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Benefits Captured from a Digital Twin Platform with Integrated Machine Learning Capabilities

Speaker: Boyd Finlay, Director of Solutions Engineering, Tignis

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Evolution of Cohu: 50+ Yrs Expertise

~$394M
LTM Revenue (1)

Time to Yield
Customer Value Creation

24,800+
Equipment Installed Base

(1) Last twelve months ending June28, 2025

A Leader in Semiconductor Test & Inspection(2)

Global infrastructure to supply equipment and services optimizing semiconductor manufacturing yield and productivity

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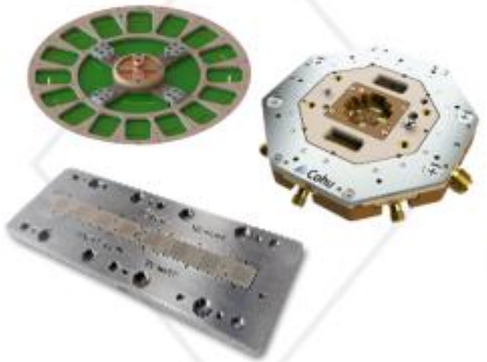
DI-Core
DATA INTELLIGENCE SYSTEM



Test Automation | Inspection

Thermal control and vision inspection technologies enabling higher yield

Services(1)

Device applications, spares, data analytics

Test Interface

High current MEMS interface architecture

Semi Tester

Compact, low-power, scalable instruments

Recurring Business

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(1) *Service business of Cohu systems.*
(2) *Based on Company estimates of addressable markets.*

Content

1. Legacy Problems
2. Data Frameworks Readiness
3. The Knock-on Effects
4. Process & Equipment Digital Twin Defined
5. PAICe Monitor® System Design
6. Answers with Validation
7. Roadmap?

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Ongoing Business Problems

- **Factory Engineering Teams**
  - Scrap / Yield Excursions
  - Cost of Ownership challenges
  - Suppressed OEE

Quality, Cost & Delivery is modulated by Tools with Problems

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- **Factory Engineering Teams**
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Quality, Cost & Delivery is modulated by Tools with Problems

- **Factory Systems Teams**
  - Many factory systems, priority is sustaining ‘automation’
  - Systems obsolescence → emergence of new data/technology stacks
  - Emerging security requirements e.g. SEMI standards
  - Opportunities to automate human workflows → improve productivity

Process Automations & Smarter Human workflows

NET: Factory Teams must continually adopt ‘Smarter System Solutions’ to mitigate business impact.

Well Discussed Engineering Problems

- Thousands of sensors, instruments, gauges / many tools!
- Missing data! Inaccessible Log-files and a lack of high-speed signals
- ML is still being done someplace else *by someone else who doesn't know the tool*
- Equipment designs are still using data repositories designed in the 1990's
- 'Surprise' Yield events keep happening on long-tail equipment failures

NET: Equipment Data Systems are not 'Designed for AI'

ingest > store + contextualize > (assist) > query / compute / visualize > (assist)

What Are We Going To Do Differently?

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Data Frameworks Readiness (summarized)

Equipment Data	Work-in-Progress Data	Equipment History Data	Measurement Data
• Sensor Traces • Instrument Spectra • Log-files • Tool Alarms • Sequencer Events • Equipment Constants • Sub-Fab • Etc.	• Tech ID • Product ID • Route ID • Layer ID • Oper ID • Recipe ID • Etc.	• Work Request # • Work Order # • Part # • Component Serial # • Technician Comments • Fault Codes • Etc.	• Metrology • Inspection • WET • Sort • Burn-in • Final Test • Etc.

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Multiple Systems 'Legacy Problem'	Host MES 'Framework'	Host CMMS 'Framework'	Host SPC 'Framework'

Critical Equipment Data
Residing in Siloes

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Multiple Systems
'Legacy Problem'

Critical Equipment Data
Residing in Siloes

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Host MES
'Framework'

Host CMMS
'Framework'

Host SPC
'Framework'

Critical Process Context
is not embedded with all the Equipment Data over Maintenance Lifetimes (>3-7 years)

The Knock-On Effects?

