KEYSIGHT WORLD 2019

Deploying Data Analytics in the Smart Manufacturing

SAP Account manager/ Keysight Technologies

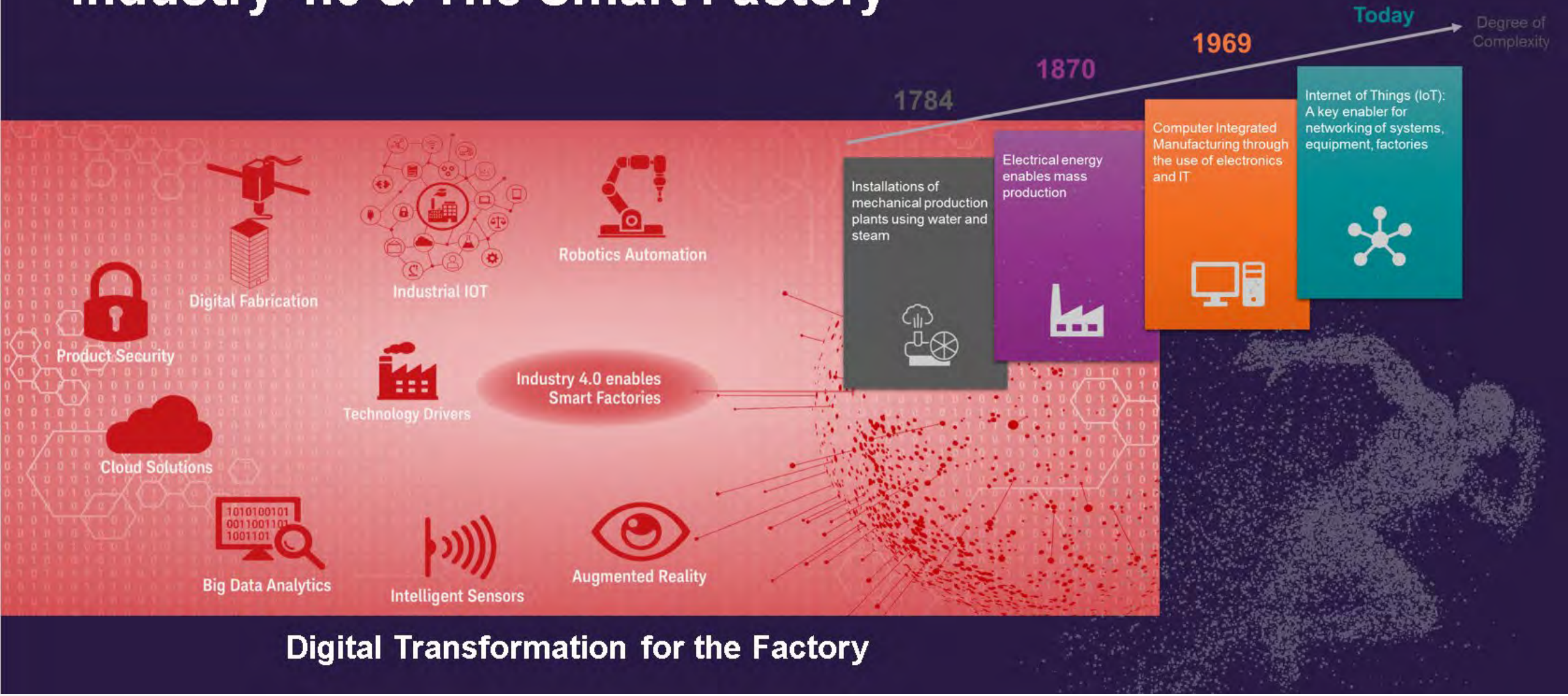
Robin Tan

Forward-Looking Statements

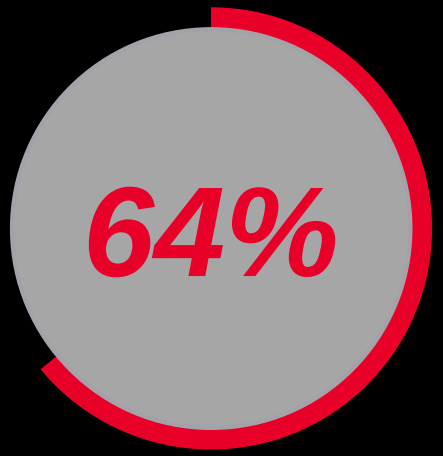
Except for the historical information contained here, many of the matters discussed in this presentation are forward-looking statements, based on expectations at the time they were made, that involve risks and uncertainties that could cause our results to differ materially from those expressed or implied by such statements. These risks are detailed in the “Factors That May Affect Future Results” section of our Form 10-K or Form 10-Q filing. Keysight assumes no obligation to update these forward-looking statements.

In addition, any information about our roadmap and forward looking strategies are a generic representation of our current general direction and is subject to change at any time without notice. Keysight reserves no obligation to incorporate the following information into any contract, features, functionality or any other commitment.

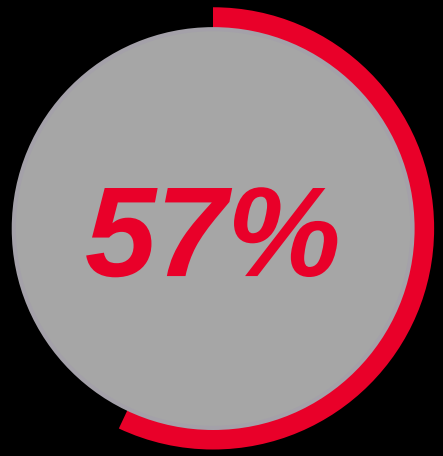
Industry 4.0 & The Smart Factory



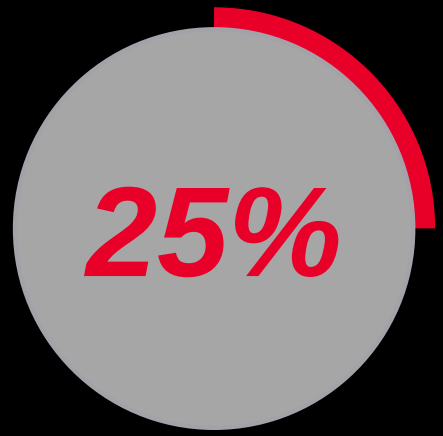
Digital Transformation for the Factory



RELY ON EXPERIENCE TO SOLVE ISSUES



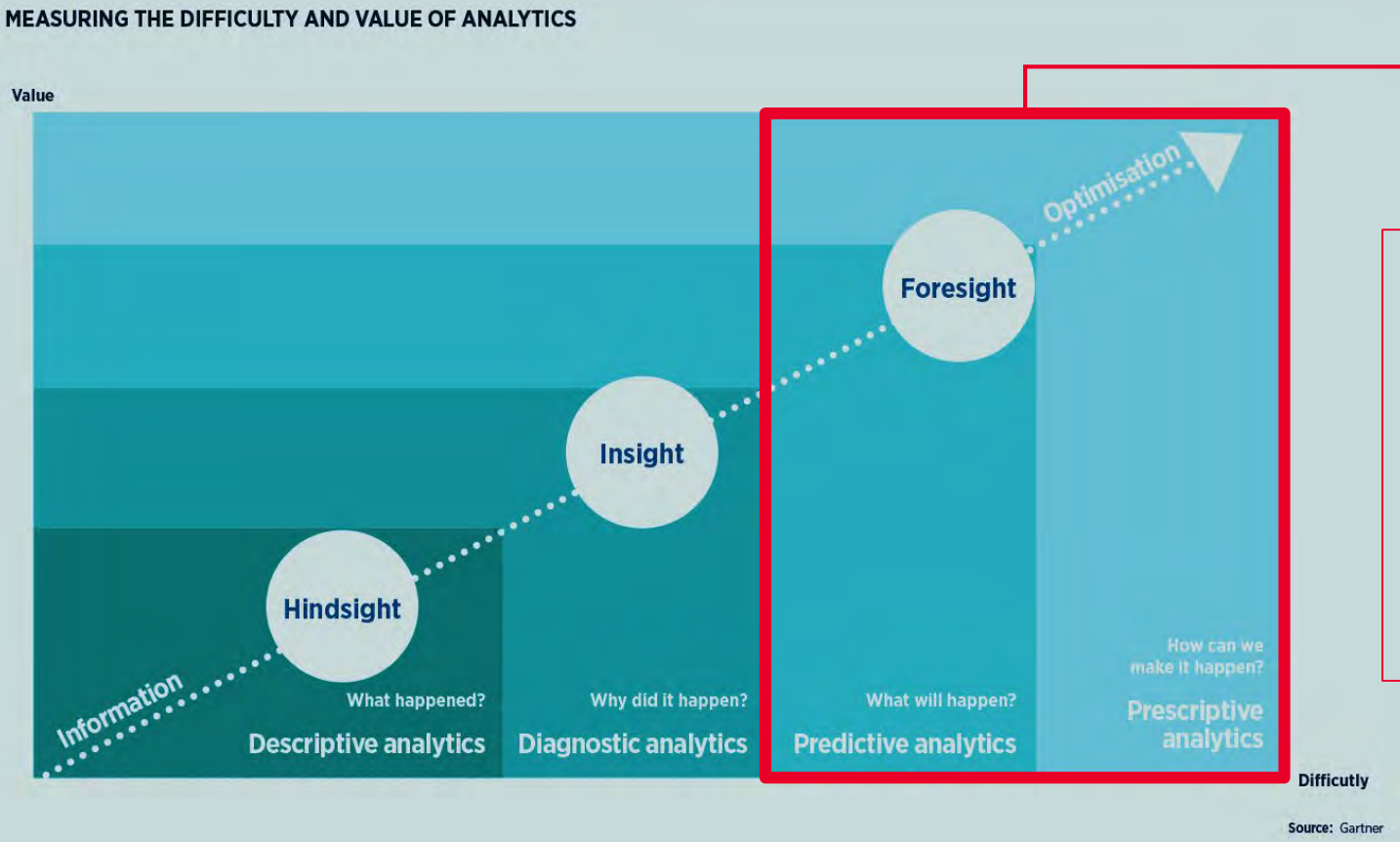
USE DATA FOR PREVENTION



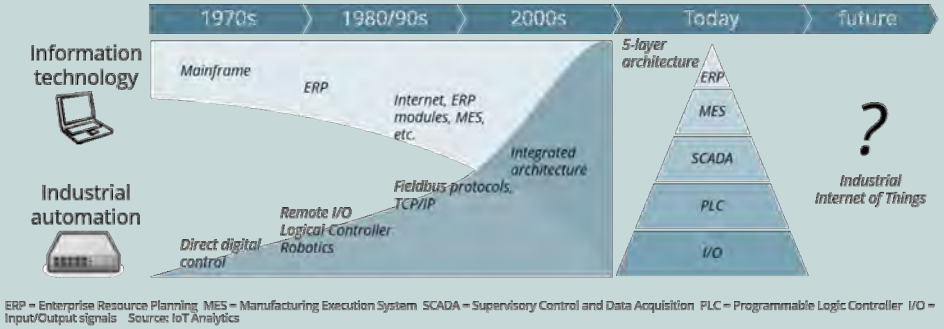
STILL USES EXCEL FOR DATA ANALYSIS

Source: IndustryWeek, MESA, ARC

Advanced Analytics Enables Smart Factory



'Can we do this with what we have now?'



