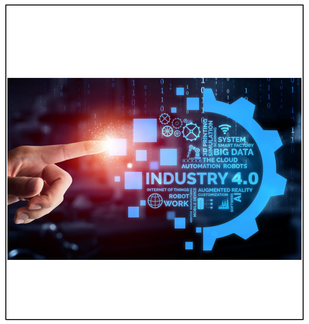
Tech Expo, Fall 2025 – Team 3

Dudley Smart Factory

Team: Spencer Didat, Yiming Xu, Pierce Finnerty, Nikhil Modi

Mentors: James Condron and Stephen Musick



Problem Statement

The skateboard production line in Bay 3030 of Purdue's Dudley Smart Lab experiences unplanned downtime, high failure rates, and minimal visibility into equipment health. Current maintenance processes are reactive and provide no early warning of failures. Our team is developing a predictive maintenance system using IoT sensors, Kepware, AWS cloud services, and AI-driven analytics to collect live machine data, identify failure patterns, detect anomalies, and generate actionable maintenance insights. This improves operational efficiency, reduces downtime, and extends equipment lifespan.

Customer Background

Purdue's Smart Factory is a teaching and research facility that uses autonomous systems, cobots, and Industry 4.0 technologies to assemble skateboard components across a series of production bays.
Bay 3030 currently offers limited machine visibility: no real-time sensing, lengthy troubleshooting, high failure rates, and only simple pass/fail quality checks. By introducing structured data collection, cloud analytics, and AI-assisted interpretation, Bay 3030 can shift from guess-based troubleshooting to data-driven decision making.

Requirements

- Collect quantitative, real-time data from Bay 3030's sensors and PLC tags.
- Dashboard must visualize key KPIs clearly and update automatically.
- System must support AI-assisted maintenance recommendations using historical logs.
- Data ingestion must remain stable under continuous, high-volume sensor input.
- Must maintain a reliable connection to Kepware for AWS IoT data transfer.
- Dashboard must refresh at least daily, ideally continuously, for accurate monitoring.

Experimentation and Concepts

We evaluated multiple approaches for improving visibility and maintenance reliability in Bay 3030:

1. Real-Time Process Optimization Tool
Analyzes production flow to reduce bottlenecks using cycle time, run-time, and part-per-hour metrics from QuickSight.

2. Predictive Maintenance Generator (Selected)
Uses sensor-derived KPIs—such as downtime frequency, fail counts, and efficiency—to forecast mechanical or process failures. This aligns with our dashboard's data structure and produced the strongest reliability improvements.

3. Generative Maintenance Assistant (TROY)
A large language model fine-tuned on Smart Factory Bay 3030 documentation, PLC tag lists, maintenance logs, and operating procedures.
TROY can answer operator questions, explain anomalies detected in the dashboard, and assist with forecasting downtime or part failures.

We selected concepts **2 + 3** for implementation because they support predictive analytics and provide real-time operator assistance.

Final Design

IoT → Cloud Pipeline

Kepware streams PLC and sensor data into AWS IoT Core, where it is routed to Amazon S3 and visualized through a live QuickSight dashboard. This provides continuous monitoring of Bay 3030 machine activity and performance.

Dashboard KPIs

The dashboard displays real-time production metrics including run time, downtime, throughput, reject rate, and overall efficiency. Additional trend visualizations—such as fail-to-good ratios, downtime percentages, and parts-per-cycle behavior—help identify performance shifts and potential anomalies.

AI Assistant (TROY)

TROY is a fine-tuned AI model trained on Smart Factory documentation, maintenance logs, PLC tag definitions, and Bay 3030 operational behavior.
It can:

- Interpret dashboard metrics and explain trends in clear, operator-focused language
- Diagnose likely causes of downtime or efficiency loss
- Forecast failures based on patterns in throughput, reject rate, and cycle behavior
- Answer domain-specific questions about machines, sensors, and historical performance
- Support students and operators with step-by-step troubleshooting guidance

Outcome

A unified predictive maintenance system that delivers real-time visibility, early anomaly detection, and AI-supported diagnostics, improving overall operational reliability for Bay 3030.

Testing and Results (Dashboard)

Dashboard Testing

- Validated PLC → Kepware → IoT Core → S3 → QuickSight data accuracy
- Confirmed acceptable event-to-dashboard latency
- Demonstrated stable MQTT transmission with no packet loss
- KPI trend lines matched expected machine behavior

AI Assistant (TROY) Testing

- Identified likely causes of downtime using historical data
- Produced forecasts for fail-rate and performance trends
- Interpreted dashboard metrics in operator-friendly language
- Answered domain-specific questions about Bay 3030 operations

Outcome

- Real-time visibility into Bay 3030 production health
- Automated interpretation of complex sensor and KPI data
- Early detection of patterns indicating potential failures
- AI-supported troubleshooting for operators and students