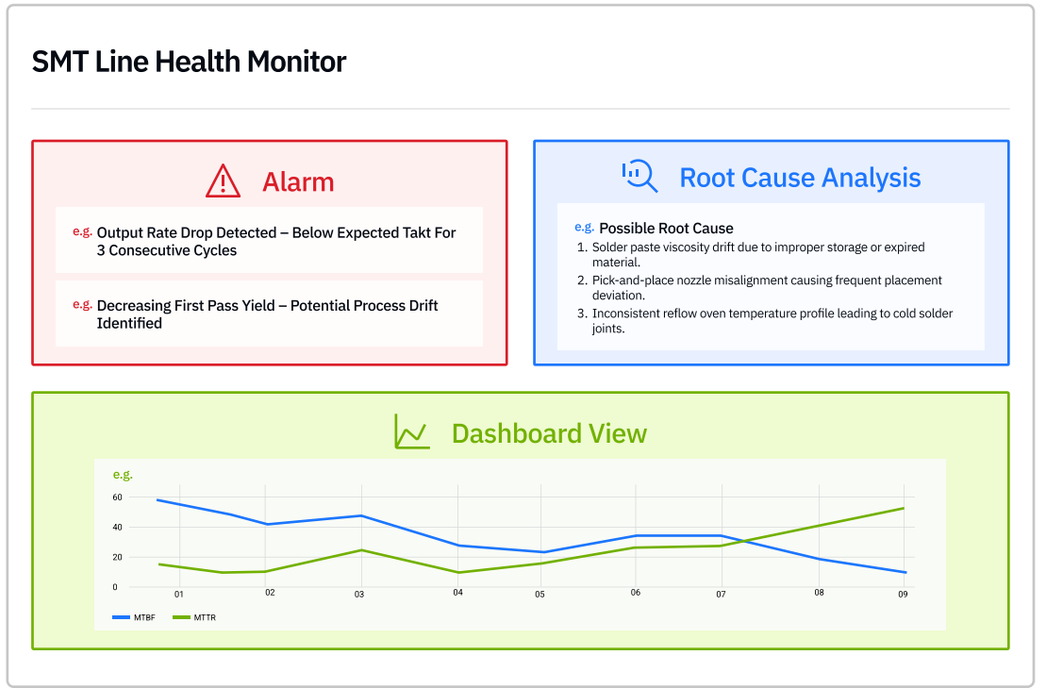


2.2 Agile Production

Minimize Downtime Through Real-Time Anomaly Monitoring

Traceability And Long-Term Reliability

Beyond immediate handling, all anomalies are logged for retrospective analysis. Manufacturers can view dashboards showing fault trends, calculate KPIs like MTBF (Mean Time Between Failures) and MTTR (Mean Time to Repair), and perform root-cause analysis across different equipment categories. With this infrastructure in place, factories can gradually transition toward predictive maintenance(In Section 4.2, we'll explore how AI models power predictive maintenance in greater detail), offer value-added digital services like remote diagnostics, and build resilient smart operations that minimize unscheduled downtime.

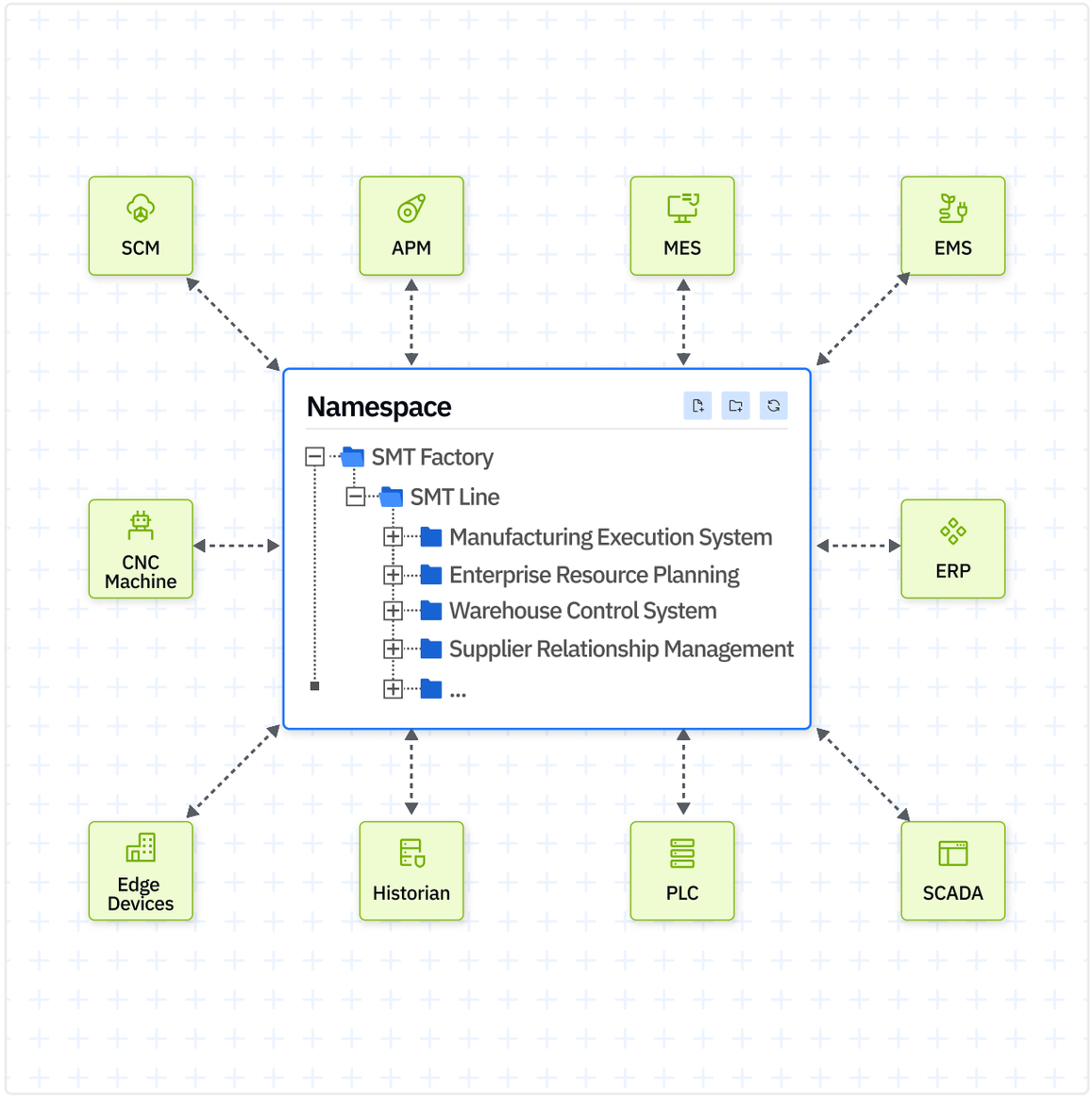


2.3 Agile Production

Synchronize Order Statuses Across MES, ERP, WMS, And SRM Systems

The Need For Single Source Of Truth

For manufacturers operating in complex supply chains, the ability to monitor order progress across systems—MES, ERP, WMS, and SRM—is no longer a future plans but a necessity. In facilities like SUPCON Fuyang, this need has become especially pressing. External customers often request updates based on their own identifiers, yet inconsistencies in master data—such as order numbers or product IDs—make accurate cross-system tracking difficult. Internally, operators still spend time manually collecting information from siloed systems, causing extra workload and diminishing service quality.



A Unified Namespace For Seamless Data Alignment

Tier0 addresses this challenge by implementing a Unified Namespace (UNS)—a central, semantically structured data layer where production, logistics, and order information is aggregated in real time. This architecture acts as a single source of truth, ensuring that every stakeholder—from line operators to supply chain managers—accesses the same, up-to-date view of factory operations.