The New Stack

Typical Factory Stack

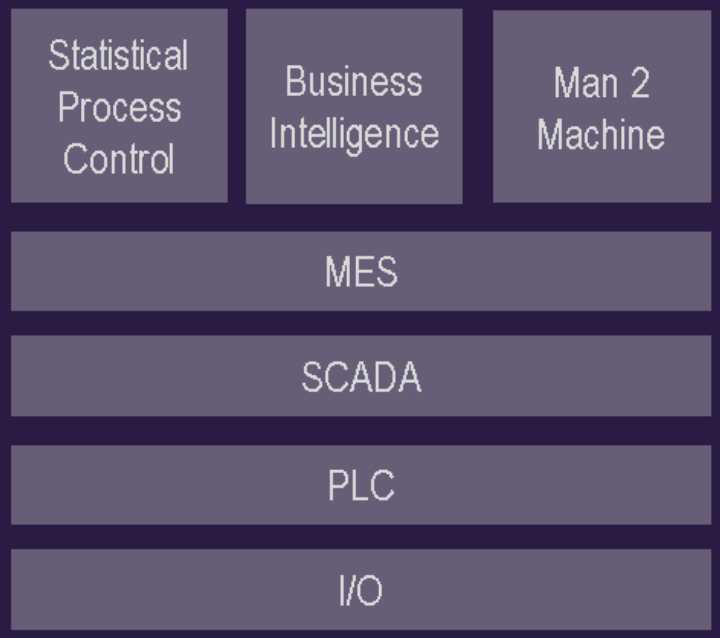
Hierarchical

Reactive

Limited Data Types

Small Data

Selective Consumption



Industry 4.0 *Smart* Factory

High Resolution Data and View

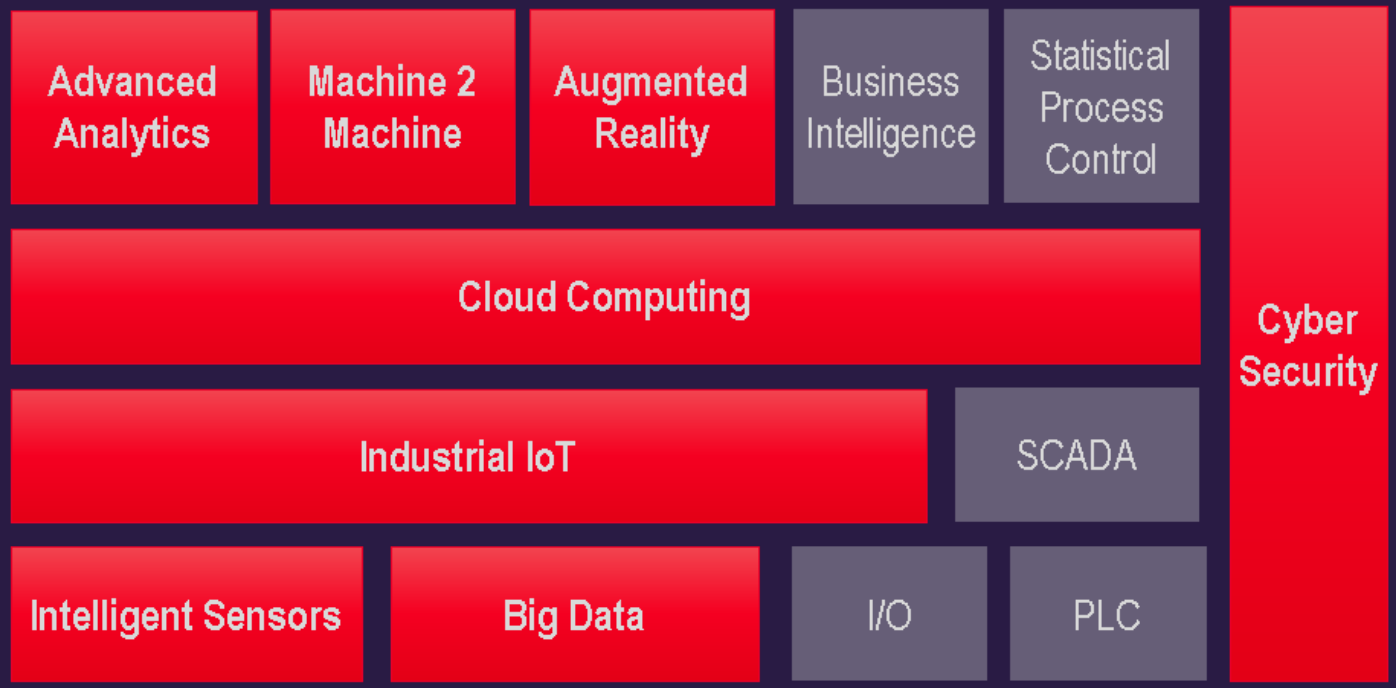
All Level Data Transparency

Real-time & Instant

Built-for-Purpose Intelligence

Multi-Level Easy Consumption

Multi-Level Actionable Insights



Source: IndustryWeek, MESA, ARC

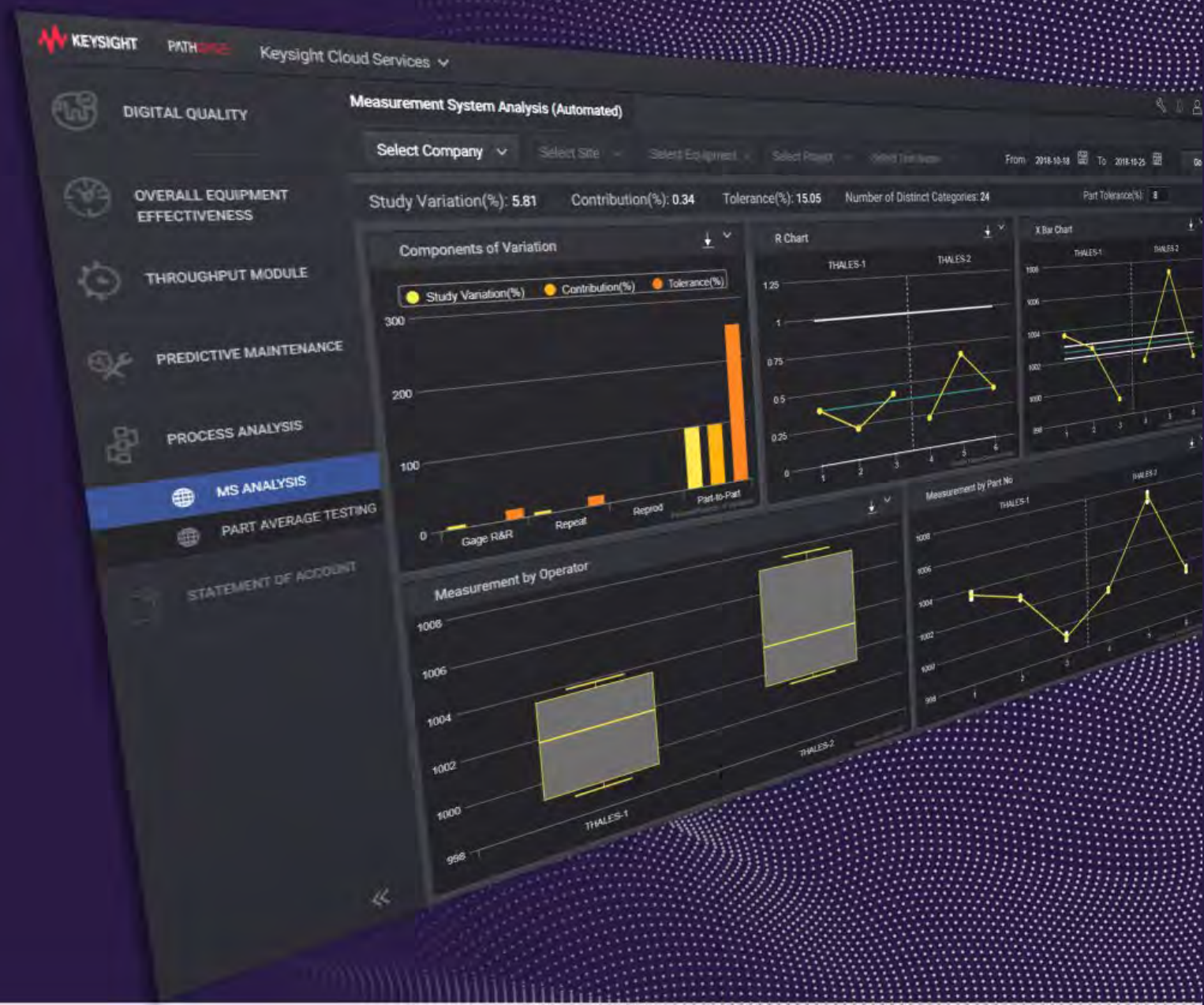
KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Industry 4.0 Strategy

Built on a strong foundation of
Security, Connectivity, Scalability

Automation	Acquisition	Analytics
Productivity	Data Management	Big Data
Asset Utilization	M2M Connectivity	Advance Analytics
Robotics	IIoT Solutions	Machine Learning
A.I.	High Resolution	Deep Learning
Cybersecurity		



The PathWave Platform

Key Customer Benefits

- **Faster Time To Market**
- **Improved Productivity (OEE)**
- **Lower Total Cost of Ownership (TOC)**
- **Lower Cost of Poor Quality (COPQ)**

Keysight Industry 4.0 Strategy

Key Technology Innovations

Automation
Productivity | Asset Utilization | Robotics | A.I. | Cybersecurity

Acquisition
Big Data | M2M Connectivity | IIoT Solutions | High Resolution Data

Analytics
Proactive | Advance Analytics | Machine Learning | Deep Learning

Keysight PathWave Platform

PATHWAVE

- Faster solution development
- Higher performance solutions
- Interoperability across applications

Workflow

Many Plugins & Solutions

A few Environments

One Framework

Open.
PathWave connects and integrates all your design and test resources.

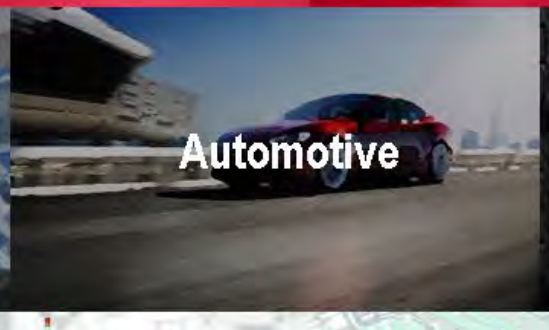
Scalable.
PathWave offers flexible computing power that scales to meet varying workloads

Predictive.
PathWave provides powerful analytics tools for faster troubleshooting.

PATHWAVE

Manufacturing Analytics
Imaging Analytics
Waveform Analytics

Keysight's Industry 4.0 and Industrial IoT big data smart factory enterprise solution that provides real time business intelligence and advanced analytics.



Global Use Cases, Customer Types

Customer Subscribed

11+

Data Ingested

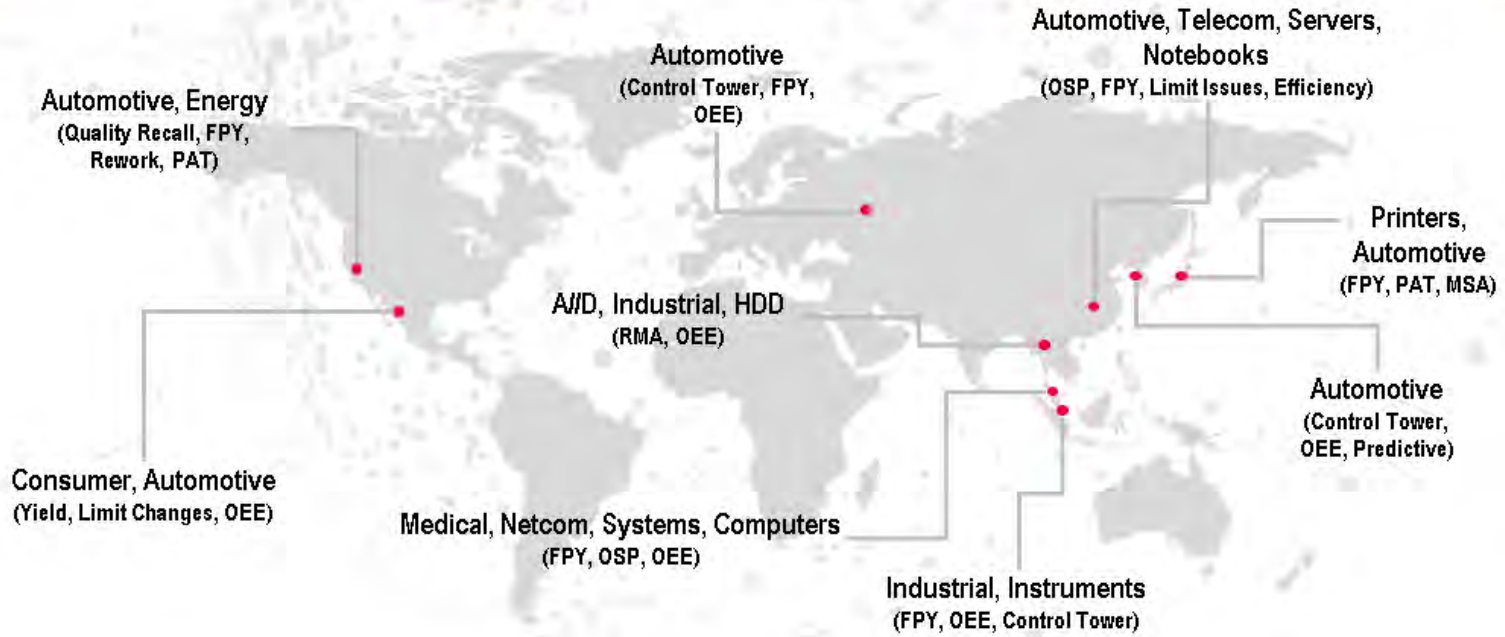
>1TB

Projected Savings

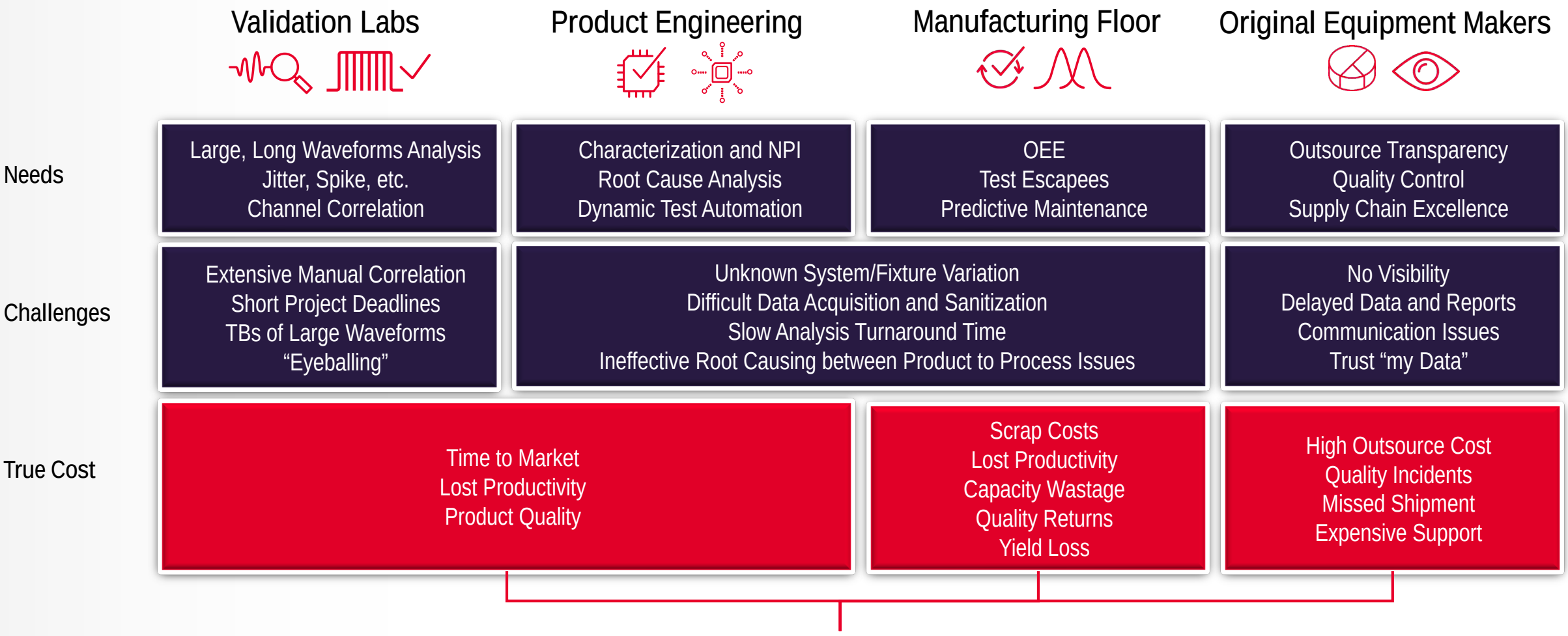
>$10M

Customers Pilots

50+



Example of Application Challenges

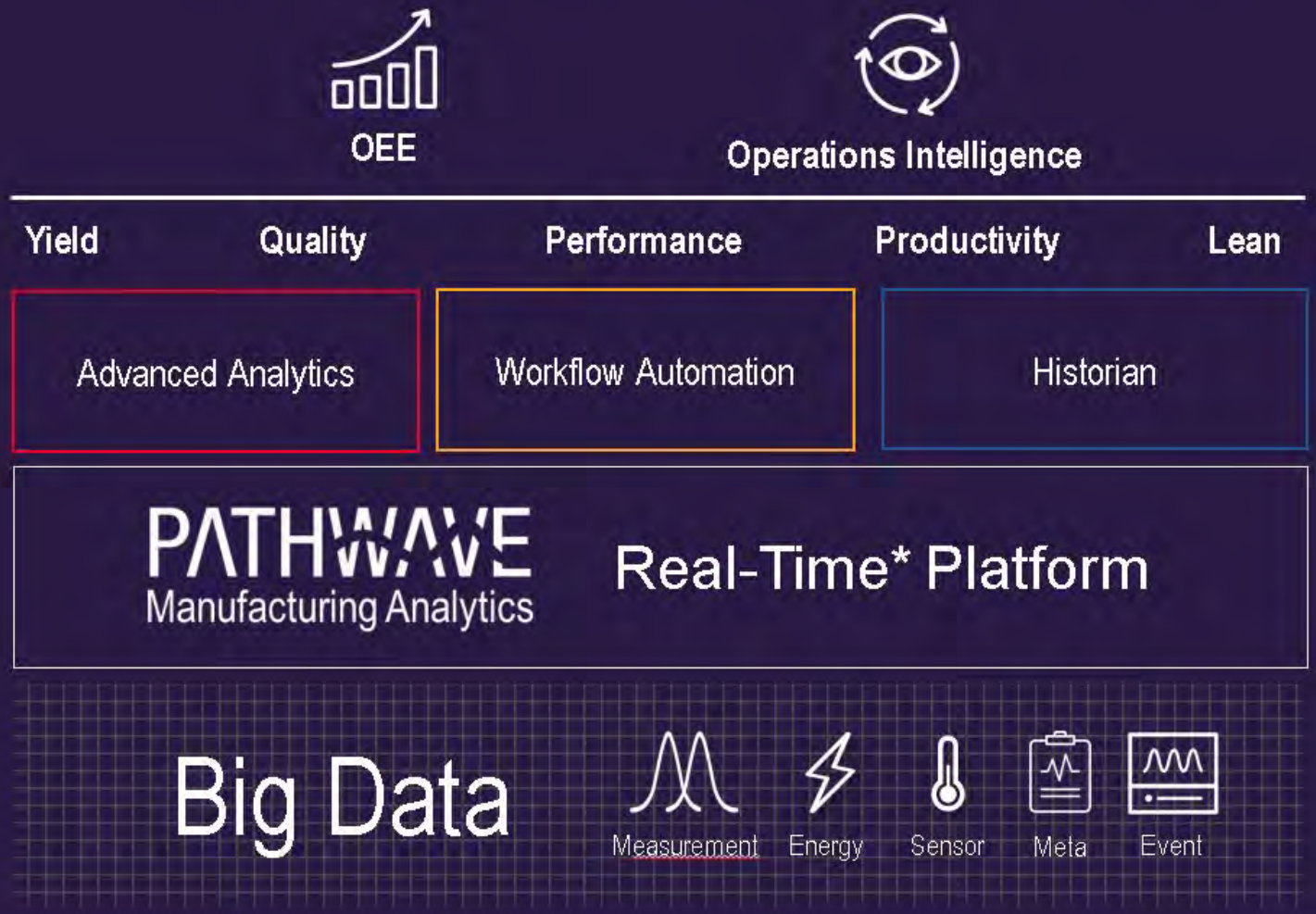


These are very expensive and affects your company’s competitiveness in the market.