Factory Workflows e.g.	Time to Set-up	Why?
Setting-up Tool Data Collection	Months to Years	Manually intensive work
Create FDC models on all Full Traces	Years (programs are perpetual)	FDC is mostly scrap driven, reactive and is NOT the same as PdM, **manually intensive work**
Set-up and Manage Tool Alarms	Years (programs are perpetual)	Thousands of alarms, **manual review required**
Maintenance Planning	Rate-based rather than signal based	Reactive, missing instrument health signal
Maintenance Troubleshooting	Hours to Weeks	Not all data is made available or accessible
Yield Troubleshooting	Hours to Weeks	Problem complexity and a lack of tool insights
Engineering Analytics for CIP	Hours to Days	Data siloes; data wrangling & DS support teams

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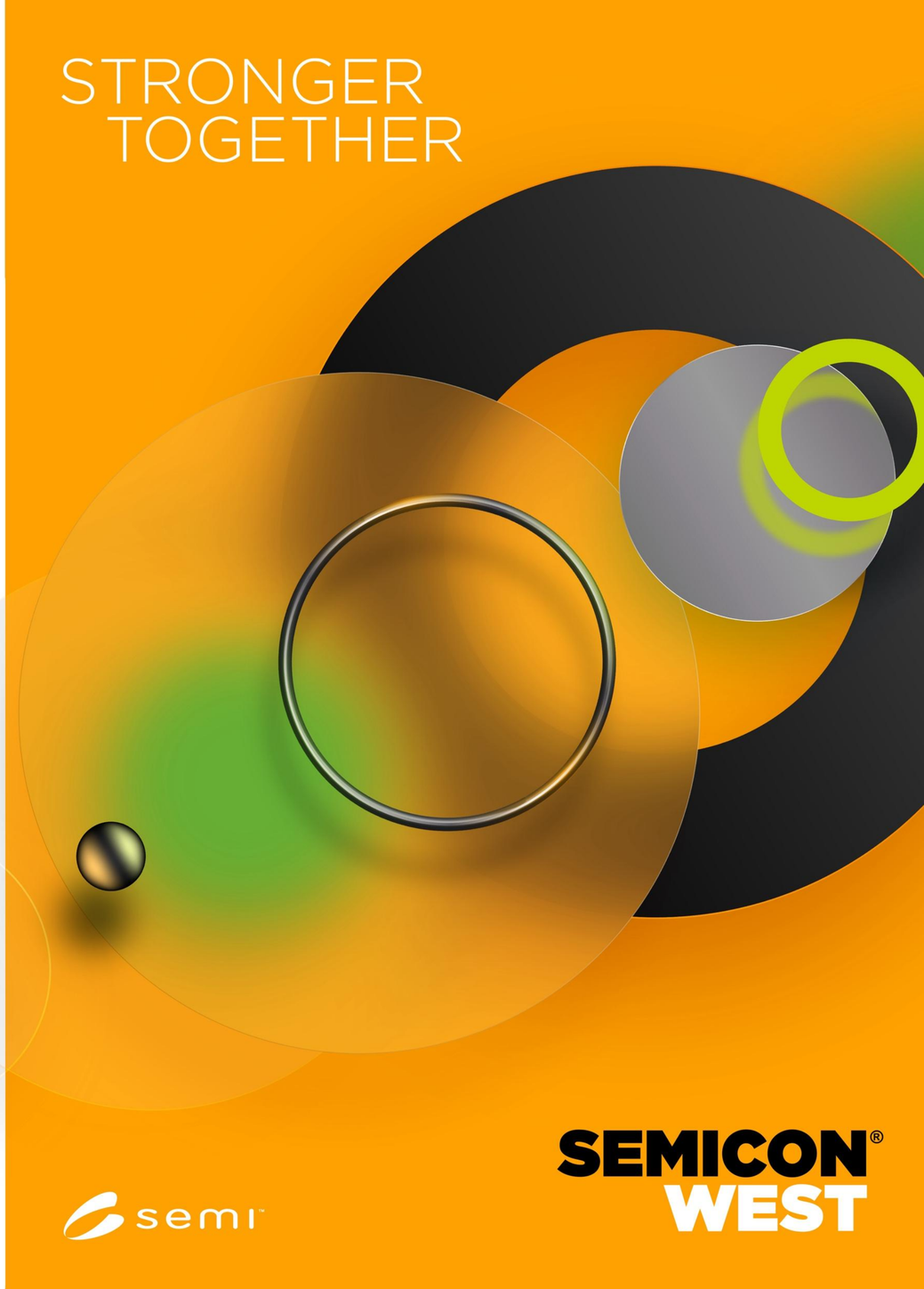
Time = Money (Yield, Rel, OEE, NPI)