2.3 Agile Production

Synchronize Order Statuses Across MES, ERP, WMS, And SRM Systems

Cross-System Mapping And Normalization

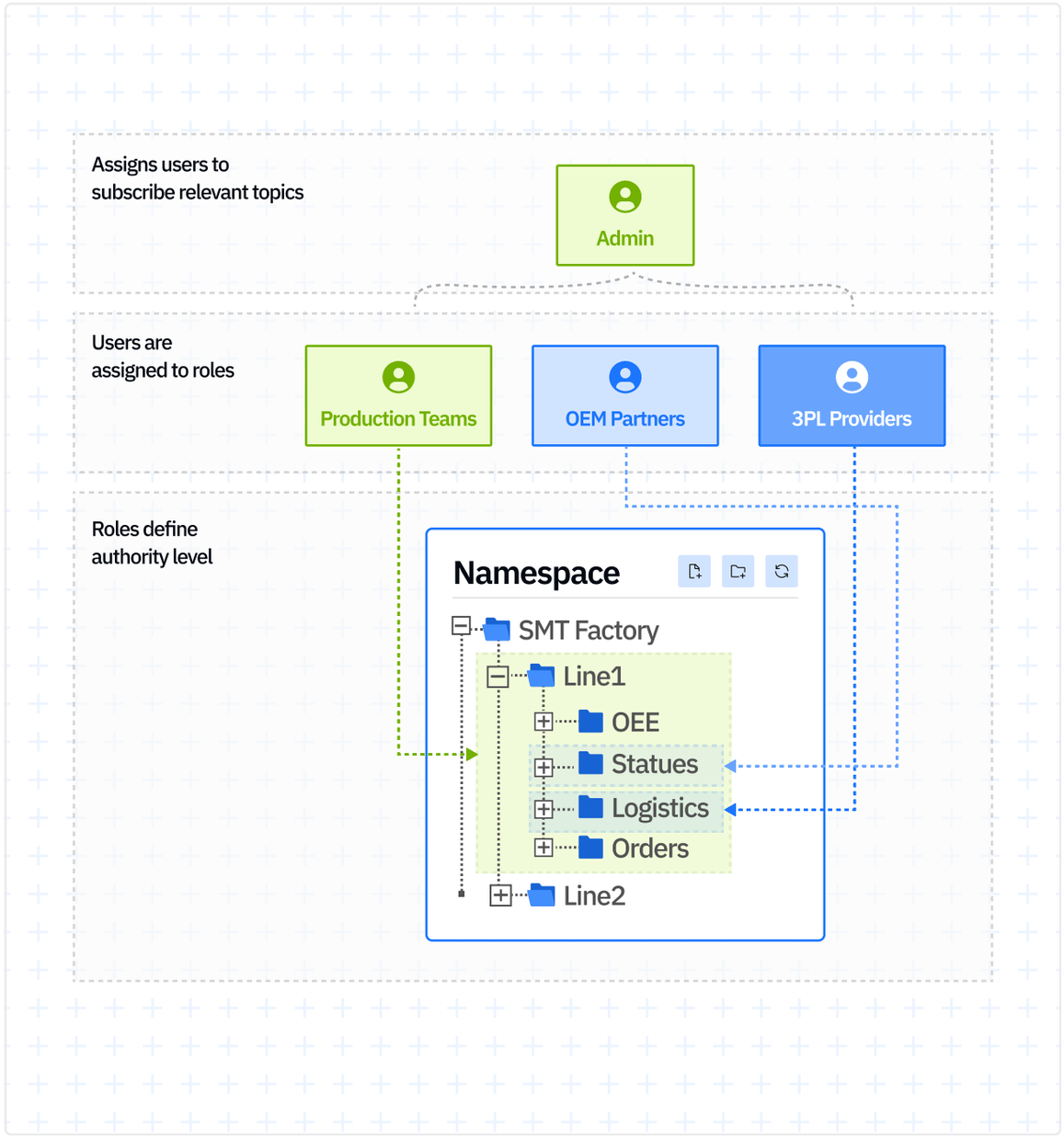
Master data from MES, ERP, WMS, and SRM is harmonized through customizable mapping rules. For example, different product or order IDs used across systems are matched and resolved into a single canonical reference in the UNS. This eliminates inconsistencies and prevents duplication.

Role-Based Data Access

Instead of building rigid, one-off APIs, Tier0 uses MQTT-based publish/subscribe interfaces for lightweight, real-time, and decoupled data access. Role-based access control ensures that each stakeholder—whether internal teams, OEMs, or 3PLs—only sees the topics relevant to their responsibilities.

Operation Upgrade

With real-time signals flowing across systems and simplified integration logic, manufacturers gain better order visibility, faster responsiveness to customer queries, and improved supply chain agility—while also reducing long-term costs tied to interface maintenance and manual coordination.



LEARN MORE →

Chapter3

Operational Insights

◇ 3.1 Improve Asset Utilization With Automated OEE Dashboards
◇ 3.2 Detect And Resolve Quality Issues Faster With Inline Analytics
◇ 3.3 Optimize Energy Usage With Real-Time Consumption Analysis

3.1 Operational Insights

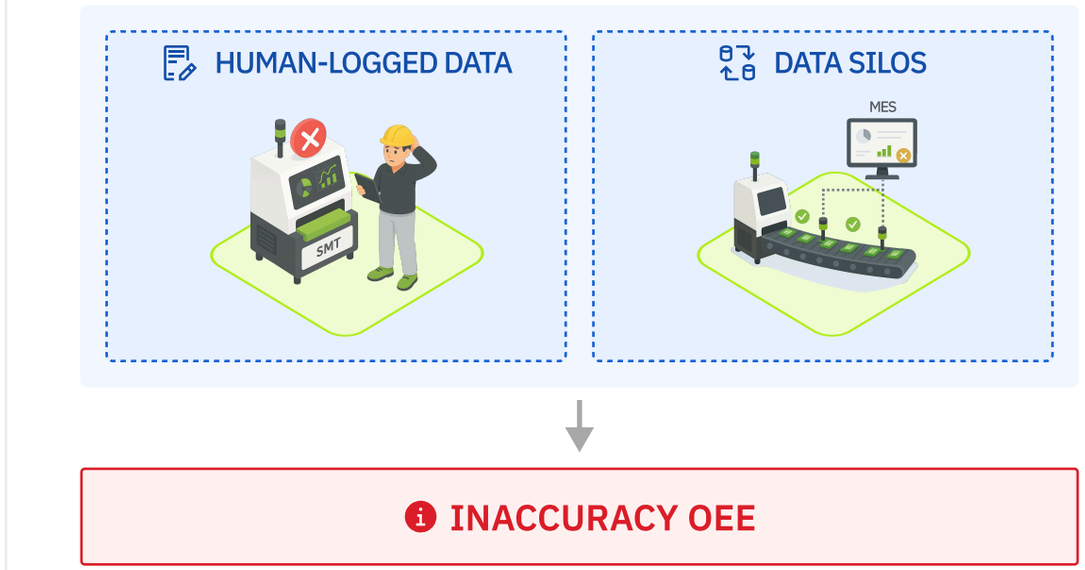
Improve Asset Utilization With Automated OEE Dashboards

Human-Reported OEE? Slow, Error-Prone, And Unsustainable

In many SMT factories, OEE(Overall Equipment Effectiveness) is still calculated by hand. For example, line workers manually log machine uptime, downtime reasons, and shift reports using Excel sheets or daily reports. These reports are then reviewed by team leads to estimate loading time, uptime, and derived OEE metrics. But human-logged data—such as delays due to upstream supply or machine debugging—is often incomplete, delayed, or subjective. As a result, the resulting OEE figures are unreliable and poorly suited for continuous improvement.

Data Gaps Between Equipment And MES

Accurate OEE depends on three real-time components: availability (equipment status), performance (production speed), and quality (yield rate). However, most SMT equipment lacks the capability of exposing detailed operational states through PLCs. Simultaneously, MES data—such as product models, standard takt times, or planned stops—is often misaligned or unavailable when needed. Minor faults, quality-related downtime, or routine handovers are either missed entirely or aggregated into broad categories, making it difficult to identify bottlenecks or root causes.



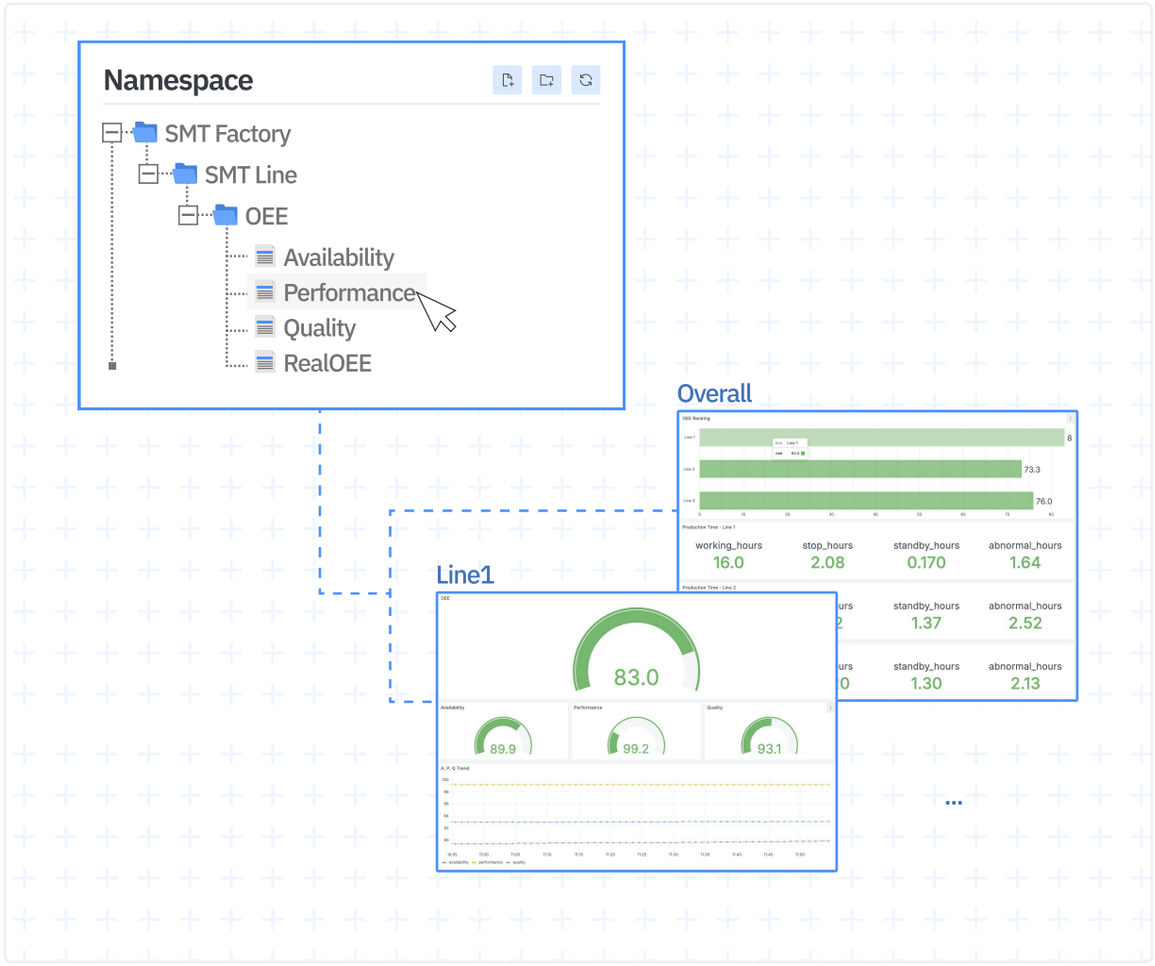
Real-Time, Data-Driven OEE With Tier0

Tier0 enables IT/OT convergence by integrating real-time device states, MES work orders, and production records into a unified, contextualized data flow. Even with minimal machine signals—like online/offline/fault—OEE can be automatically calculated when paired with MES inputs such as standard cycle

3.1 Operational Insights

Improve Asset Utilization With Automated OEE Dashboards

times and production counts. Intermediate metrics such as load time, uptime, and good unit count are stored and made queryable, supporting traceability, exception analysis, and improvement actions.