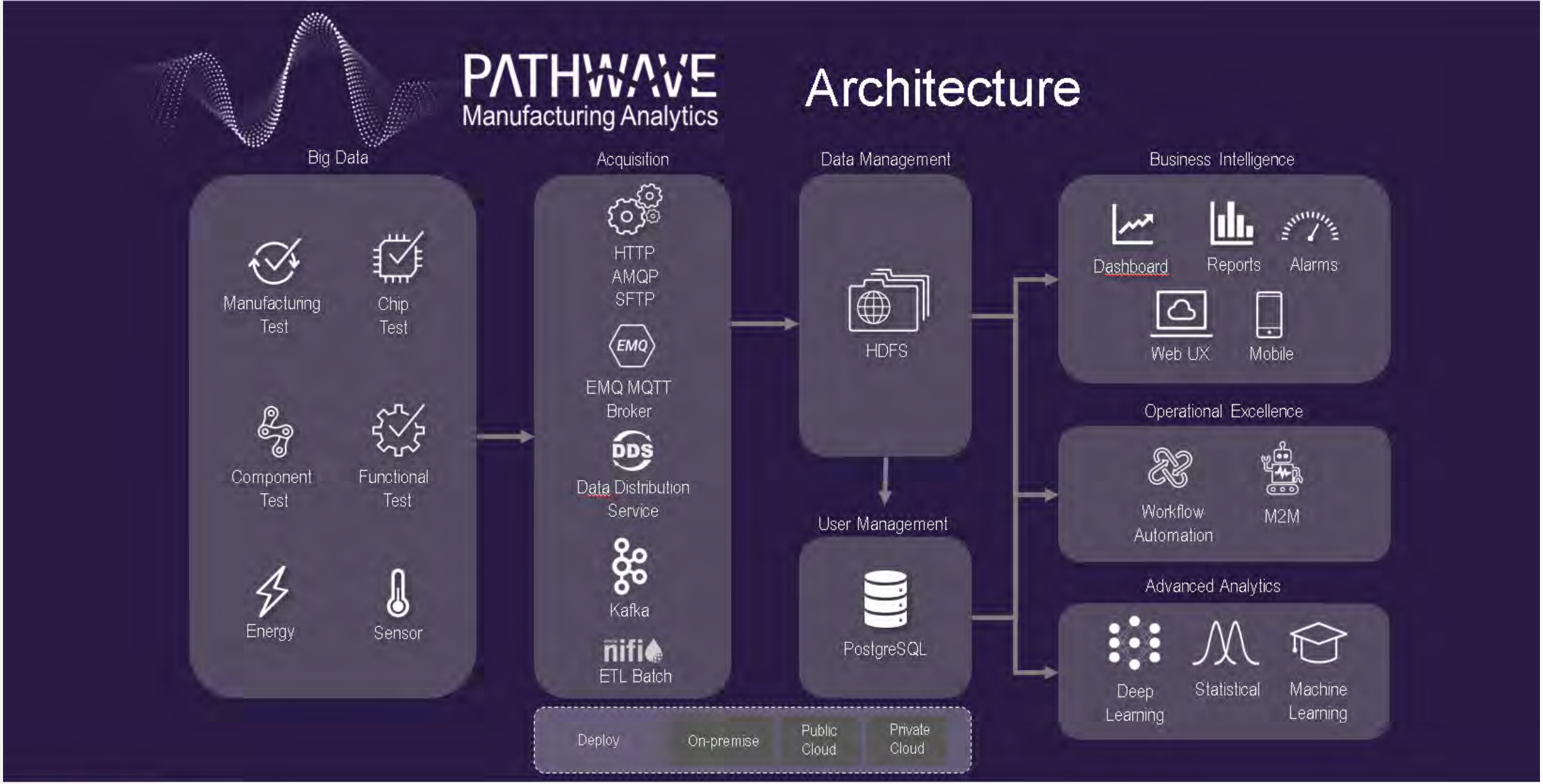
Addressing Applications Challenges with PathWave

	Validation Labs	Product Engineering	Manufacturing Floor	Original Equipment Makers
Needs	Large, Long Waveforms Analysis Jitter, Spike, etc. Channel Correlation	Characterization and NPI Root Cause Analysis Dynamic Test Automation	OEE Test Escapees Predictive Maintenance	Outsource Transparency Quality Control Supply Chain Excellence
Platform	PATHWAVE			
Solution	• Rapid Auto Multi-Channel Correlation to Detect Spike, Jitter, etc. • Efficient waveform data management • Reduced Storage Capacity	• Instant High Resolution Big Data Advanced Analytics • End to End Acquisition, Ingestion and Cloud-Based Stack • Applied Machine Learning • Predictive Anomaly Detection and Classification • Real-time Actionable Insights and User Experience		• Full Global Visibility • OnDemand & Real Time Reports and Alerts • Data Transparency • Trusted Data
Modules	Waveform Analytics	Imaging Analytics Test Automation Platform Manufacturing Analytics		

PathWave for Manufacturing



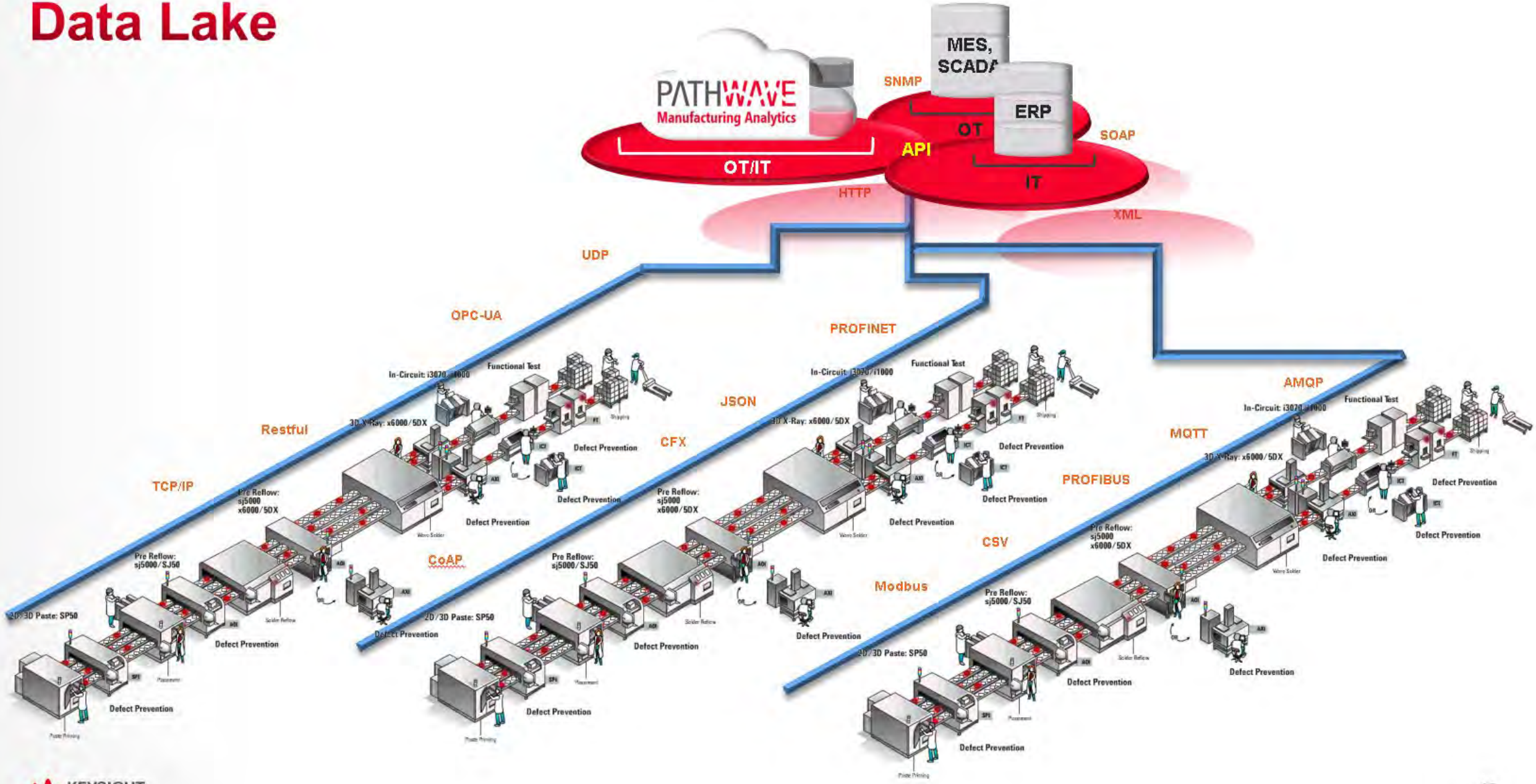
* Pseudo or best cast depending on requirements


PATHWAVE
Manufacturing Analytics
Architecture
Big Data
Manufacturing Test
Chip Test
Component Test
Functional Test
Energy
Sensor
Acquisition
HTTP
AMQP
SFTP
EMQ
EMQ MQTT Broker
DDS
Data Distribution Service
Kafka
nifi
ETL Batch
Data Management
HDFS
User Management
PostgreSQL
Business Intelligence
Dashboard
Reports
Alarms
Web UX
Mobile
Operational Excellence
Workflow Automation
M2M
Advanced Analytics
Deep Learning
Statistical
Machine Learning
Deploy
On-premise
Public Cloud
Private Cloud

Smart Factory Digital Transformation

DATA LAKES AND RIVERS

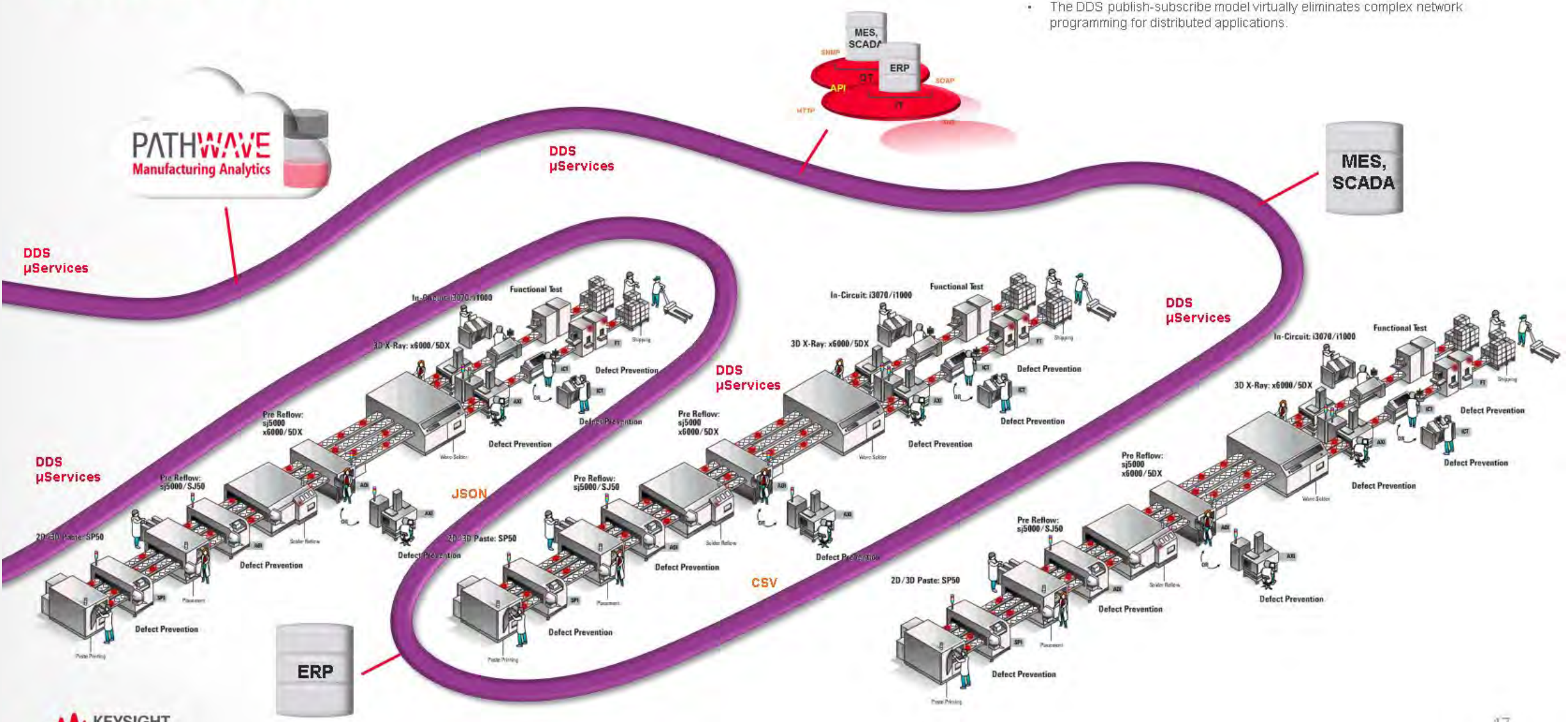
Data Lake


PATHWAVE
Manufacturing Analytics
MES,
SCADA
ERP
SNMP
OT
SOAP
API
OT/IT
IT
HTTP
XML
UDP
OPC-UA
PROFINET
AMQP
JSON
MQTT
Restful
CFX
PROFIBUS
TCP/IP
CSV
CoAP
Modbus
In-Circuit: i3070 / i1000
Functional Test
3D X-Ray: x6000/5DX
Defect Prevention
Pre Reflow:
sj5000
x6000/5DX
Pre Reflow:
sj5000/SJ50
2D/3D Paste: SP50

Data River

Data Distribution Service (DDS)

- Object Management Group (OMG) machine-to-machine standard that is essentially Broker-less.
- Scalable, real-time, dependable, high-performance and interoperable data exchanges using a publish–subscribe pattern.
- The DDS publish-subscribe model virtually eliminates complex network programming for distributed applications.



What is DDS?