Prompt: ***Computer, tell me what's wrong with my problematic tool.***

Assistant: ***I checked all the available data and all the existing analytics. There are no signals observed for the tool at this time. The tool is fine.***



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Assistant: ***I checked all the available data and all the existing analytics. There are no signals observed for the tool at this time. The tool is fine.***

Data Engineer: ***Captain, we didn't design the Equipment Data Framework for this!***

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Process & Equipment Digital Twin Defined

- ✓ A data replica of a processing machine that can be used to model its behavior
- ✓ Ingests real-time streaming data sources from the machine and environment
- ✓ Stores a historical record of fully contextualized process and machine history
- ✓ Comprises an embedded automation layer of insights and visualizations derived from data
- ✓ Reveals answers to an organization to optimize operational & business outcomes
- ✓ Provides feed-back to the Equipment for controls applications

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- ✓ **Is a required capability for AI Assistants**

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System Design

- Context Aware Trace Data + Integrated Query
- Ingestion Layer
- Embedded Automation for Insights/Visualization
- Auto-ML based Answers

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Lots of Data! How Best to Store it?

Technique	Engineering Complexity (Ingest)	Engineering Complexity (Query)	Engineering Maintenance	Storage Footprint	Fast-Query Friendly
Dump Logs to Cloud	Very Low	Very High	Very Low	Very Large	No
Traces in Key-Value Store Events in Relational DB	High	Low	High	Low	Yes
Traces in Key-Value Store Events in Document DB	Medium	Medium	Low	Medium	No
Tignis Records (Hybrid ~~DB~~ Log)	Medium	Low	Low	Very Low	Rapid

Trade Offs! We can query unstructured metadata at relational speeds, but…

- **Storage is immutable. Think logs rather than DB**
- **Metadata must be categorized as one of a few ‘concepts’**
- **As a bonus we save some space!**

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Trace Data Storage (1 Billion Traces)

Storage Type	Footprint
Raw JSON	3.16 TB(1)
Column-Oriented Arrays	1.92 TB
PAICe Monitor® Context-Aware Compression	**120 GB**

(1) Assumes average trace contains ~120 points

MetaData Storage (1 Billion Events)

Storage Type	Footprint	Golden Trace Query(1)
Raw JSON (traces not telemetry!)	340 GB	?(3)
Column-Oriented Arrays(2)	300 GB	40 min(4)
PAICe Monitor® Records(2)	**110 GB**	**150 ms**