Beyond OEE: A Transparent, Smarter Line

Tier0 extends beyond standard OEE with native support for more kPIs like MTBF (Mean Time Between Failures), MTTR (Mean Time to Repair), and TEEP (Total Effective Equipment Performance). These metrics are visualized through live dashboards, enabling a shift from retrospective reporting to real-time operational visibility. This lays the foundation for more autonomous, less labor-intensive SMT production environments—delivering the responsiveness and transparency modern factories demand.

> ☑ Want to build your own Real-Time OEE Dashboard?
> Check out **Section 5.1** for a step-by-step tutorial.

3.2 Operational Insights

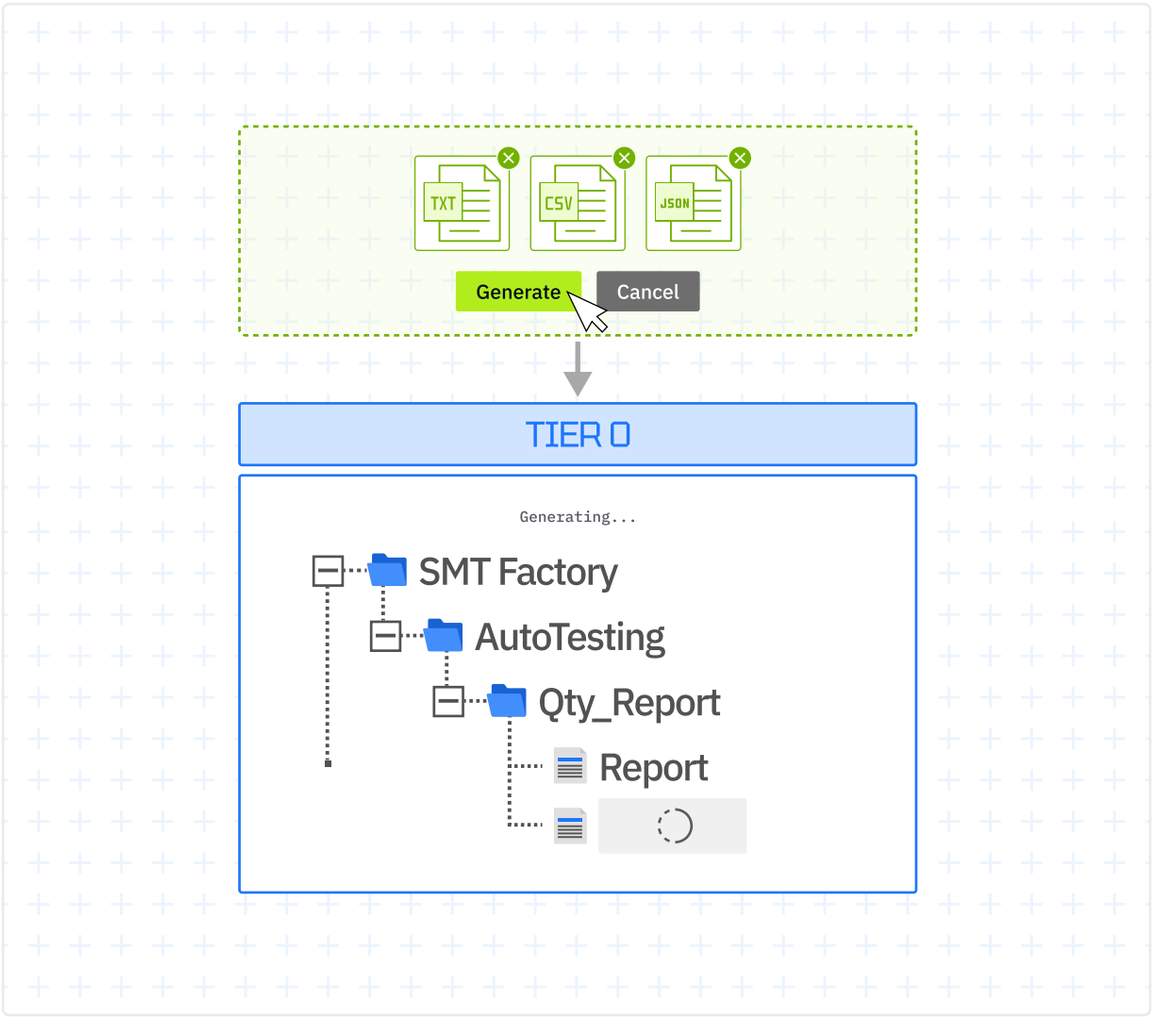
Detect And Resolve Quality Issues Faster With Inline Analytics

The Challenge Of Unstructured Quality Reports

In many SMT factories, test data from ICT and functional test stations is still stored as plain .txt files or ftp files on local servers. These formats lack structure, standardization, and contextual linkage to systems like MES or QMS. When defects arise, engineers must manually retrieve and interpret these logs—often inconsistent in format—making root-cause analysis inefficient. Without connection to serial numbers, work orders, or material lots, it becomes difficult to find the causes of product quality across batches.

Generate Structured Data With Reverse Modeling

Tier0 addresses this challenge through **Batch Reverse Modeling**, which transforms unstructured test reports into structured, queryable time-series data—automatically mapped into a Unified Namespace (UNS). Whether dealing with multi-channel analog readings (e.g., 4mA, 12mA, 19.2mA), protocol validation like HART, or metadata such as SNs, operators, and timestamps, the system parses and organizes all key information. This no-code modeling process dramatically reduces analyzing time for heterogeneous test formats and lays the foundation for more advanced quality analytics—making it easier to trace defects across batches, identify root causes, and drive faster corrective actions.



3.2 Operational Insights

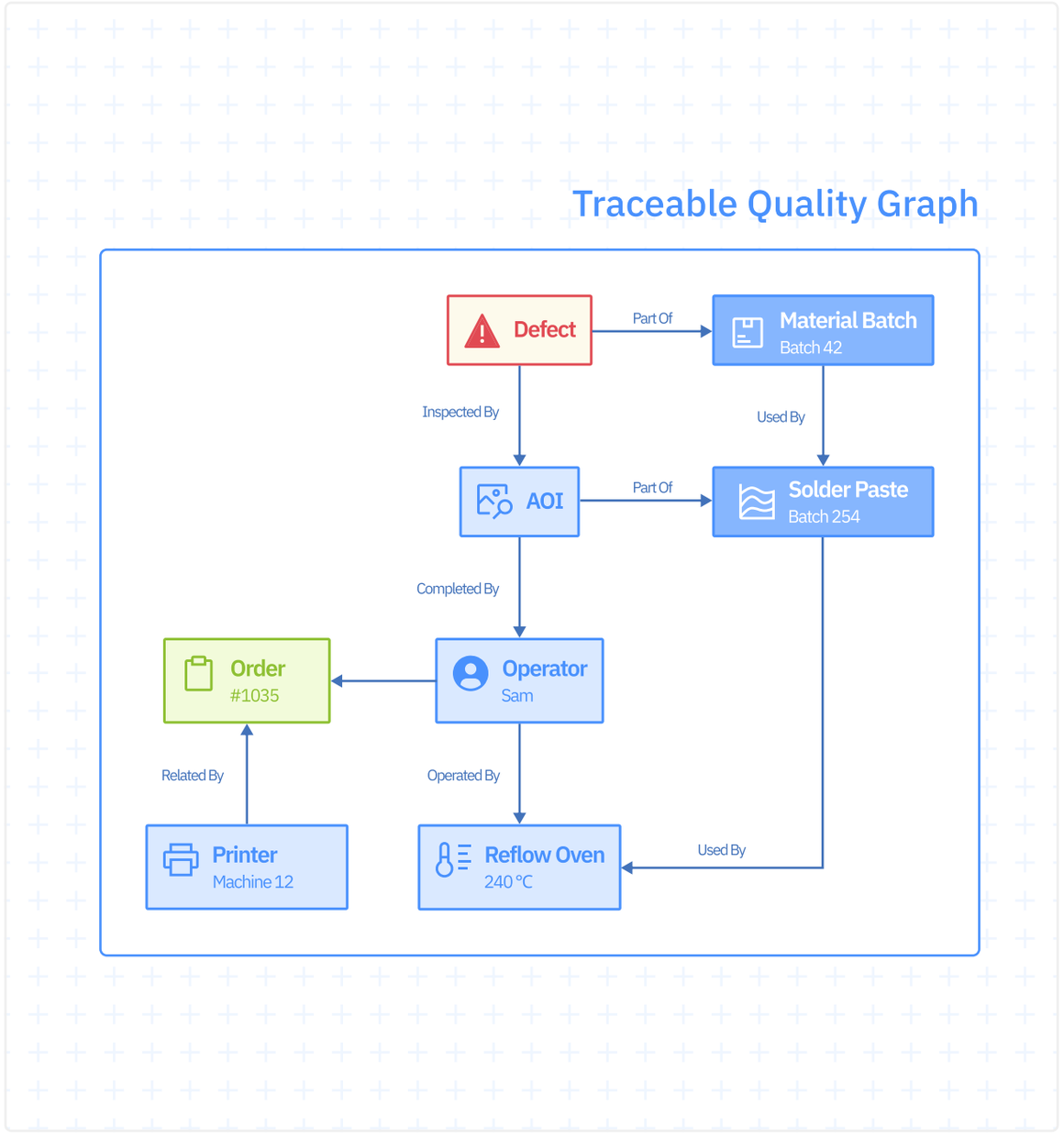
Detect And Resolve Quality Issues Faster With Inline Analytics