Data Distribution Service (DDS)

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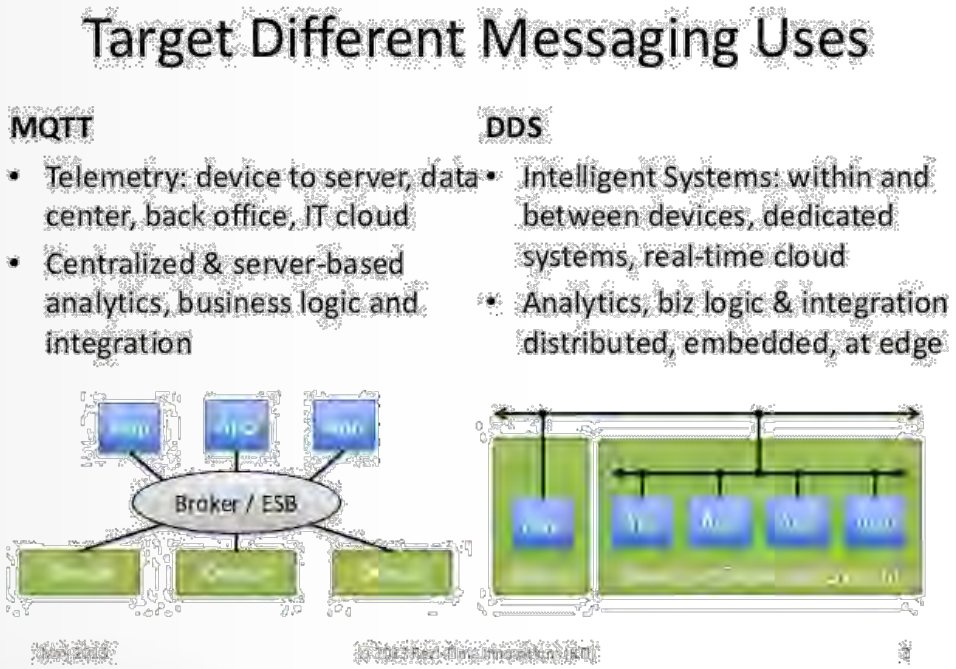
MQTT vs DDS



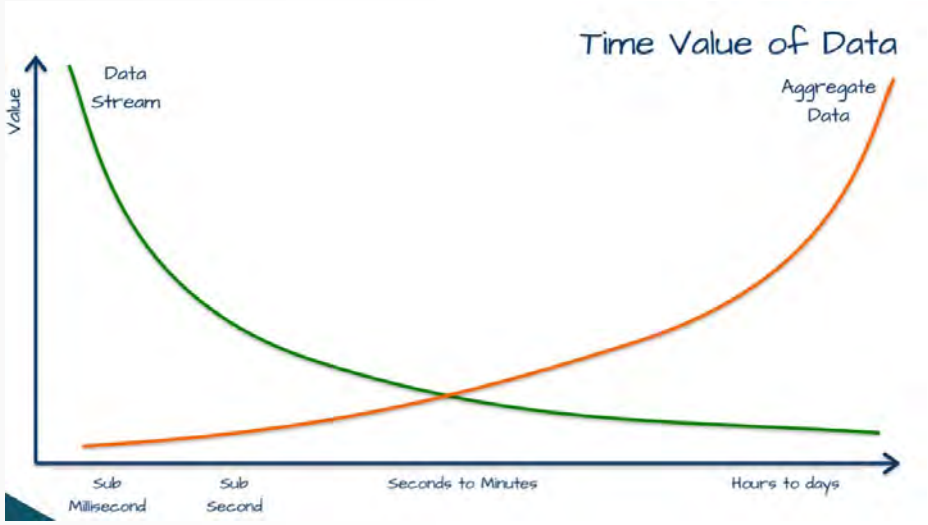
Comparing Protocols

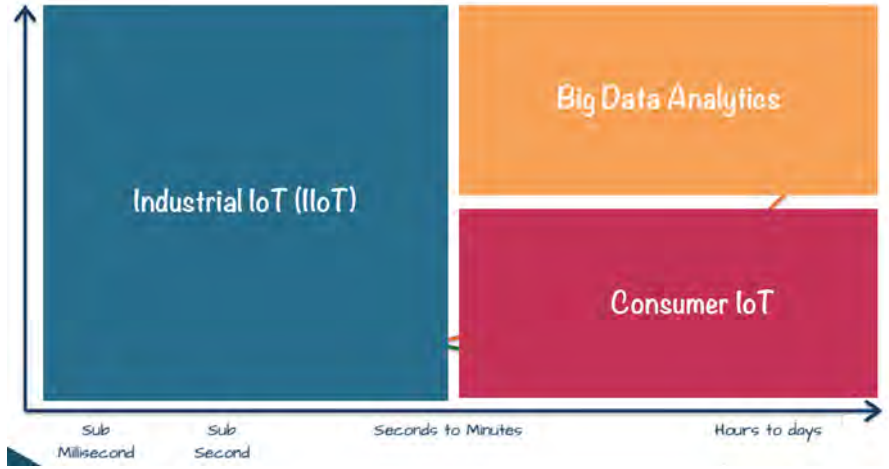
	Transport	Paradigm	Scope	Discovery	Content Awareness	Data Centricity	Security	Data Prioritization	Fault Tolerance
AMQP	TCP/IP	Point-to-Point Message Exchange	D2D D2C C2C	No	None	Encoding	TLS	None	Impl. Specific
CoAP	UDP/IP	Request/ Reply (REST)	D2D	Yes	None	Encoding	DTLS	None	Decentralized
DDS	UDP/IP (unicast + mcast) TCP/IP	Publish/ Subscribe Request/ Reply	D2D D2C C2C	Yes	Content-Based Routing, Queries	Encoding Declaration	TLS, DTLS, DDS Security	Transport Priorities	Decentralized
MQTT	TCP/IP	Publish/ Subscribe	D2C	No	None	Undefined	TLS	None	Broker is the SPoF

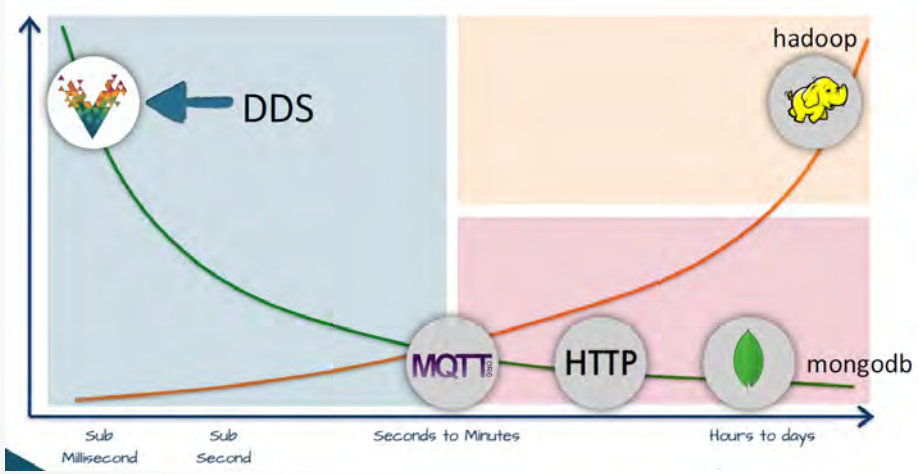
TCP: Transmission Control Protocol IP: Internet Protocol D2D: Device-to-Device D2C: Device-to-Cloud C2C: Cloud-to-Cloud
TLS: Transport Layer Security DTLS: Datagram Transport Layer Security
Qualitative Comparison of IoT Standards

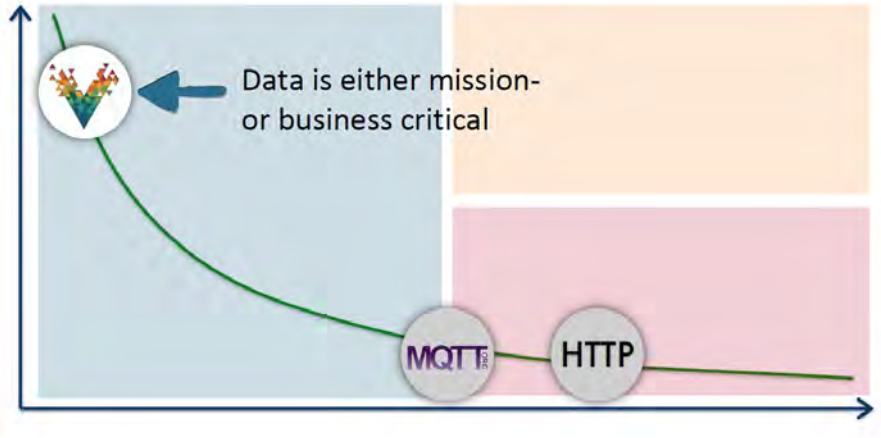
What is DDS?

DATA DISTRIBUTION SERVICE









Smart Factory Digital Transformation

DATA ACQUISTION

PMA Acquisition

ADLINK

DEX-100 *Data Extractor*
- Collect data from any legacy or non-plug/play (brownfield)

MCM-120 16Ch IoT Edge
- Intel Atom® x7-E3950 Processor-Based Machine Condition Monitoring Edge Platform

DEX-200 Legacy PLC
- Domain Ready Data Extraction Platform for Legacy-PLC based Machines

Co-NECT
with Cogiscan

FUJI ASM Assembly Systems JUKI ITW EAE kurtz ersa

Plug & Play with:
- ✓ AOI/AXI/SPI
- ✓ Placement
- ✓ Printer Dispenser
- ✓ Wave Soldering
- ✓ Reflow Oven

PATHWAVE Manufacturing Analytics

In-Circuit Test (ICT)
- i3070
- Others

Apr'19

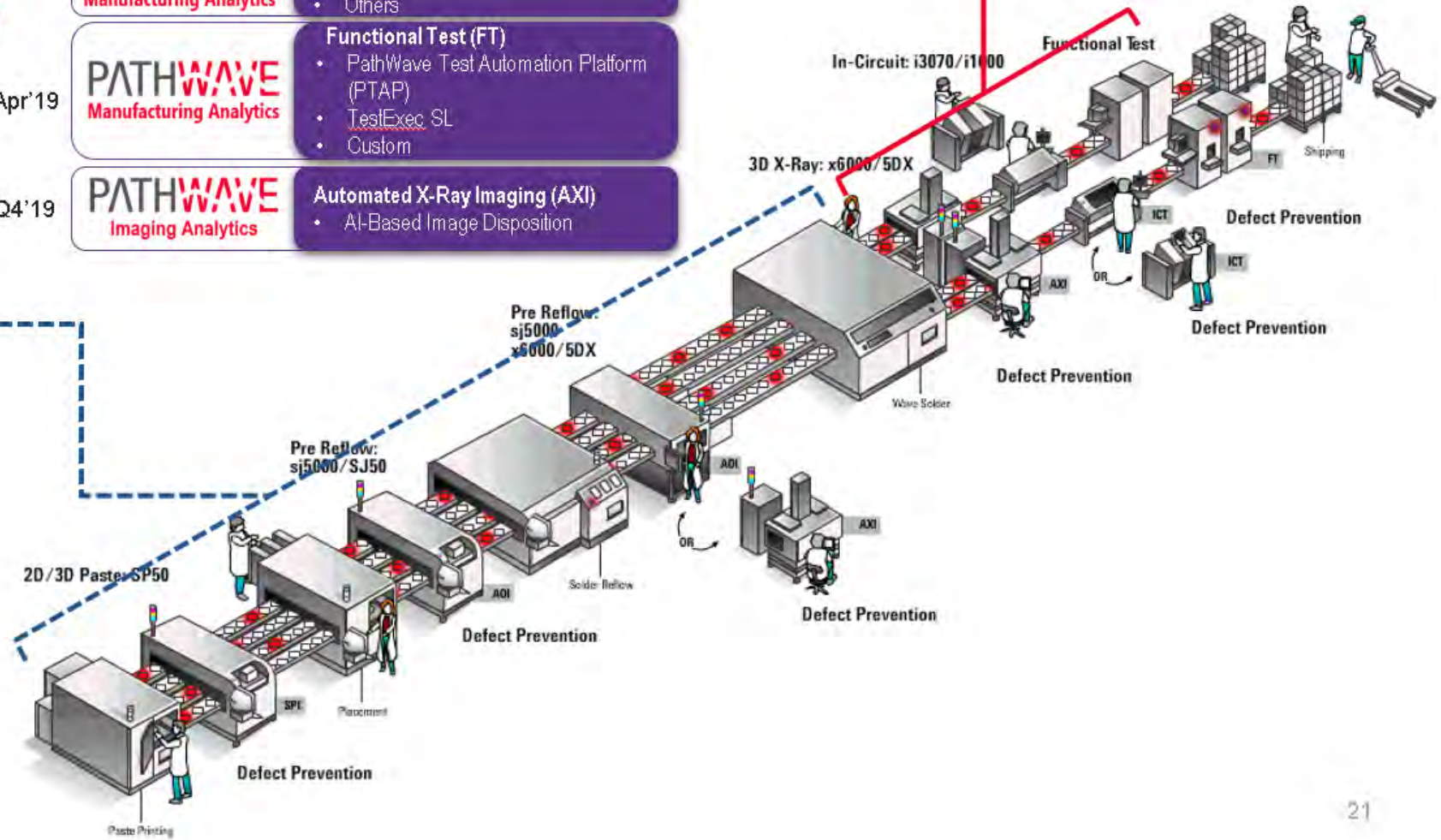
PATHWAVE Manufacturing Analytics

Functional Test (FT)
- PathWave Test Automation Platform (PTAP)
- TestExec SL
- Custom

Q4'19

PATHWAVE Imaging Analytics

Automated X-Ray Imaging (AXI)
- AI-Based Image Disposition

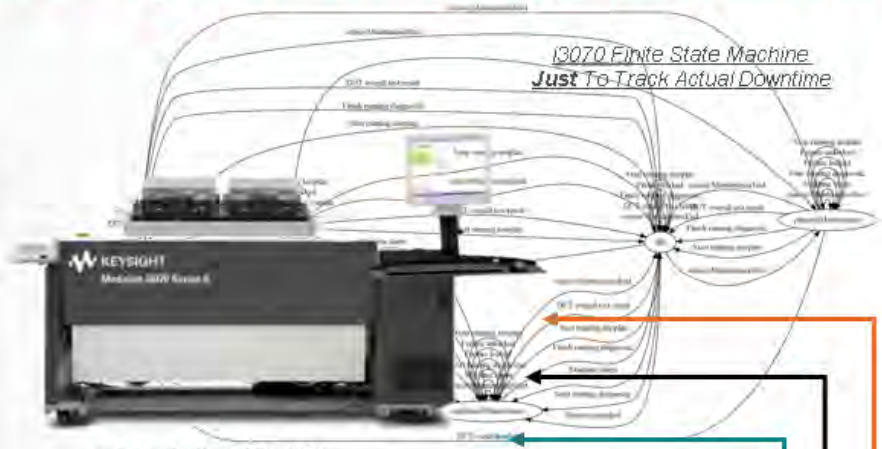


Test System Acquisition

Machine
- Machine alarm
- Machine diagnostics
- Machine status
- Fixture status
- Downtime
- Sensor Data
- Power Data

Test
- Test results
- Board file status
- Testplan status
- UUT information
- Test times
- Unique Tests
  - Pins
  - Shorts/Opens
  - VTEP

In-Circuit Testers



- Medalist i3070
- Medalist i1000

Functional Testers

- PathWave TAP
- TestExec SL
- Custom CSV/XML/etc.

Grabber Application

JSON JSON JSON

REST API

MQTT Broker (Event)

Other Protocols (customization)

Datalog Parser

MES, SCADA ERP

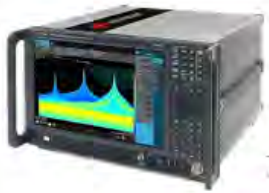
Other SMART Factory Interfaces
CAMX, FLEX Smart, Hermes etc)

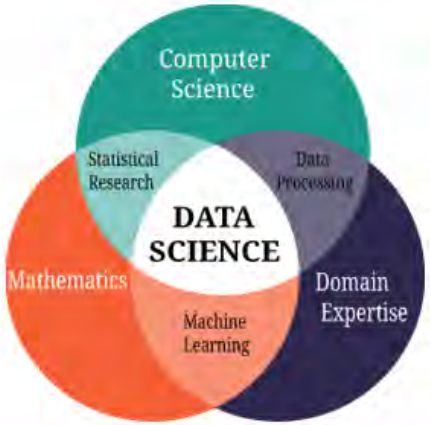
Smart Factory Digital Transformation

APPLIED ADVANCED ANALYTICS

Unique Value Differentiation

Data Acquisition	Data Transformation & Management	Data Analytics Generic Platform
OEM	Company D	Company A
	Company S	
Company C		





Measurement Science

+

Data Science

PathWave Manufacturing Analytics

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Manufacturing Analytics

Advanced Analytics

Yield
- Low First Pass Yield
- Final Yield Optimization
- Tests Optimization
- Limits Optimization
- No Trouble Found
- Probe Degradation

Performance
- Tests Optimization
- Downtime Monitoring
- Test Time Insights
- Machine Event Monitoring
- Machine Sensor Monitoring
- Power Monitoring

Quality
- Return Merchandise Authorization (RMA) Investigation
- High Number of Retest or Touches
- Good Component Anomalies
- Measurement Integrity

PathWave Analytics as a Service

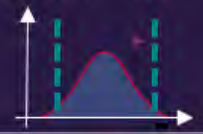
Domain Knowledge

Machine Learning Models

Testing Data

Rules & Statistics → Machine Learning → Deep Learning, Cognitive Computing

Distribution Tests



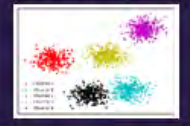
Regression Analysis

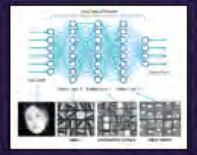
Linear classifier

Support Vector Machine

Decision tree inference

Clustering





Semantic networks, NN, Deep NN, Convolutional networks, ...