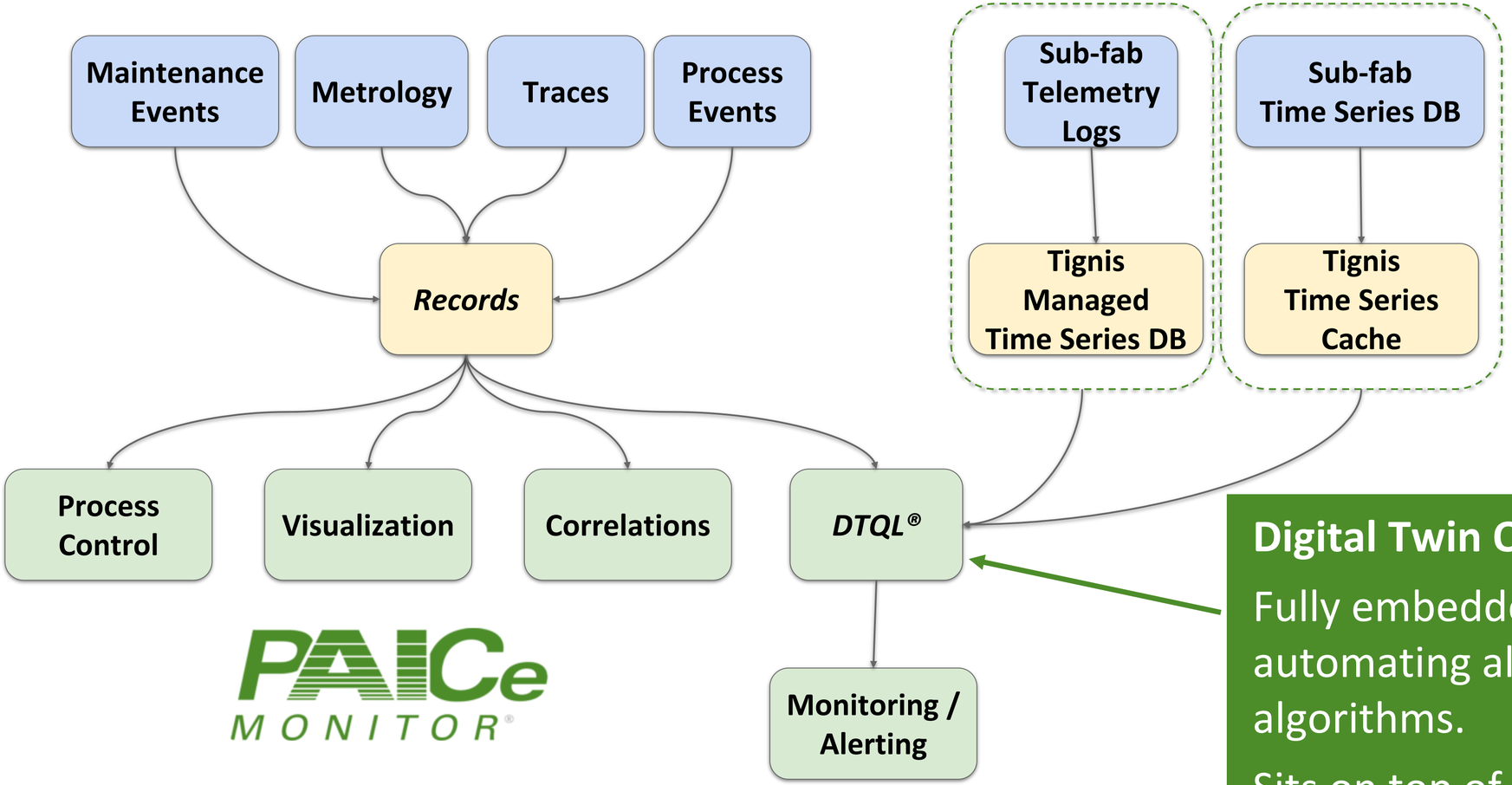
(1) Find a set of related traces for building a golden trace

(2) Single instance (no sharding)

(3) Requires a map-reduce style scan. Will be time consuming.

(4) Full scan required (wildcard indices don't support compound filters)

Data + Context + Query Layer



Digital Twin Query Language:

Fully embedded ‘query’ layer automating all feature extraction & algorithms.

Sits on top of Python and includes DS best practices.