Build Traceable Quality Graph With UNS

In PCBA manufacturing, quality data is often scattered across MES, ERP, edge devices, and manual reports—lacking semantic structure or consistent links like serial numbers or process steps. When defects occur, engineers must manually search through scattered logs and records, making root-cause analysis slow and cross-process correlation nearly impossible.

Tier0 builds a traceable quality graph, combining factory process maps, UNS data, and equipment behavior models. This semantically linked architecture connects test outcomes with upstream elements such as raw material batches, operator assignments, environmental conditions, and equipment states.

By mapping these relationships, manufacturers can move from reactive firefighting to proactive risk prevention. The case can trace related batches, suggest root causes, and flag similar risks in real time—forming a foundation for digital twins, semantic search, and AI-assisted diagnostics.



3.3 Operational Insights

Optimize Energy Usage With Real-Time Consumption Analysis

Coarse-Grained Energy Data in Discrete Manufacturing

In SMT and discrete manufacturing environments, energy data is often too coarse-grained to support actionable insights. For factories running high-mix, low-volume production, it becomes especially difficult to quantify energy usage per line, shift, or product model—leaving manufacturers blind to where and how energy is being wasted.

Semantic Energy Modeling With UNS

Tier0 solves this by integrating sub-meters and sensors into a Unified Namespace (UNS), semantically binding energy data to production entities such as equipment, work orders, and teams. This creates a shared context between energy usage and operational data from MES.

Real-Time Monitoring And Visualization

With Source-Flow and dashboards modules, Tier0 enables manufacturers to create real-time visualizations of energy data using Grafana. Users can monitor trends, compare consumption across lines or shifts, and investigate anomalies.

Leaner And Greener Operations

By making energy consumption both visible and contextualized, factories can systematically eliminate inefficiencies, extend equipment life, and reduce utility costs. More importantly, aligning energy data with production insights supports carbon reduction goals and ESG reporting—making operations not only more efficient, but also more sustainable.

LEARN MORE →

Chapter4

AI-Enhanced Operations

◇ 4.1 Factory Agents Deliver Actionable Insights For Real-Time Decisions
◇ 4.2 Predict Equipment And Quality Issues Before They Occur

4.1 AI-Enhanced Operations

Factory Agents Deliver Actionable Insights For Real-Time Decisions

Why Are AI Agents A Game Changer In Manufacturing?

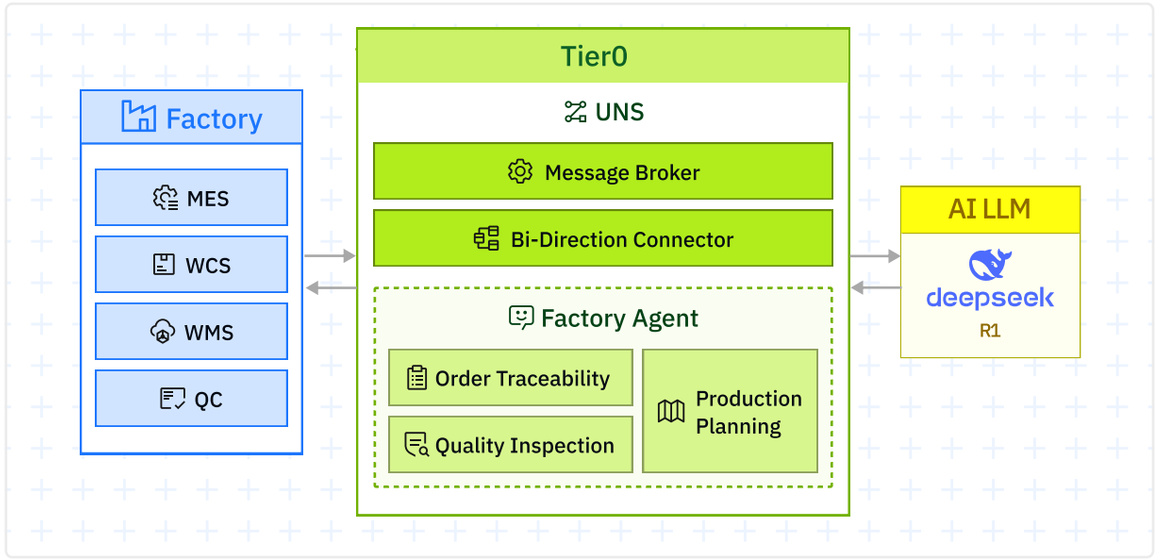
In today's dynamic manufacturing environments, static rules and manual decision-making are no longer sufficient. Factory Agents—powered by real-time data and large language models (LLMs)—introduce a new level of intelligence. Rather than reacting to fixed thresholds, they continuously interpret operational data, evaluate multiple strategies, and generate actionable insights to guide decisions in production, quality, and logistics.

Built On Unified Namespace For Real-Time Context

Tier0 Factory Agents operate atop a Unified Namespace (UNS), which harmonizes data from MES, WMS, quality, and automation systems. Semantic modeling and bi-directional pipelines ensure that AI-generated insights are grounded in real-time context. Tier0 supports frontier LLMs such as ChatGPT-4o and DeepSeek R1 for advanced factory-state reasoning.

Validated In A Simulated Factory

We simulated a discrete manufacturing factory using the SimPy framework to assess the effectiveness of Tier0 + Factory Agent. The virtual factory handled daily customer orders and experienced real-world dynamics like machine failures, demand shifts, and worker shortages. The Factory Agent responded by recommending actions such as predictive maintenance, staffing adjustments, or inventory clearance. In a 30-day simulation, the LLM-driven agent outperformed human decision-makers, generating $50,000 more in cumulative profit across 11 strategies.



4.1 AI-Enhanced Operations

Factory Agents Deliver Actionable Insights For Real-Time Decisions

Real-World Deployment At SUPCON Fuyang

According to the World Economic Forum, real-time AI agents can boost productivity by up to 14% and reduce decision latency by 80%—a shift that is already underway at SUPCON Fuyang's smart factory. Here, multiple Factory Agents have been deployed to enhance operational responsiveness and intelligence across production lines.

One Agent autonomously dispatches AGVs by interpreting real-time equipment status events, while another continuously monitors OEE performance, identifies inefficiencies, and recommends optimizations on the fly. These AI agents transform raw machine data into actionable insights, helping engineers respond faster, improve throughput, and reduce manual workload—bringing the vision of intelligent, data-driven factories into practice.



- [x] Want to build your own AGV Auto-Scheduling?
  Check out **Section 5.2** for a step-by-step tutorial.

4.2 AI-Enhanced Operations

Predict Equipment And Quality Issues Before They Occur

Why Wait For Failure?

We've already detailed Why Downtime Hurts SMT So Deeply in Section 2.2, so we won't repeat those points here. Instead, this section focuses on how predictive maintenance (PdM) transforms how factories respond to potential failures—before they happen.

As production systems grow in complexity and scale, traditional approaches like reactive repairs or fixed-interval servicing fall short. They either catch problems too late or waste resources maintaining equipment that's still in good condition. Predictive Maintenance flips the script. Instead of reacting to breakdowns or relying on guesswork, factories can now anticipate failures before they happen—using real-time sensor data, historical patterns, and AI-driven anomaly detection. According to Deloitte, predictive maintenance can reduce breakdowns by 70%, cut maintenance planning time by 50%, and significantly boost OEE [5] .