Training Data

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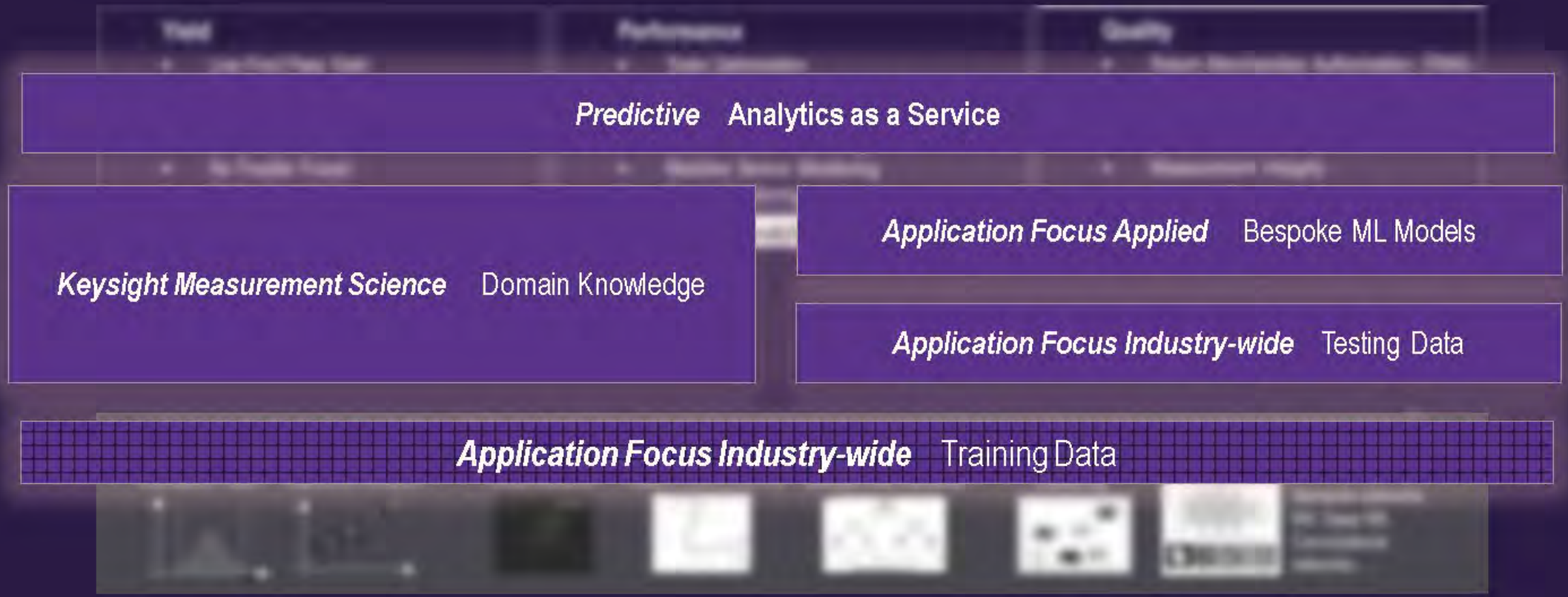
Applied Analytics



PATHWAVE Manufacturing Analytics

Simply Works Better

Benchmark against state of the art open source algorithms for anomaly detection

- Local Outlier Factor
  - The Local Outlier Factor (LOF) algorithm is an unsupervised anomaly detection method which computes the local density deviation of a given data point with respect to its neighbors. It considers as outliers the samples that have a substantially lower density than their neighbors.“
  - https://scikit-learn.org/stable/auto_examples/neighbors/plot_lof_outlier_detection.html
- Autoencoder Neural Network
  - In deep learning, an autoencoder is a neural network that “attempts” to reconstruct its input. It can serve as a form of feature extraction, and autoencoders can be stacked to create “deep” networks. Features generated by an autoencoder can be fed into other algorithms for classification, clustering, and anomaly detection.
  - https://deeplearning4j.org/tutorials/05-basic-autoencoder-anomaly-detection-using-reconstruction-error
- Dataset
  - 10000 time series data. 500 of them are anomalous windows (imbalance dataset)
- Error Metrics
  - F1-score
  - Matthews’ correlation coefficient
  - Weighted average precision
  - Weighted average recall

Smart Factory Digital Transformation

ADVANCED ANALYTICS AS A SERVICE

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Manufacturing Analytics

Analytics As A Service

Descriptive

Comprehensive Dashboards
- Digital Quality (Yields, Volume, Failures)
- Overall Equipment Efficiency (OEE)
- Drilldowns to Individual Projects and Tests
- Dedicated False Failure Module

Product Test Summary
Downtime Monitoring
Machine Sensor Monitoring
Alert Review Module

Diagnostic

Real-time, On-Demand and Instant
- CPK Analyzer
- Test Results Viewer
- Test Statistics
- Measurement Comparisons
  - Fixture to Fixture
  - Tester to Tester
  - Combinations of Both

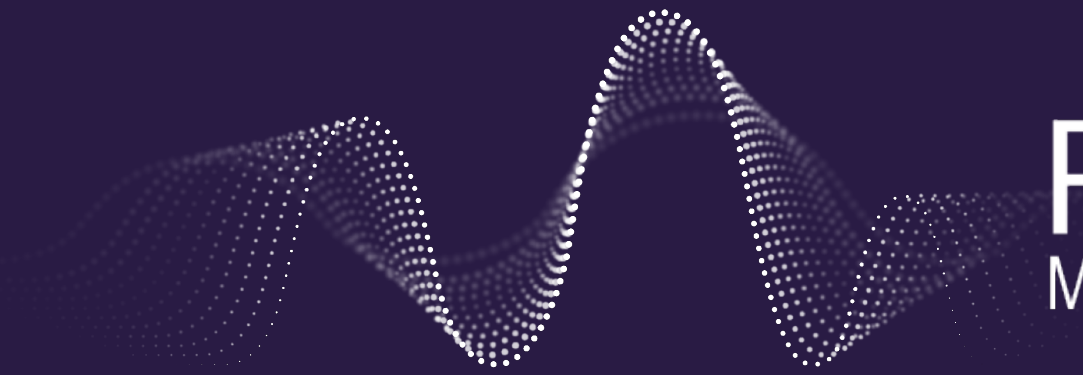
Predictive

Real-time Predictive Alerts
- Anomaly Detection
- Probe Degradation Prediction
- Part Average Test (PAT) Anomalies
- Golden Units Prediction
- AUTO Measurement System Analysis (MSA)
- PAT Limits Recommendation/Reference
- Test Limit Change Detection
- Low CPK

PATHWAVE
Manufacturing Analytics

Secured by Open Source

- ✓ OpenID Connect (OIDC) standard based Authentication and Authorization
- ✓ HTTPS Encryption of “Data in Motion”
- ✓ Encryption of “Data at Rest”
- ✓ Sensitive information such as user password is encrypted in database
- ✓ Auto deletion of old data is supported based on data-retention policy
- ✓ Source code security scanning is an ongoing practice in software development lifecycle



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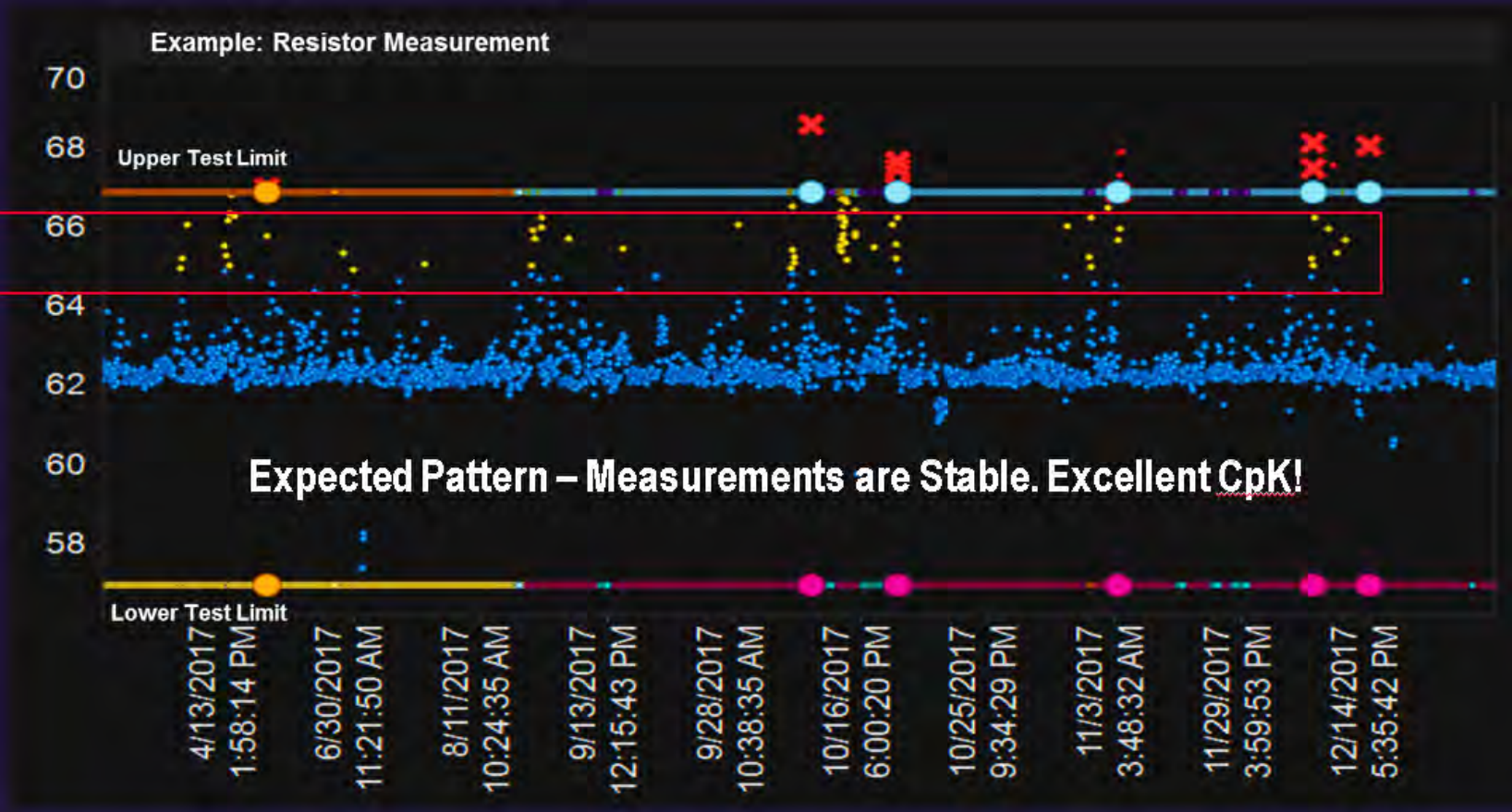
Manufacturing Analytics

Measurement Science Meets Data Science

The Power of Anomaly Detection

These are Anomalies

- Bad/Dirty Probes/Fixtures
- Machine Out of Calibration
- Dual Source Suppliers
- Component Quality Issues