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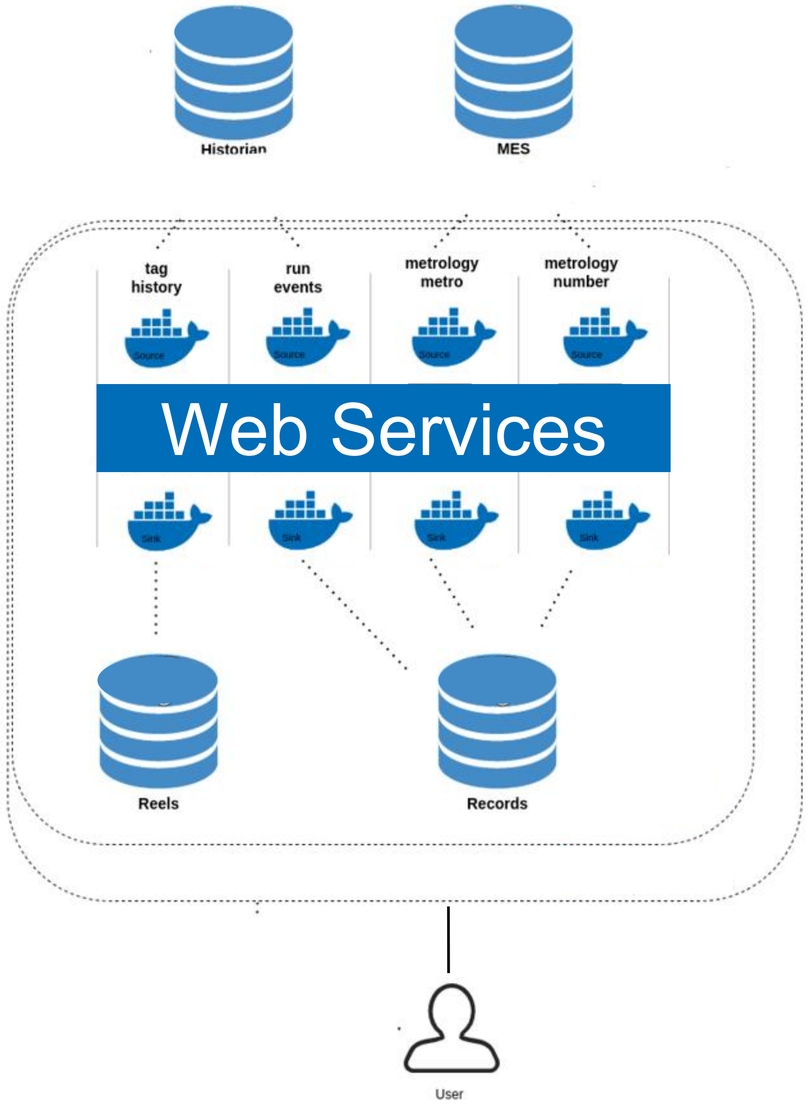
Data Ingestion Layer

- **Reels: real-time ingestion of streaming tool data**
- **Records: a complete historical ‘record’ for a run with all associated metrology and yield data**



Note: Actual ingestion layer at onsemi

Embedded ‘Data Engineering’ Automation

Manual Equipment Workflows	Time to Execute without Digital Twin	Time to Execute with Digital Twin	Why?
Setting-up Tool Data Collection	Months > Years	**Weeks (Cloud or On-Prem)**	Purpose built ingestion scheme
Create FDC models on all Full Traces	Months > Years	**Not required**	**Automated statistical feature extractions**
Set-up and Manage Tool Alarms	Months > Years	**Not required**	**Alarms are now context for tool operation**
Maintenance Planning	Hours (Reactive, Rate-based)	**<1 hr (Predictive, Cond-Based)**	Embedded sensor health features
Maintenance Troubleshooting	Hours > Days	**< 5 minutes**	View thousands of contextualized traces
Yield Troubleshooting	Hours > Days	**< 5 minutes**	Auto-ML provides multivariate signals
Engineering Analytics for CIP	Hours > Days	**< 5 minutes**	Auto-ML + Tignis Templates

Auto-ML Incorporates Automated Data Science & ML-Ops Best Known Practices

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Auto-ML ‘Answers’ with SME Validation

Auto-ML Correlation Answers	Time to Insight With Digital Twin Deployed	Time to Insight Without Digital Twin	Validation by onsemi team
Insight 1 ‘Component’	**<5 minutes**	Weeks	Mismatched component, confirmed
Insight 2 ‘Metrology’	**<5 minutes**	Not observed	New insight, confirms theory
Insight 3 ‘Materials’	**<5 minutes**	Months	New insight, confirms theory
Insight 4 ‘Machine’	**<5 minutes**	Not observed	New insight, now being explored
Insight 5 ‘Machine’	**<5 minutes**	Not observed	New insight, now being explored

Auto-ML Correlations using FULLY CONTEXTUALIZED PROCESS & TOOL DATA to predict METROLOGY RESPONSES

Harnessing Regression & Classification capabilities to produce answers faster.