With Tier0, manufacturers gain a unified platform to:

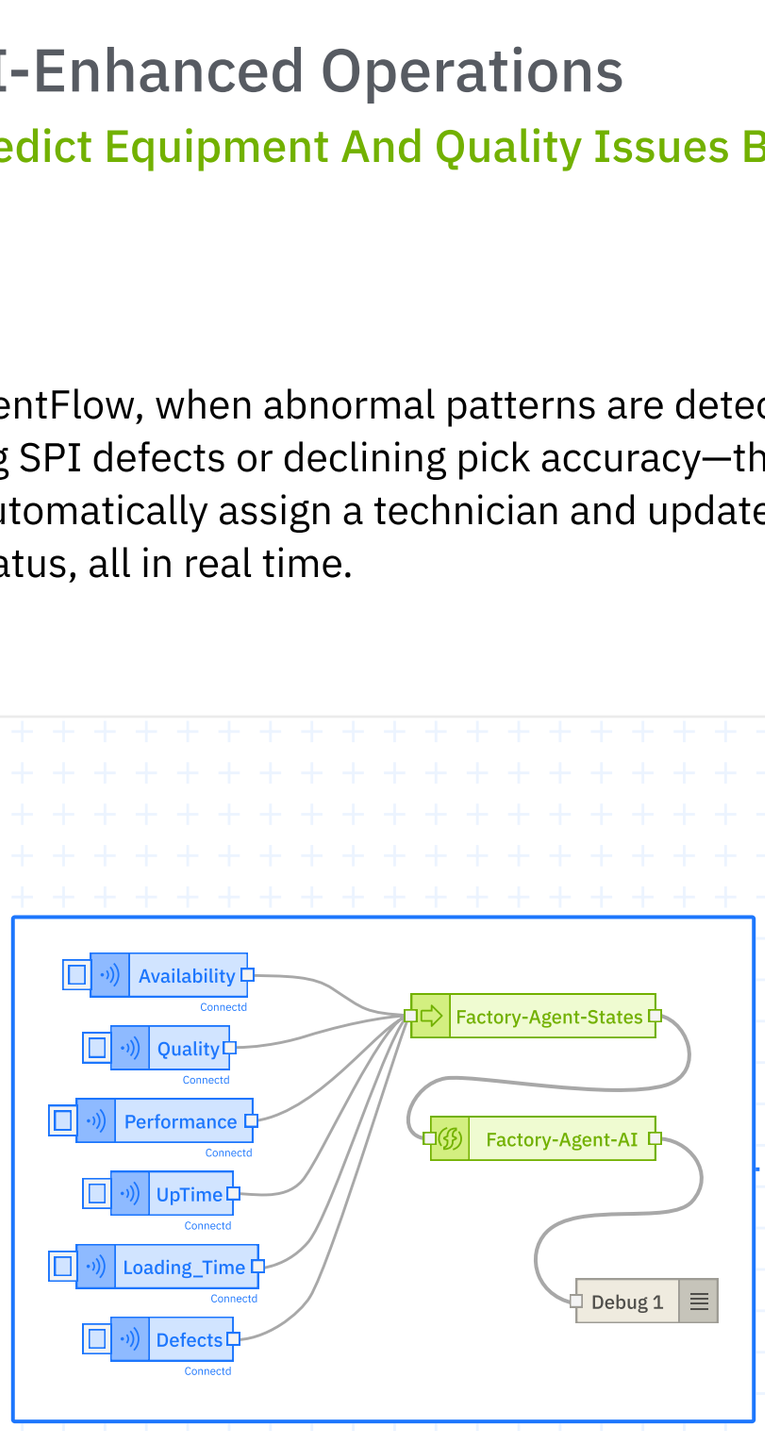
- Continuously track equipment, process & environment condition—monitoring vibration, electrical, air/gas flow, vacuum pressure, temperature, humidity and status in real time.
- Monitor PCB quality data such as product geometry like dimension, thickness, and error rate, yield, etc.
- Identify early signs of failure such as nozzle wear, stencil degradation, heating anomalies or process issues through trend analysis and AI models.
- Integrate maintenance decisions with live production context through the Unified Namespace.
- Automate early warnings and maintenance triggers before damage escalates.

4.2 AI-Enhanced Operations

Predict Equipment And Quality Issues Before They Occur

With Tier0 EventFlow, when abnormal patterns are detected—like increasing SPI defects or declining pick accuracy—the system can automatically assign a technician and update the equipment status, all in real time.

No more isolated logs or blind spots—just actionable insights where and when they're needed. PdM helps reduce unplanned downtime, extend asset life, and optimize spare parts usage—all while empowering teams to focus on performance, not just repairs.



AI

```
### Assessment
Status: Needs Improvement.

### Overall OEE Calculation
Overall OEE = Availability × Performance × Quality
= 88.0% × 65.0% × 90.2% ≈ 51.6%

### Analysis and Conclusion
**Conclusion:** Overall OEE of 51.6% indicates a moderate level of equipment effectiveness.
While availability and quality are acceptable, performance remains a key limiting factor—
suggesting slow cycle times, material supply delays, or minor stoppages.

**Key Insights:**
- **Availability (88.0%)**: Good. Minimal unplanned downtime, equipment is mostly ready.
- **Performance (65.0%)**: Suboptimal. May be caused by slow placement rates, changeovers,
or speed limitations in feeders or conveyors.
- **Quality (90.2%)**: Slightly below target. Elevated defect rates detected in SPI or AOI
stages.

**Recommendation:**
- Analyze pick-and-place speed trends and machine logs for slowdown patterns.
- Investigate SPI/AOI alarms for signs of nozzle clogging or PCB misalignment.
- Optimize feeder changeover procedures and consider buffer time reductions.
- Collaborate with maintenance teams to evaluate potential cycle time constraints.
```

LEARN MORE →

Chapter5

Rebuilding The Use Case Yourself

◇ 5.1 Step-By-Step Guide: Real-Time OEE Monitoring
◇ 5.2 Step-By-Step Guide: AGV Auto-Scheduling With Factory Agent

5.1 Rebuilding The Use Case Yourself

Step-By-Step Guide: Real-Time OEE Monitoring

Step1

Define The Data Structure In UNS

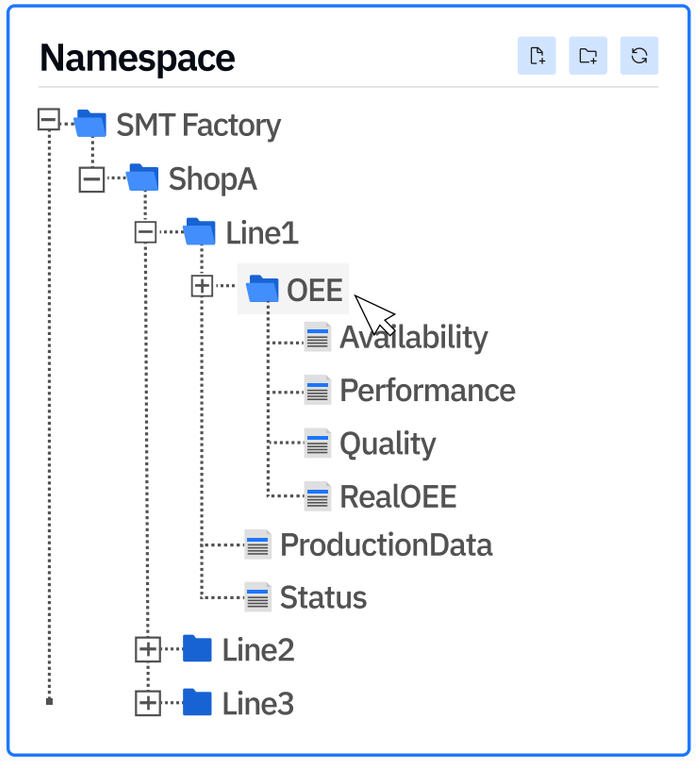
Tier0-Edge Module: UNS

OEE (Overall Equipment Effectiveness) is calculated as:

$$\text{OEE} = \underbrace{\frac{\text{Planned Production Hours - Lost Time}}{\text{Planned Production Hours}} = \%}_{\text{Availability}} \times \underbrace{\frac{\text{Actual Machine Speed}}{\text{Design Machine Speed}} = \%}_{\text{Performance}} \times \underbrace{\frac{\text{Number of Good Products}}{\text{Total Product Made}} = \%}_{\text{Quality}}$$

Where:

- **Availability** = Actual Operating Time ÷ Planned Production Time
- **Performance** = (Ideal Cycle Time × Total Units Produced) ÷ Actual Operating Time
- **Quality** = Good Units ÷ Total Units Produced



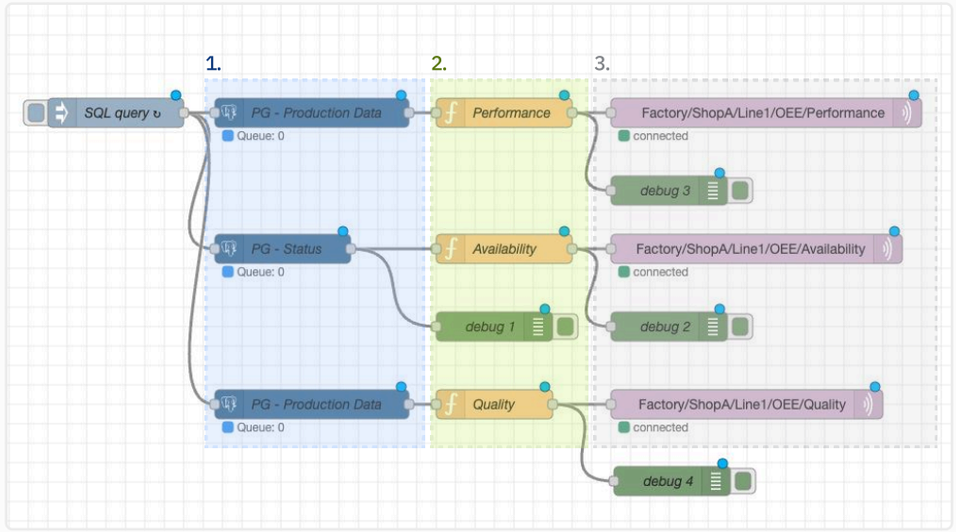
5.1 Rebuilding The Use Case Yourself

Step-By-Step Guide: Real-Time OEE Monitoring

Step2.1

Calculate Real-Time OEE Components — Availability, Performance, And Quality

Source Flow



Note:

1. SQL Query from DB

2. Function Node for Real-Time A, Q, P Calculation

3. MQTT Out Nodes to Namespace

1. Query Raw Data Using Source-Flow

In this example, we use SQL queries to retrieve historical data. Source data may come from multiple tables or databases, such as:

- **Equipment status table:**
  Factory/ShopA/Line1/Status
- **Production data table:**
  Factory/ShopA/Line1/ProductionData

e.g. Availability, SQL Query：

```sql
SELECT
  COUNT(*) FILTER (WHERE status = 1)
    AS count1,
  COUNT(*) FILTER (WHERE status IN (1, 2, 3, 4))
    AS count2
FROM public."_Status_3e4bce934c024c06b40a"
WHERE _ct  >= (NOW()::date;
```

5.1 Rebuilding The Use Case Yourself

Step-By-Step Guide: Real-Time OEE Monitoring

Step2.2-2.3

Calculate Real-Time OEE Components — Availability, Performance, And Quality

Source Flow | UNS

2. Compute A, P, Q In Function Nodes

Use separate Function nodes in Node-RED to compute:

- **A (Availability)**
- **P (Performance)**
- **Q (Quality Rate)**

Each Function node sends its result to a corresponding UNS MQTT Out node.
e.g. Function node for A(Availability):

```
const count1 = msg.payload[0].count1 || 0;
const count2 = msg.payload[0].count2 || 0;

// Convert to hours (seconds ÷ 3600)
const uphours = count1 * 10 / 3600;
const loadhours = count2 * 10 / 3600;

// //Calculate availability, keep to two decimal places, and avoid dividing by 0
let availability = 0;
if (loadhours > 0) {
    availability = Math.round((uphours / loadhours) * 10000) / 100;
}

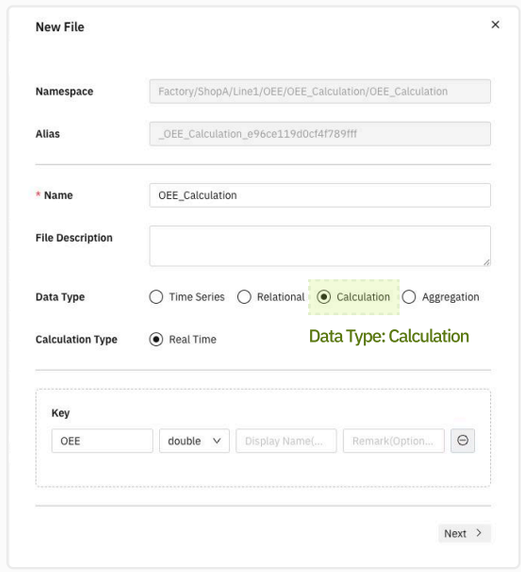
msg.payload = availability;
return msg;
```

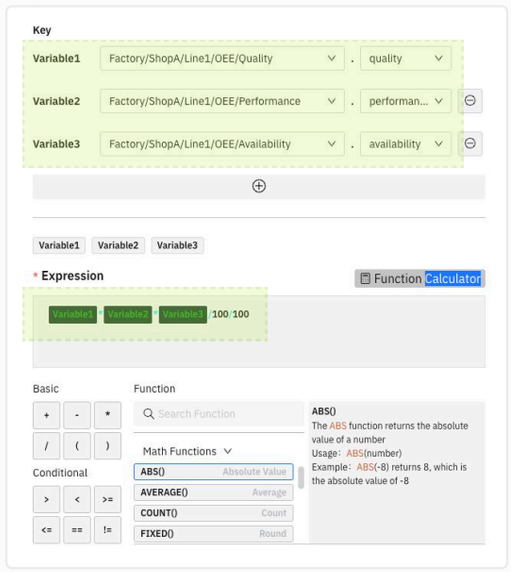
3. Set Up Real-Time OEE Stream Processing In Namespace

Define a new file such as

Factory/ShopA/Line1/OEE/RealOEE

Multiply the real-time values of A, P, and Q to calculate the full OEE score using a stream-processing node.





e.g. Stream computing configuration

- **"Factory/ShopA/Line1/OEE/Availability".availability ***
- **"Factory/ShopA/Line1/OEE/Performance".performance ***
- **"Factory/ShopA/Line1/OEE/Quality".quality) / 100 / 100**

5.1 Rebuilding The Use Case Yourself

Step-By-Step Guide: Real-Time OEE Monitoring

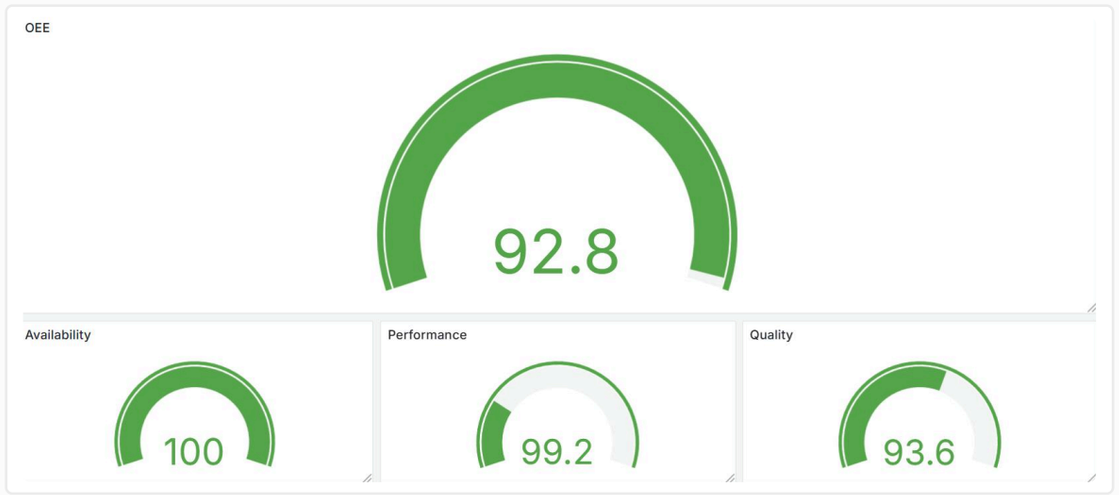
Step3

Visualize OEE Metrics On Dashboard

Dashboard

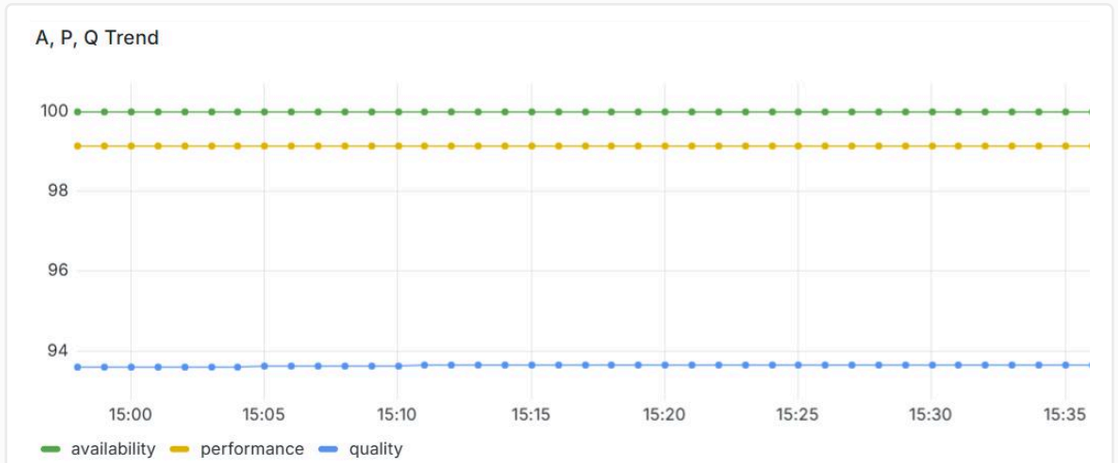
1. Open the **Dashboards** module and select the target dashboard.
2. Click **Add Visualization**, choose the Gauge component.
3. Set the **Data Source** to PostgreSQL (TimeScaleDB), and search for the table corresponding to

   Factory/ShopA/Line1/OEE/RealOEE
4. Configure visual style, color, and thresholds as needed.
5. Similarly, add separate gauges for A, P, and Q.



To enhance monitoring, you can also add a **time-series visualization**:

1. Choose the **Time-Series** component.
2. Display real-time trends of A, P, and Q in a single chart using their respective data tables.