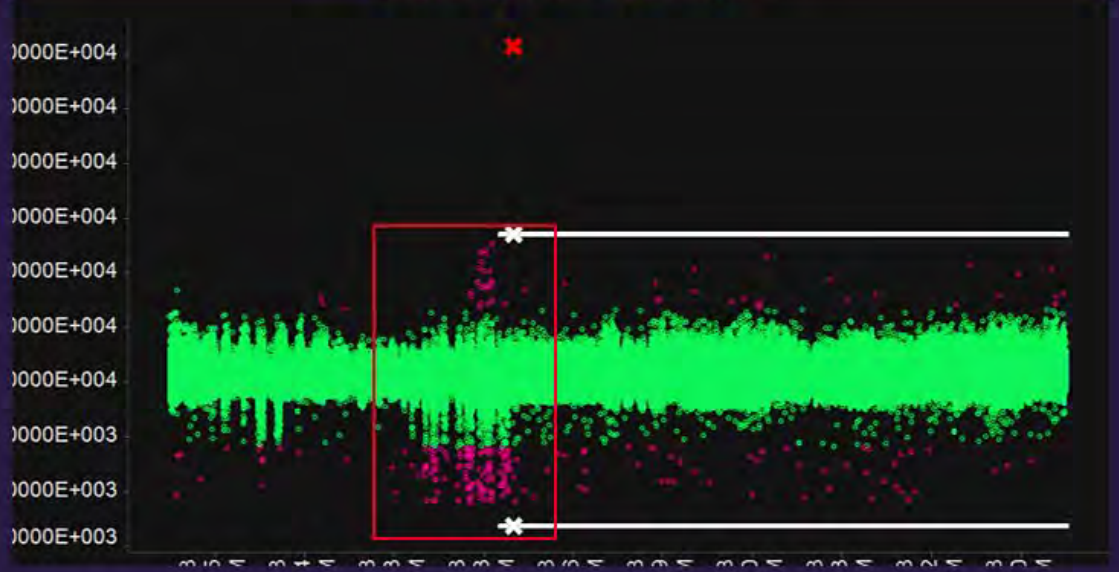


PATHWAVE
Manufacturing Analytics

Samples of Anomaly Prediction & Detection Using Advanced Algorithms

Predicting Degradation Before Critical Failure

Detecting Smear Patterns



Detecting Bimodal Pattern

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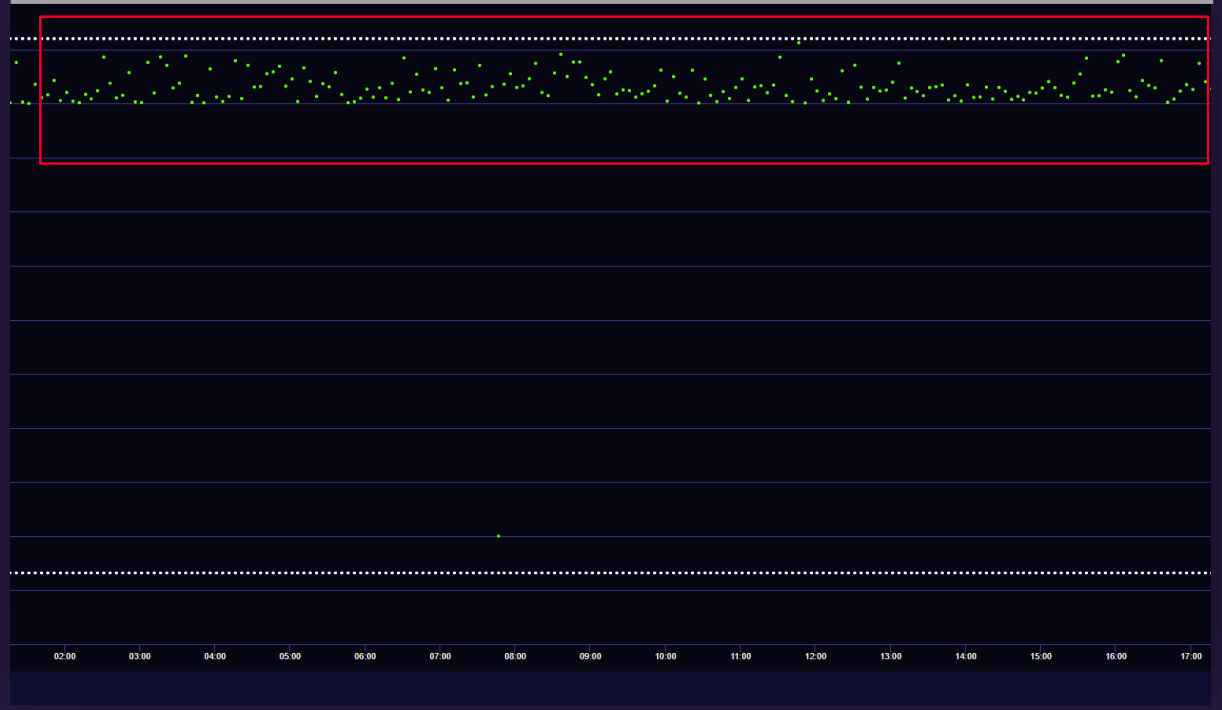
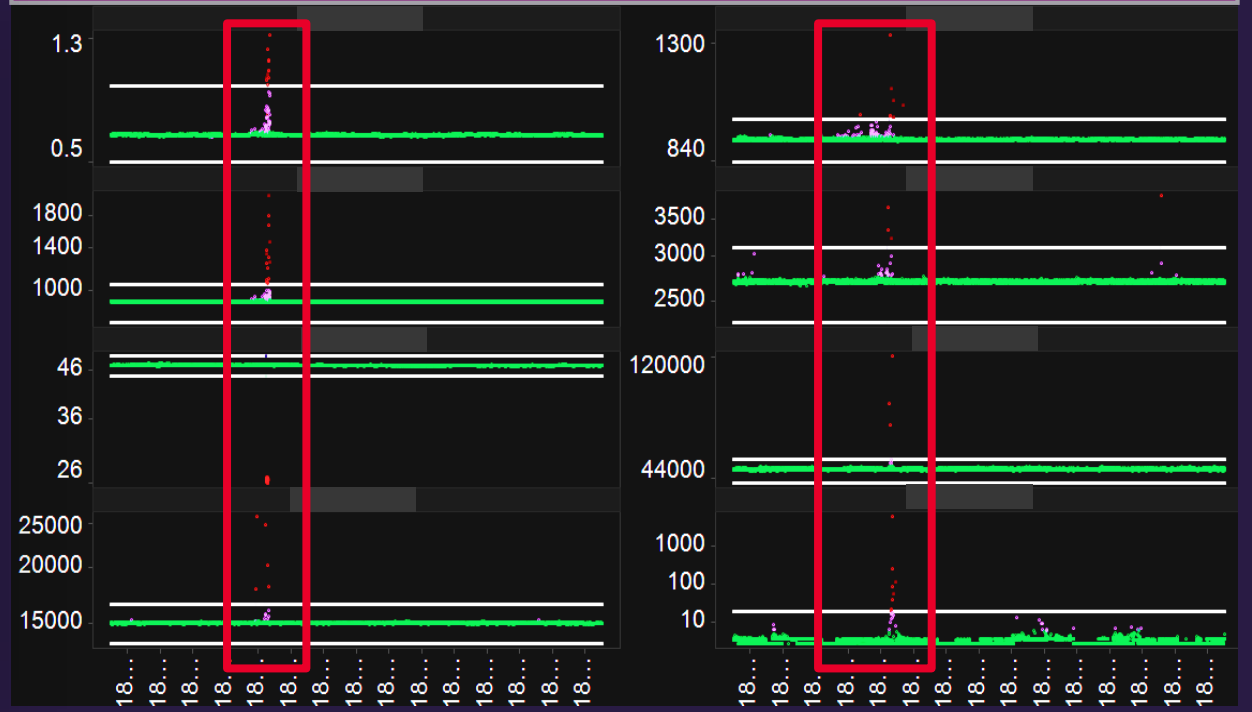
Manufacturing Analytics

Samples of Anomaly Prediction & Detection Using Advanced Algorithms

Detecting Potential Improper Limit Settings

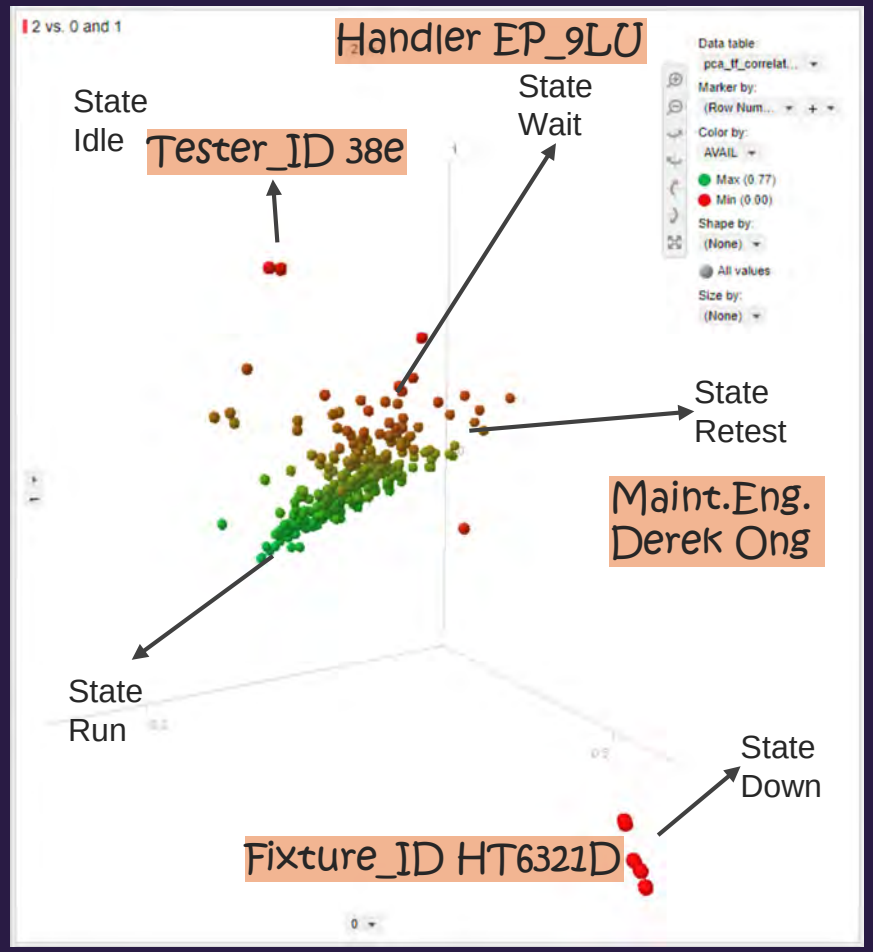


Detecting Multi Component Synced Variability

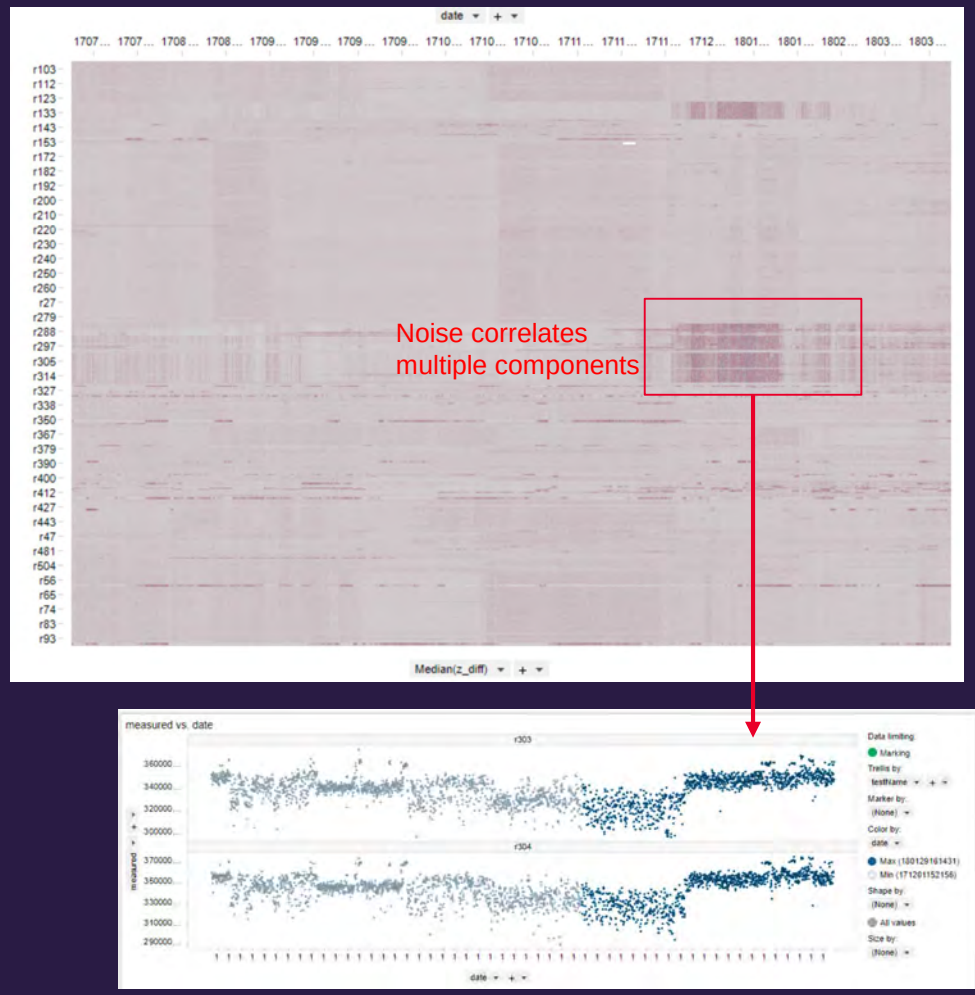


Customized Built-for-Purpose Machine Learning

Outcome: OEE Drain
Technique: 3 Dimension PCA
Data: Event and Machine State only



Outcome: Multi Component Correlation
Technique: Noise Profiling
Data: Measurements



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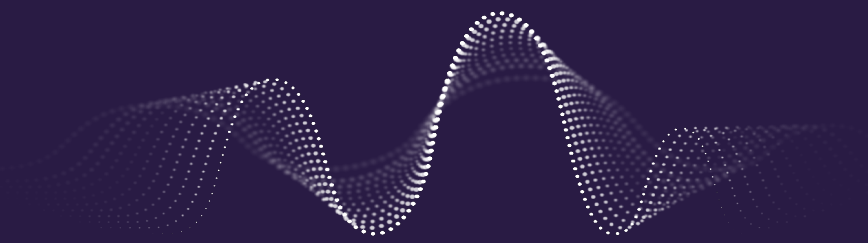
Measurement Science Meets Data Science



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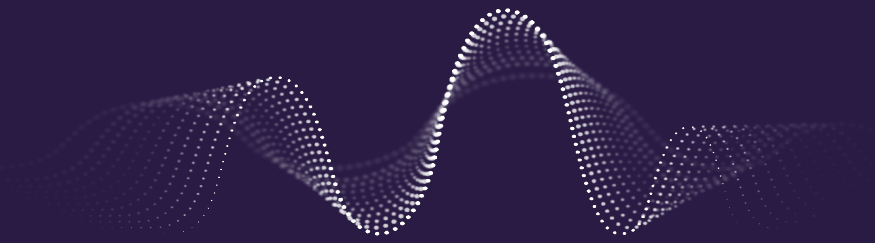


Management Dashboards

Digital Quality

- Quality Overview
- Volume, Yield by Project
- Top 5 Worst Test Names

OEE Dashboard

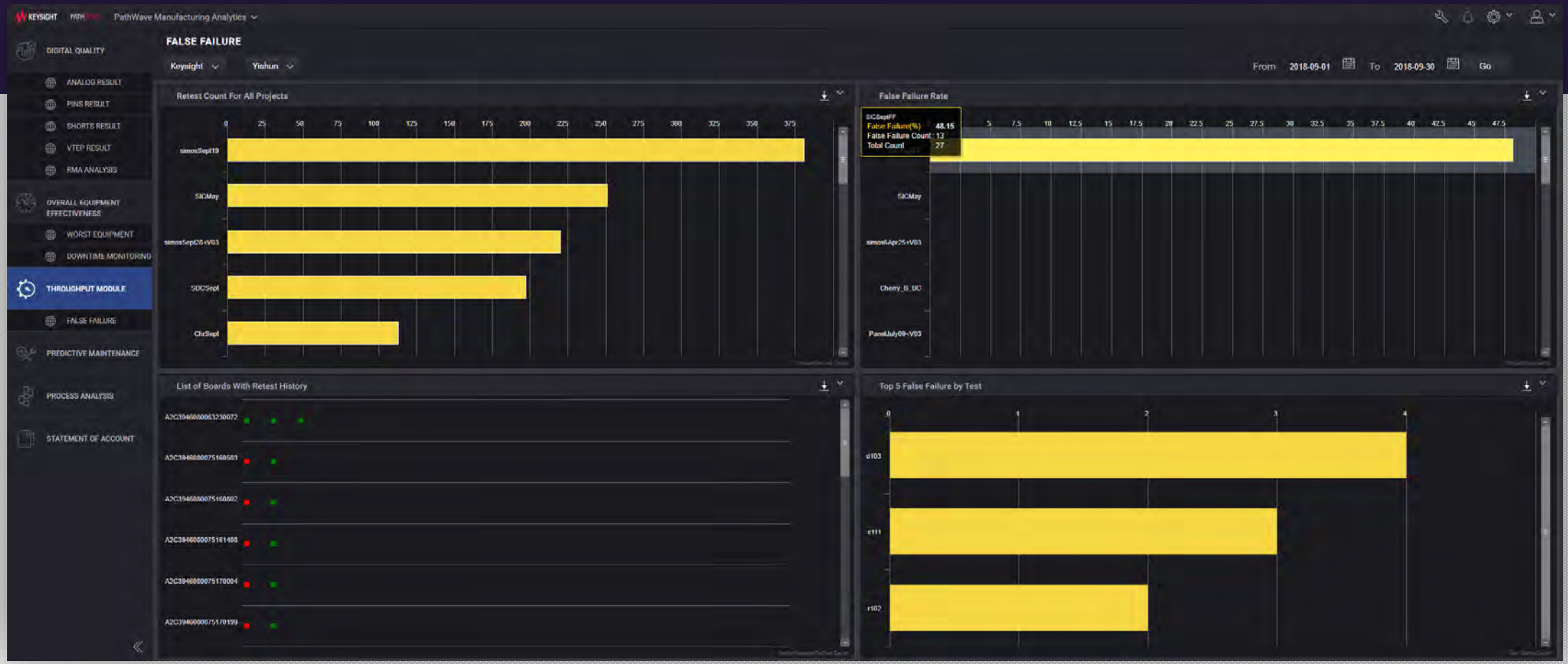
- OEE Overview
- OEE Scores
- Utilization Performance

Action Dashboard

- Time synched stock chart layout
- Failure Pareto by Project and Test Name Drill down
- Critical Action Badges

False Failure

- Retest Count and False Failure Rate
- No. of Retests History
- Top False Failures