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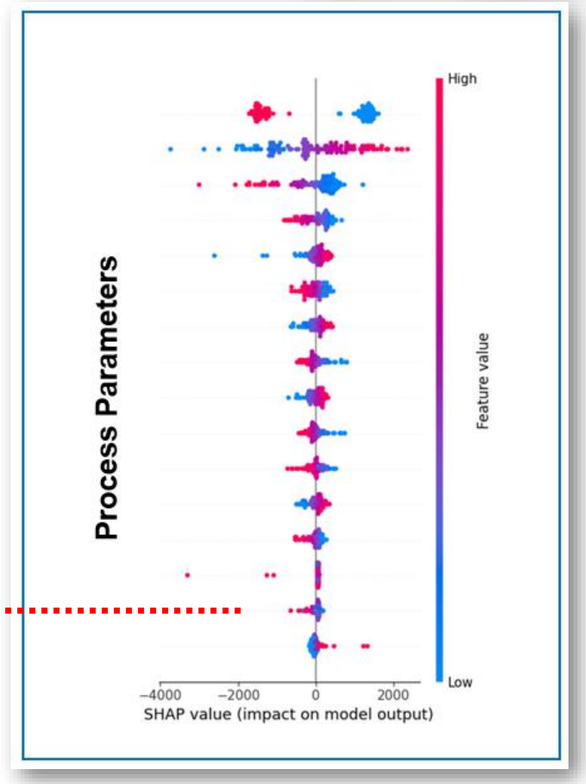
Ex1. Auto-ML revealing Trace Data Insights



Note: SHAP Value = Explanation of ML model feature importance

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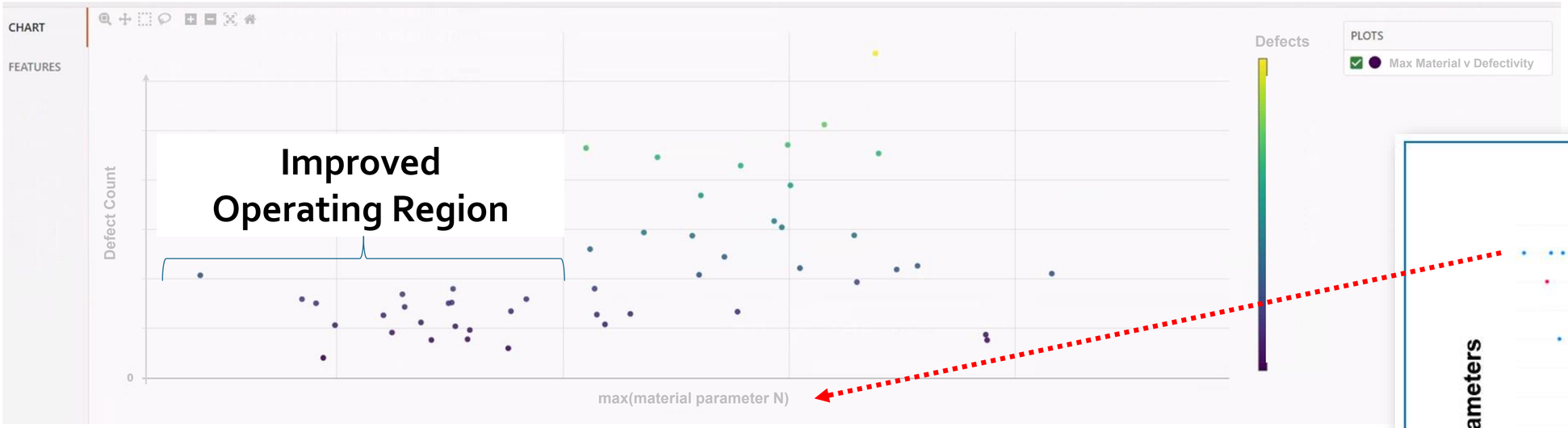
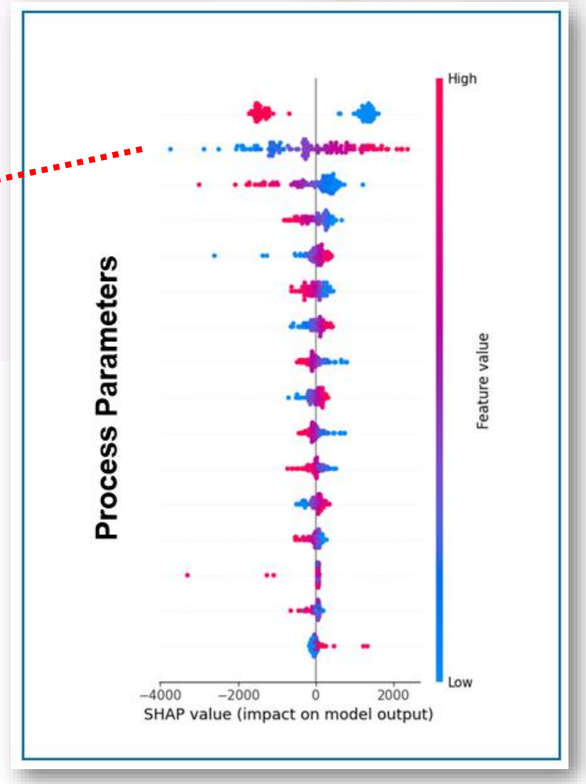
Ex2. Auto-ML revealing Materials Insights