5.2 Rebuilding The Use Case Yourself

Step-By-Step Guide: AGV Auto-Scheduling With Factory Agent

Step1

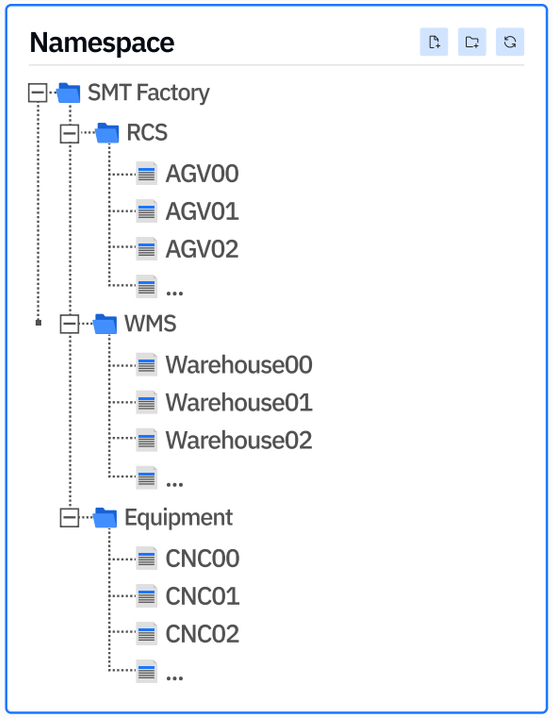
Define The Data Structure In UNS

Tier0-Edge Module: UNS

RCS – For AGV dispatching

WMS – For monitoring available inventory space

CNC – For retrieving production line status from MES production data

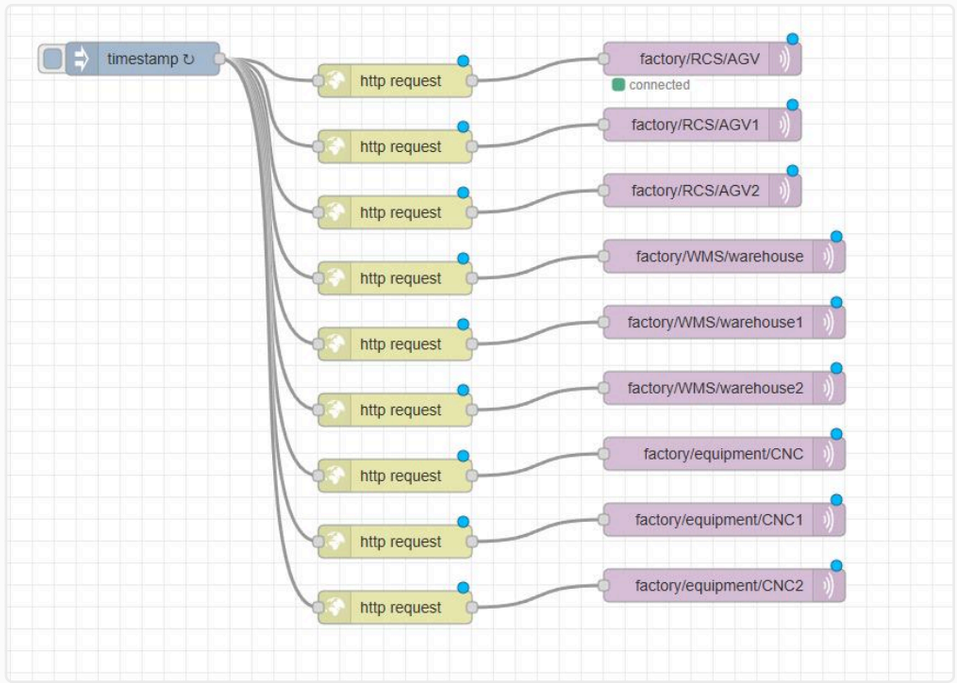


Step2

Connect Data Sources

Source Flow

Connect the APIs to get data from each system, and sends its result to a corresponding UNS MQTT Out node.



5.2 Rebuilding The Use Case Yourself

Step-By-Step Guide: AGV Auto-Scheduling With Factory Agent

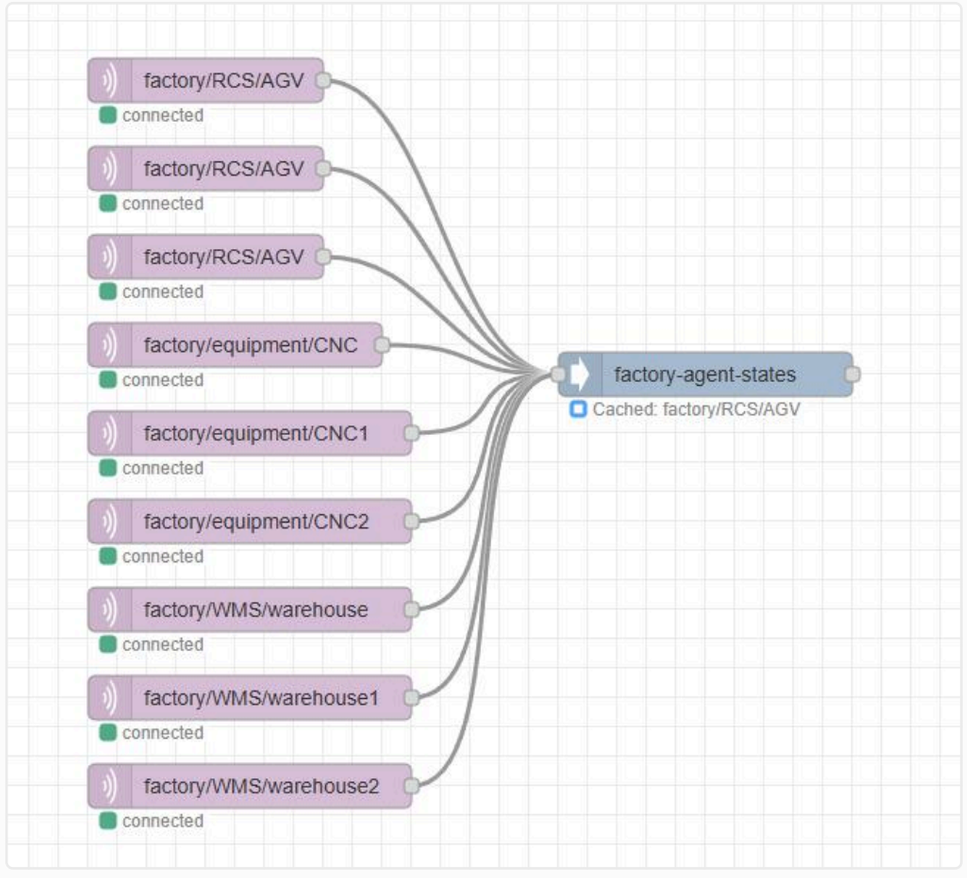
Step3.1-3.2

Build The Event-Driven Logic With Factory Agent

Event Flow

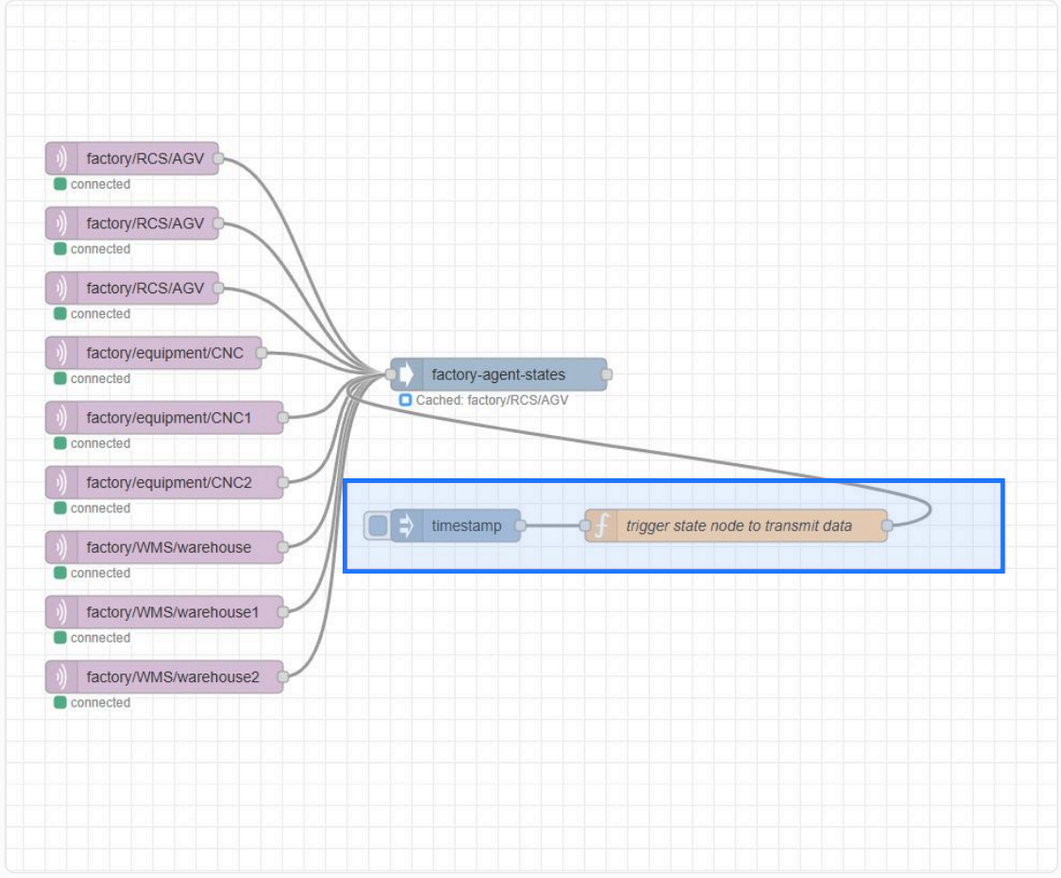
1. Aggregate Real-Time Equipment Data

Connect all AGVs, CNCs and warehouses data to the factory-agent-states node.