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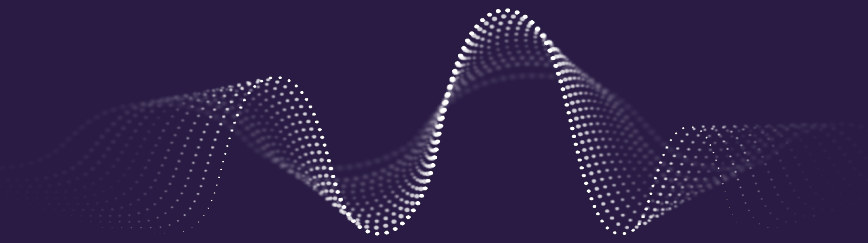
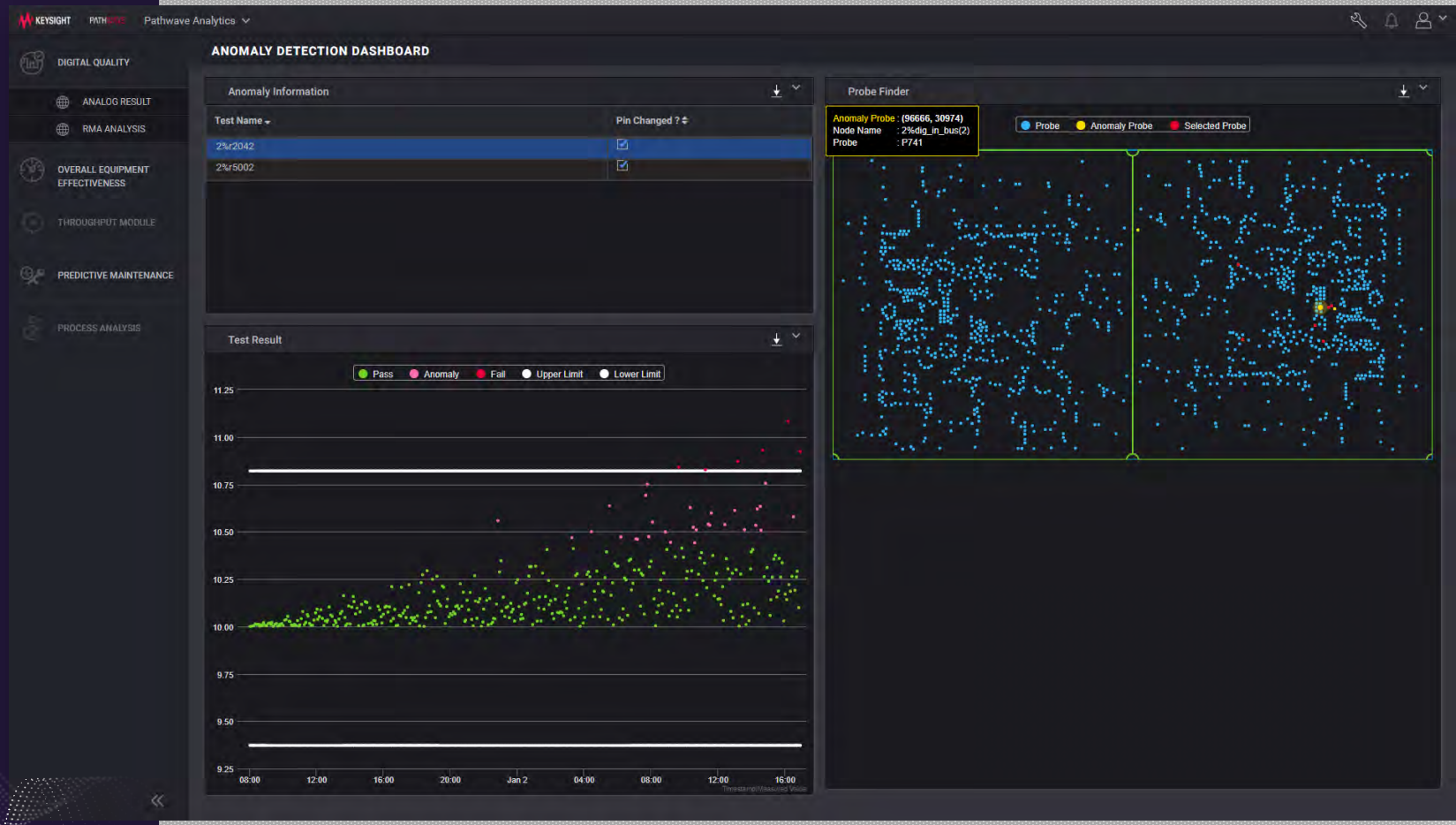


Anomaly Detection

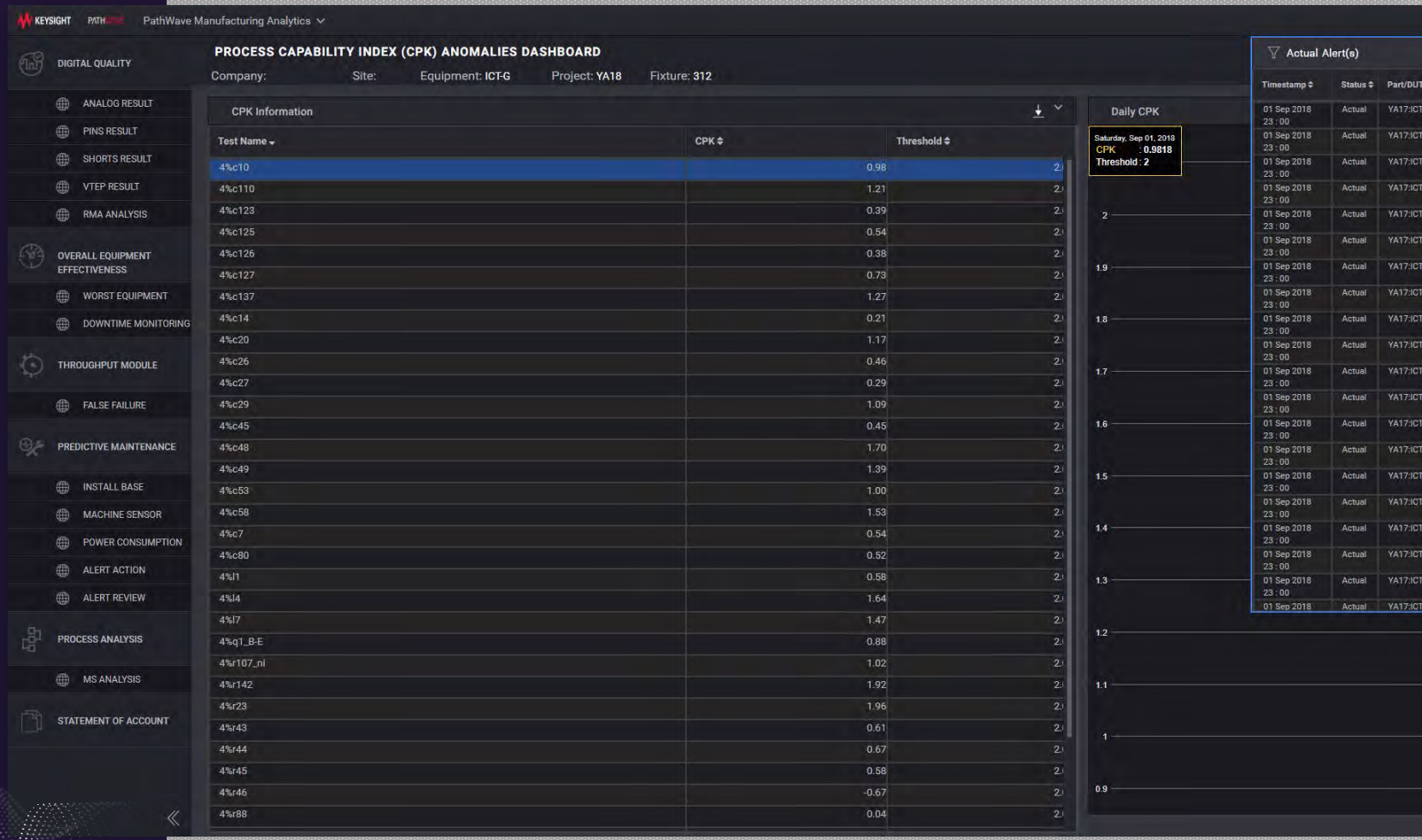
Degradation Anomaly

- Predicts anomalies before failure
- Advanced machine learning algorithms
- Probe finder for quick node location



CPK Anomalies

- Alert sent when CPK drops
- User configurable threshold

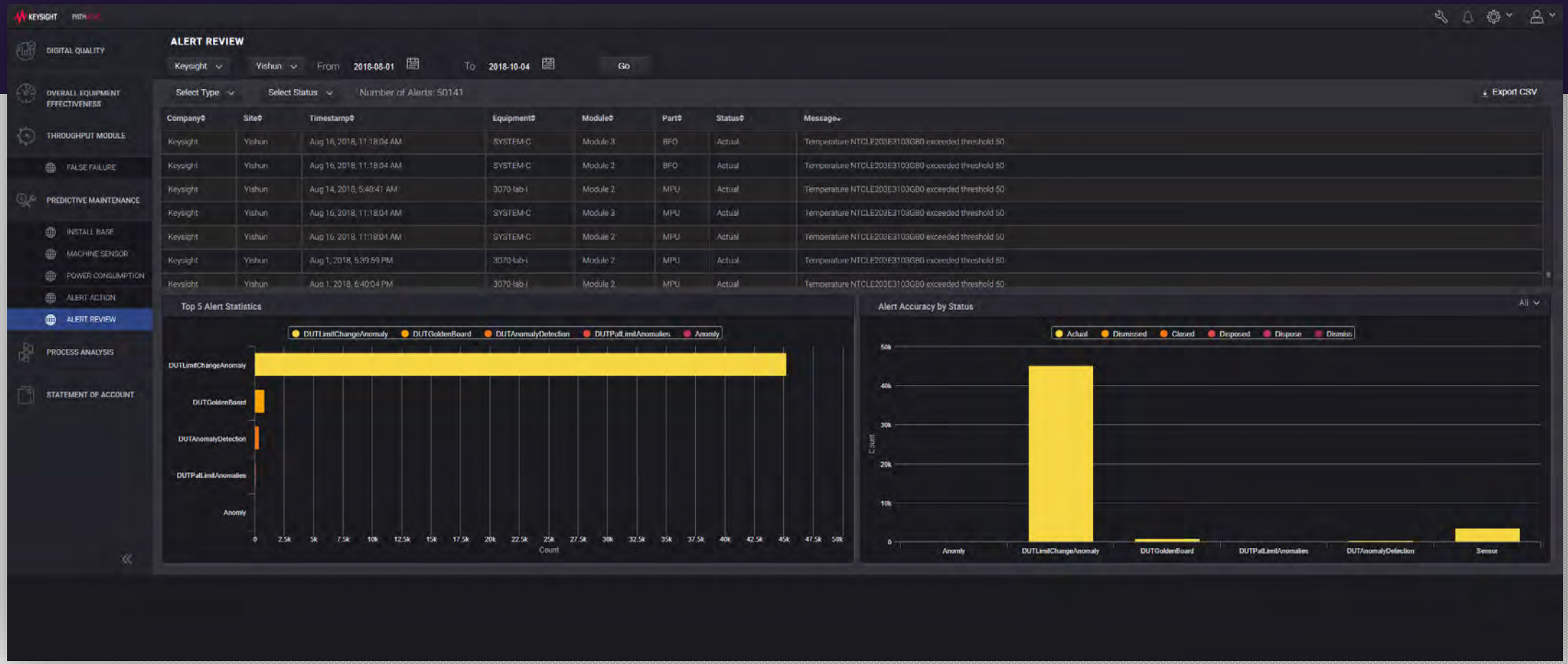


Test Limit Change

- Sends alerts when limit change detected
- Alerts can be configured per day or hour
- Can be turned off in settings

Alert Review

- Search, view, filter all alerts
- Monitor the type of alerts
- Reduce alert types



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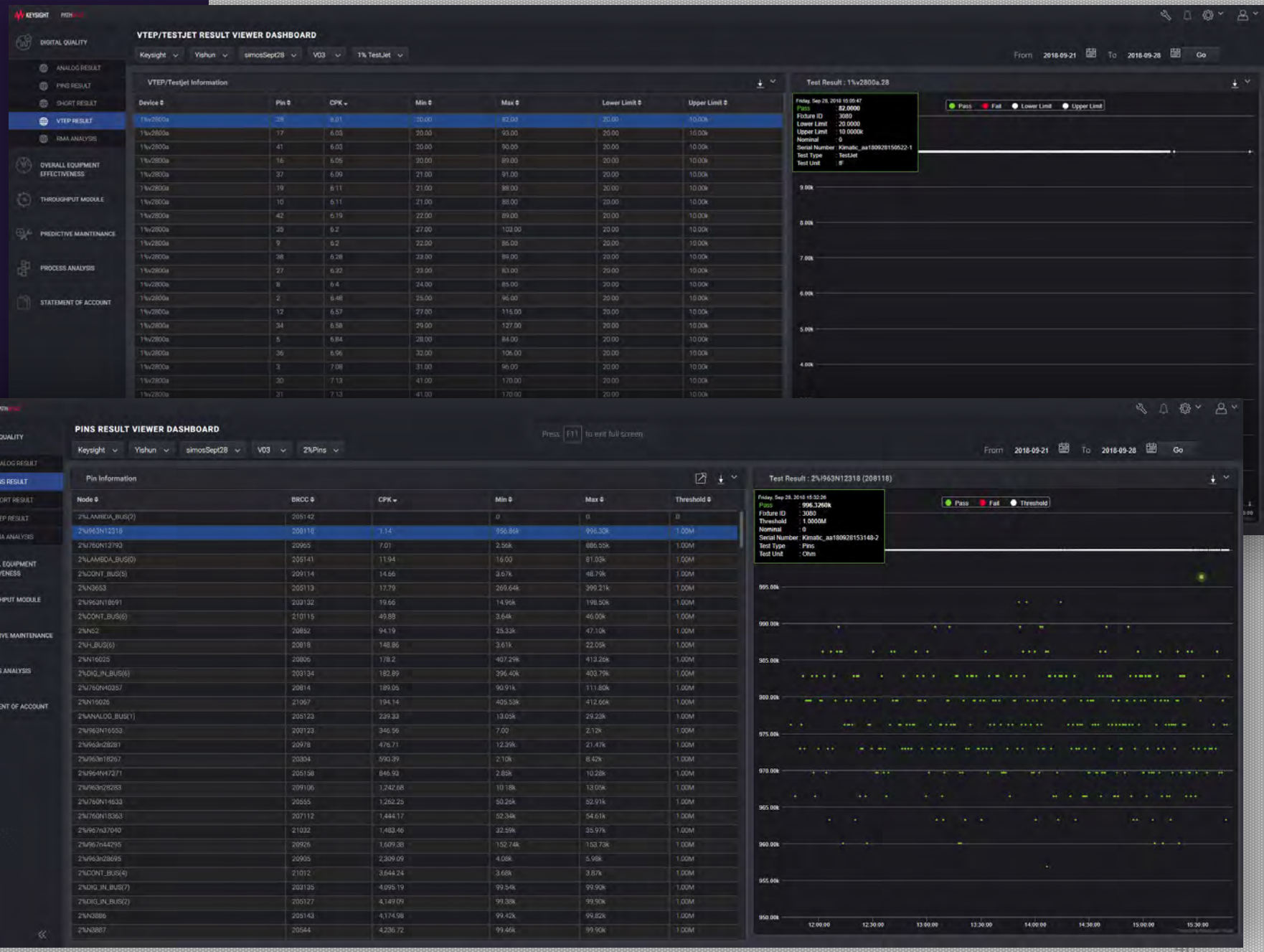
Analysis Tools

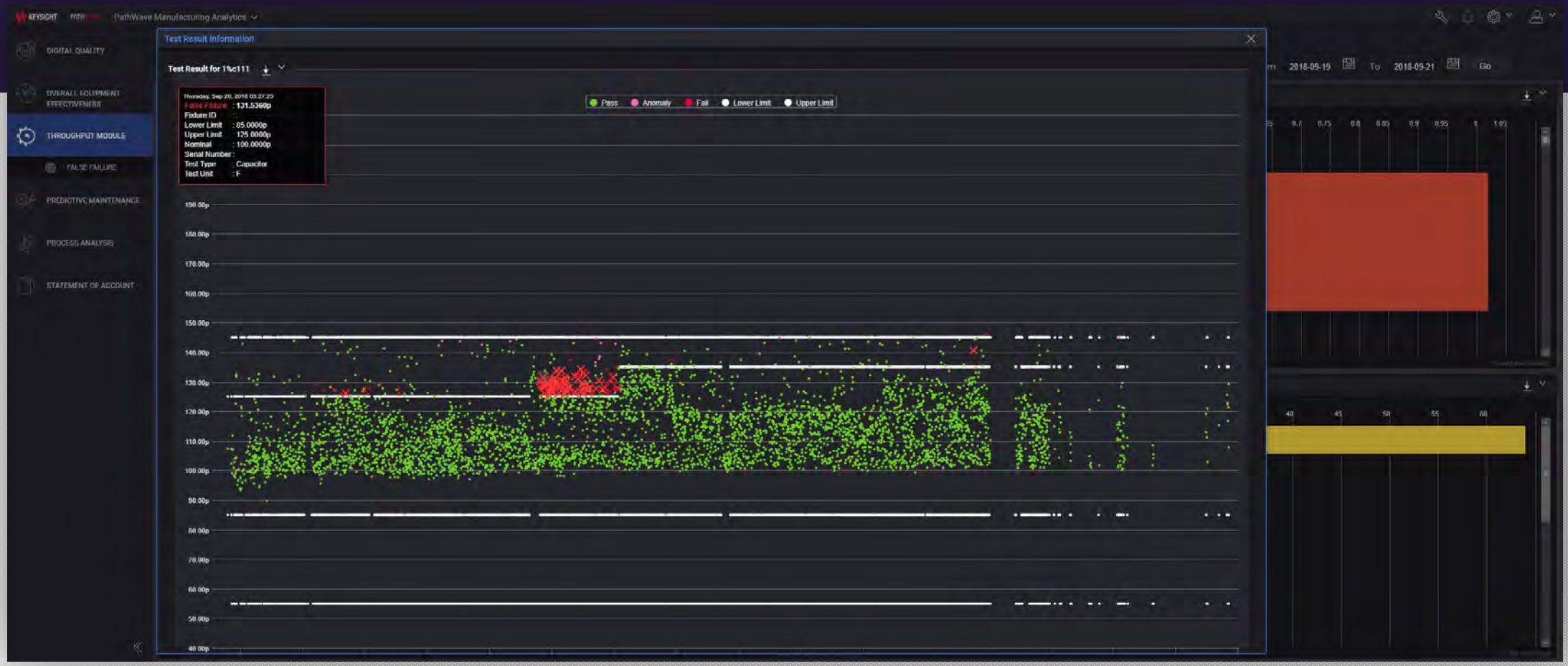
Results Viewer

- Enhanced View
- CPK, Min/Max, Limits
- Analog, PINS, SHORTS & VTEP Results
- Generate full CPK reports