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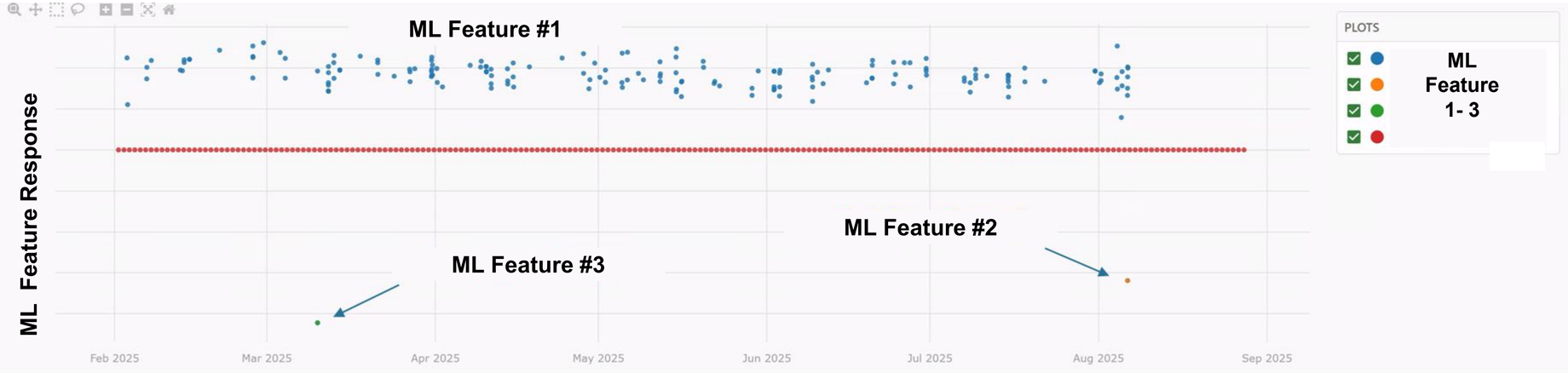
Ex3. Auto-ML enabling Predictive & Explainable Process Monitoring



- ✓ *ML Feature #1 is validated 'Healthy Process'*
- ✓ *ML Features #2 & #3 are predicting different assignable processing problems*

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Project Summary

- New Digital Twin Data Ingestion: 8 weeks!
- Several New Insights Gained: < 5 minutes!
- Engineering Hunches Validated: < 5 minutes!
- Benefits?
  - ✓ ***Faster ML based Answers***
  - ✓ ***Improved MTTD***
  - ✓ ***Better ROI than legacy system design methods***