2. Define Trigger Conditions For Agent Execution

Use a function node to trigger factory-agent-states pass data onward.



Note: Factory-Agent-States is a proprietary AI Agent Node developed by FREEZONEX, designed for data aggregation and prompt input.

5.2 Rebuilding The Use Case Yourself

Step-By-Step Guide: AGV Auto-Scheduling With Factory Agent

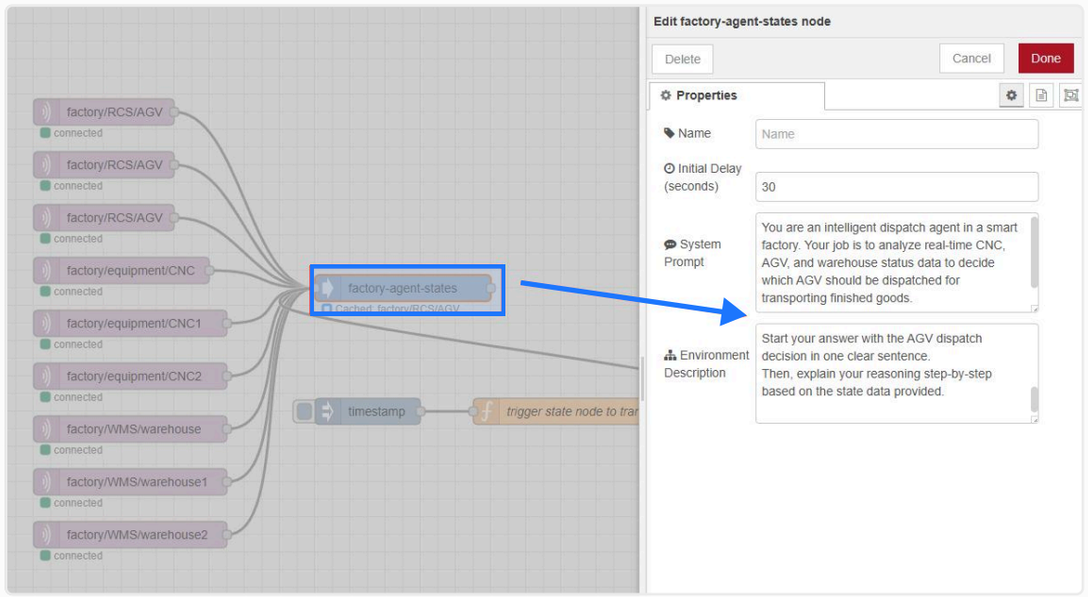
Step3.3

Build The Event-Driven Logic With Factory Agent

Event Flow

3. Configure AI Agent Prompt For Intelligent Dispatching

Configure AI Agent Prompt for Intelligent Dispatching



Try entering the prompt below:

- **System Prompt:**

> You are an intelligent dispatch agent in a smart factory. Your job is to analyze real-time CNC, AGV, and warehouse status data to decide which AGV should be dispatched for transporting finished goods.

- **Env Description:**

> If any CNC machine reports a status of "complete", you must select the most suitable AGV to pick up the product and deliver it to an available warehouse location.
>
> AGVs should be selected based on:
>
> - Their availability (must be in "idle" state)
> - Sufficient battery level (above 20%)
> - Proximity to the target warehouse (similar position codes preferred)
> - Avoid selecting AGVs that are in "error" or "in task" states
>
> Start your answer with the AGV dispatch decision in one clear sentence.
> Then, explain your reasoning step-by-step based on the state data provided.

5.2 Rebuilding The Use Case Yourself

Step-By-Step Guide: AGV Auto-Scheduling With Factory Agent

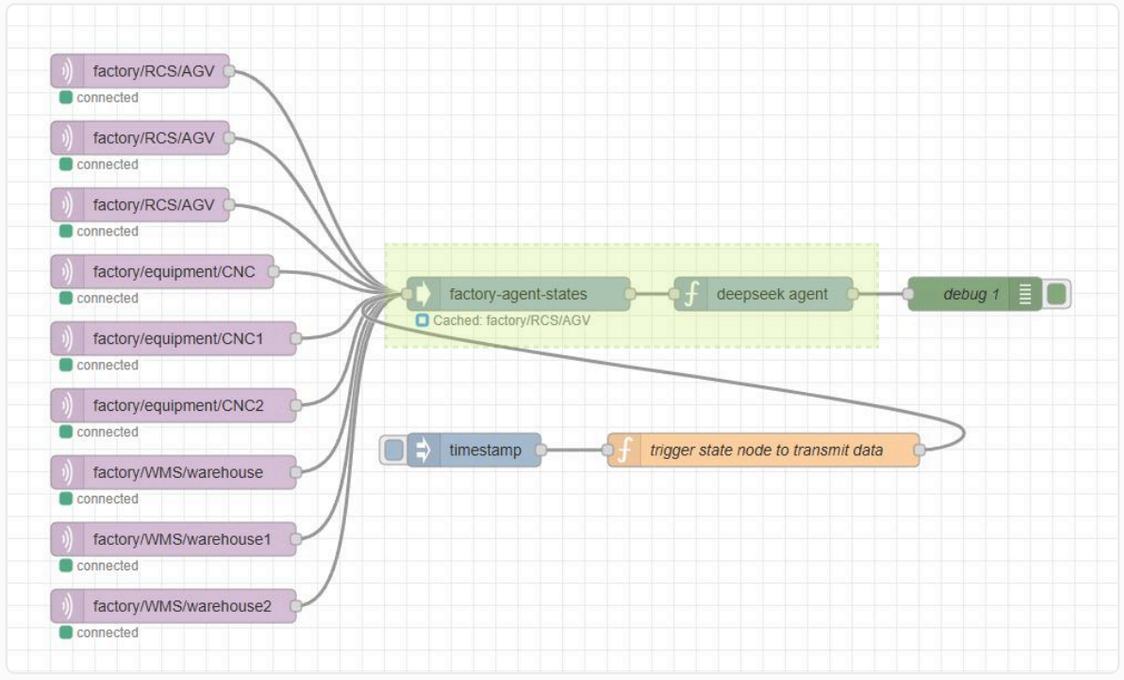
Step3.4

Build The Event-Driven Logic With Factory Agent

Event Flow

4. Connect AI Dispatch Node

Connect the AI node (here we use the **factory-agent-deepssek node**) to analyze and dispatch AGVs for product pickup and delivery.



Note: For more details on our custom nodes Factory-Agent-States and DeepSeek Agent used above, please refer to Reference【6】and Reference【7】.

Step4

Receive Real-Time, AI-Generated AGV Dispatch Insights

Receive actionable, step-by-step AGV dispatch insights generated by the AI agent in real time, including both the chosen AGV and a rationale based on current factory conditions.

```
### AGV Dispatch Decision: No AGV is dispatched because no CNC machine
reports a "complete" status requiring product pickup###

Reasoning Step-by-Step

1.**Check CNC machine statuses**
"CNC1": Status is "error"(not complete).
"CNC": Statusis "running"(not complete)
"CNC2": Statusis`"running"`(not complete)

**Conclusion **: The CNC machine has a "complete" status. Since the dispatch
trigger requires a CNC to be "complete," no AGV

2.**Review AGV availability**
(For completeness, though no action is required)
“AGV2”: State is "idle", battery is 34.7%.
“AGV1”: State is "error"(excluded)
“AGV”: State is "error"(excluded).
AGV2 is eligible, but no task exists.

3.**Warehouse status**:
warehouse(location warehouse) and warehouse2(location warehouse1) are "empty" and
"available".
warehouse1(location warehouse4) is "occupied".
-Since no CNC pro...
```

Conclusion

Whether you're building digital twins, deploying Factory Agents, or scaling data-driven operations, Tier0 helps your data do more — driving faster insights, leaner production, and more sustainable outcomes across the shop floor.



Whether you're building digital twins, deploying Factory Agents, or scaling data-driven operations, Tier0 helps your data do more — driving faster insights, leaner production, and more sustainable outcomes across the shop floor.

Reference

【1】 Little, J. D. C. (1961). A Proof for the Queuing Formula: L = λW. Operations Research, 9(3), 383–387.

【2】 George, M. L. (2002). Lean Six Sigma: Combining Six Sigma Quality with Lean Production Speed. McGraw-Hill.

【3】 LNS Research. (2019). The Cost of Not Connecting Industrial Data: Digital Transformation and ROI Gaps in Manufacturing.

【4】Aberdeen Group (2016). The Cost of Downtime: How Manufacturers Can Avoid the High Price of Unplanned Outages.

【5】Deloitte Insights, “The Smart Factory: Responsive, Adaptive, Connected Manufacturing,” 2017.

【6】**factory-agent-states** Node. https://flows.nodered.org/node/factory-agent-states

【7】**factory-agent-deepseek** Node. Node-RED Flows Library. https://flows.nodered.org/node/factory-agent-deepseek

About Tier0

Tier0 is an open-source industrial data platform that helps manufacturers **connect**, **contextualize**, and **act** on factory data in real time.

Built on a **Unified Namespace** (UNS) architecture, it connects fragmented OT and IT systems, enabling engineers, analysts, and AI agents to collaborate on **the single source of truth**.

With Tier0, manufacturers can **accelerate digital transformation**—from real-time monitoring to predictive maintenance and AI scheduling—faster, smarter, and at scale.

Follow us for the latest updates and insights:



©2025 FREEZONEX All rights reserved