Digital Twin Roadmap Drivers

- New Processes
- Existing Tools with Problems
- **Capture of Long-Tail Equipment Failures**
  - *Requires improved Data Layer Design for Query, Compute, & Visualization speeds !*
- **Best in Class AI Assistants require the Right Answers at the Right Time**

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Thank you

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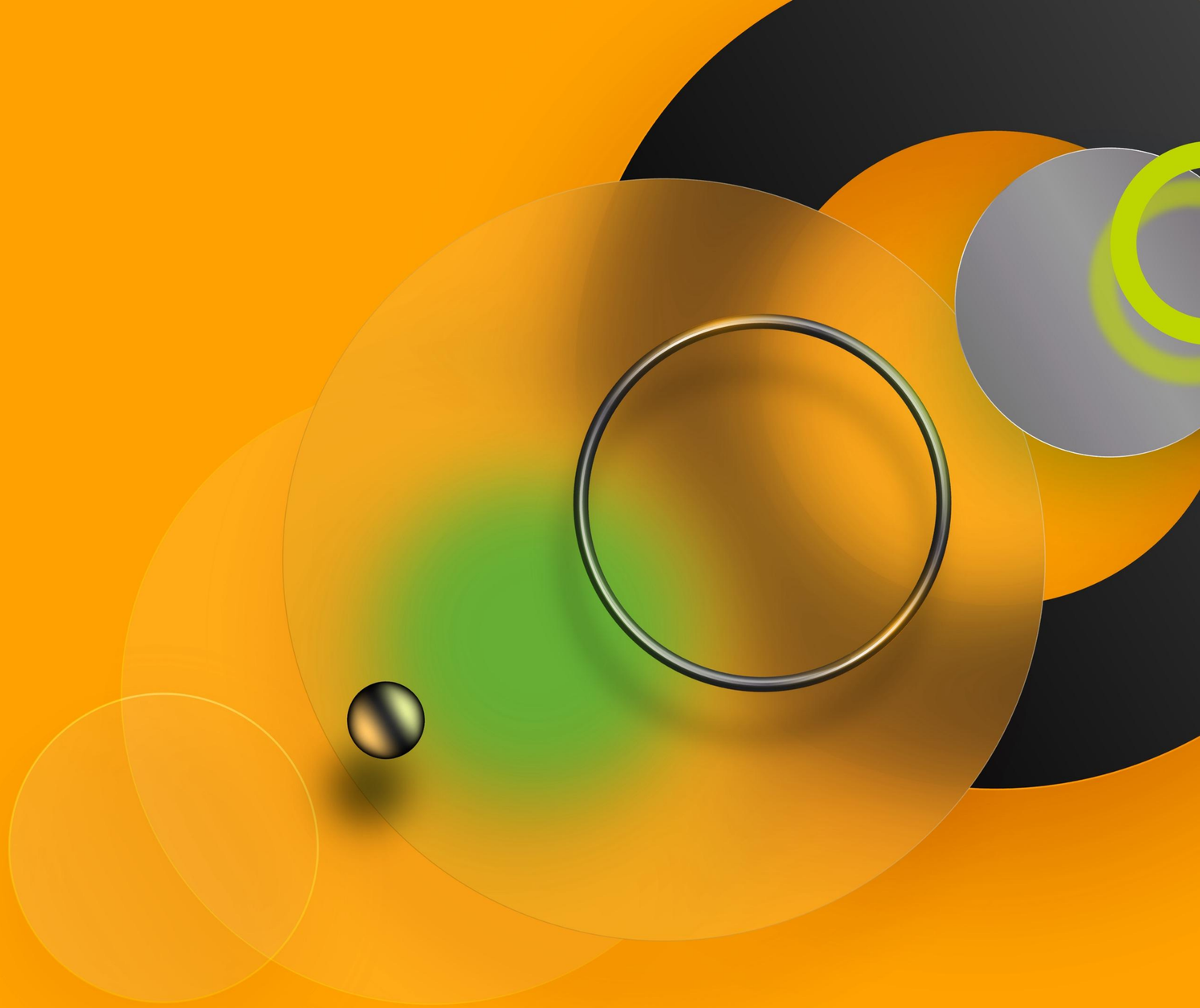

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