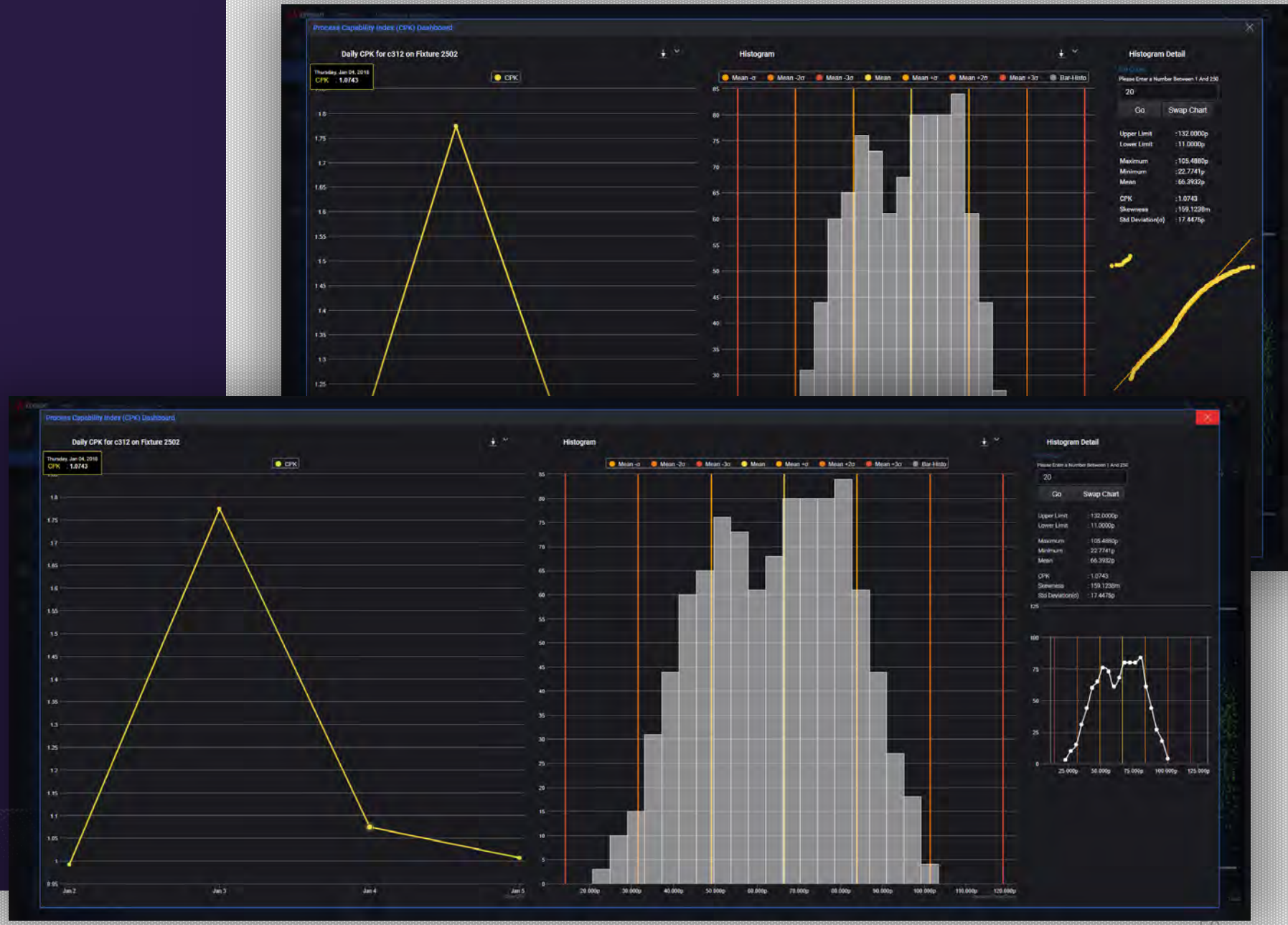
Enhanced Scatter Plots

- Full Visibility
- Pass, Fail, Anomalies and False Failures



Analytics Tools

- Daily CPK
- Histogram
- Switch to skew chart

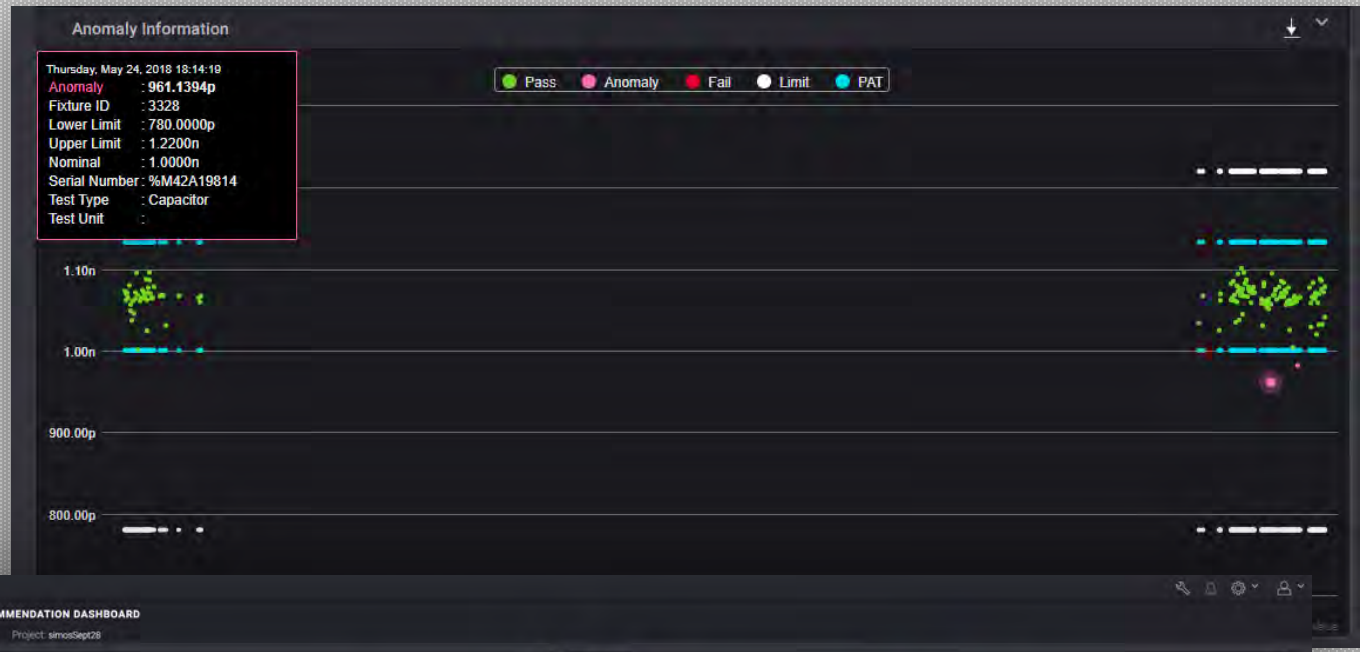


Quick Compare

- System to System
- Fixture to Fixture
- Combination

Part Averaging Test

- Automotive Electronics Council (AEC Q001.RevD)
- PAT Anomalies for CPK >2.0
- PAT Limits Recommendation for NPI or general limit debug



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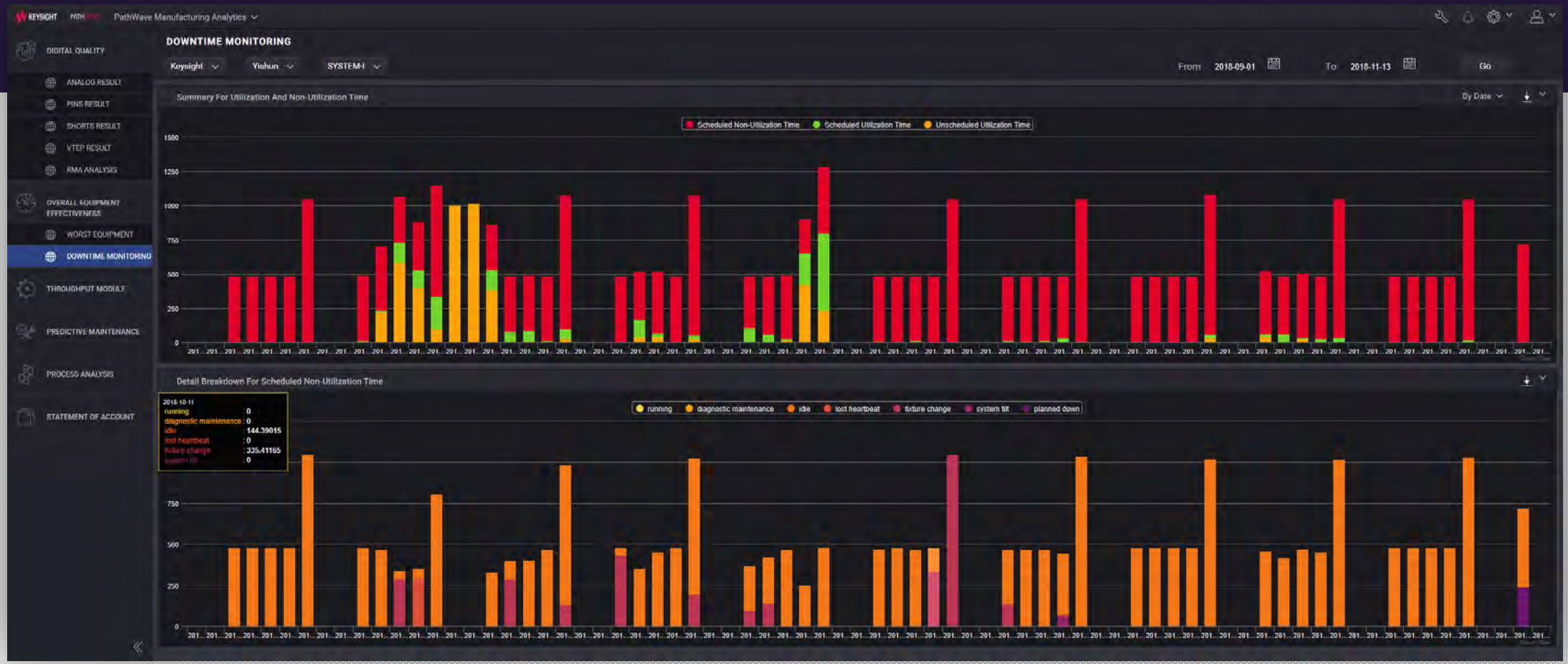
Monitoring Tools

Real Downtime Monitoring

- System event based
- Detail Breakdown

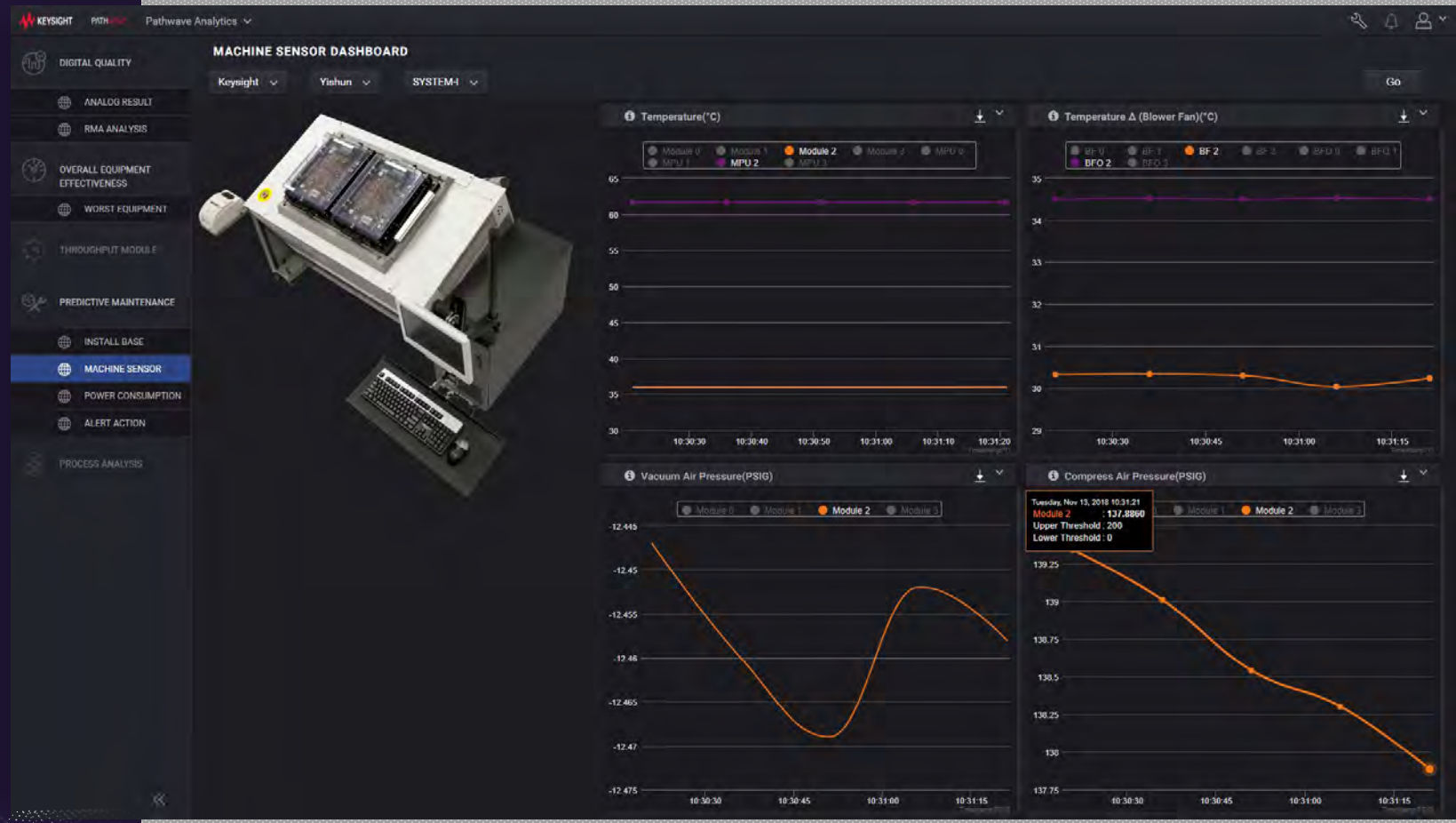


Auto-MSA

- Measurement System Analysis (MSA)
- New Six Sigma practice to identify the components of variation in that measurement process.
- World's 1st Fully Automated

Machine Sensor

- Continuous monitoring
- Real-time alerts
- In-house designed Embedded Intelligent Unit (EIU) sensor module

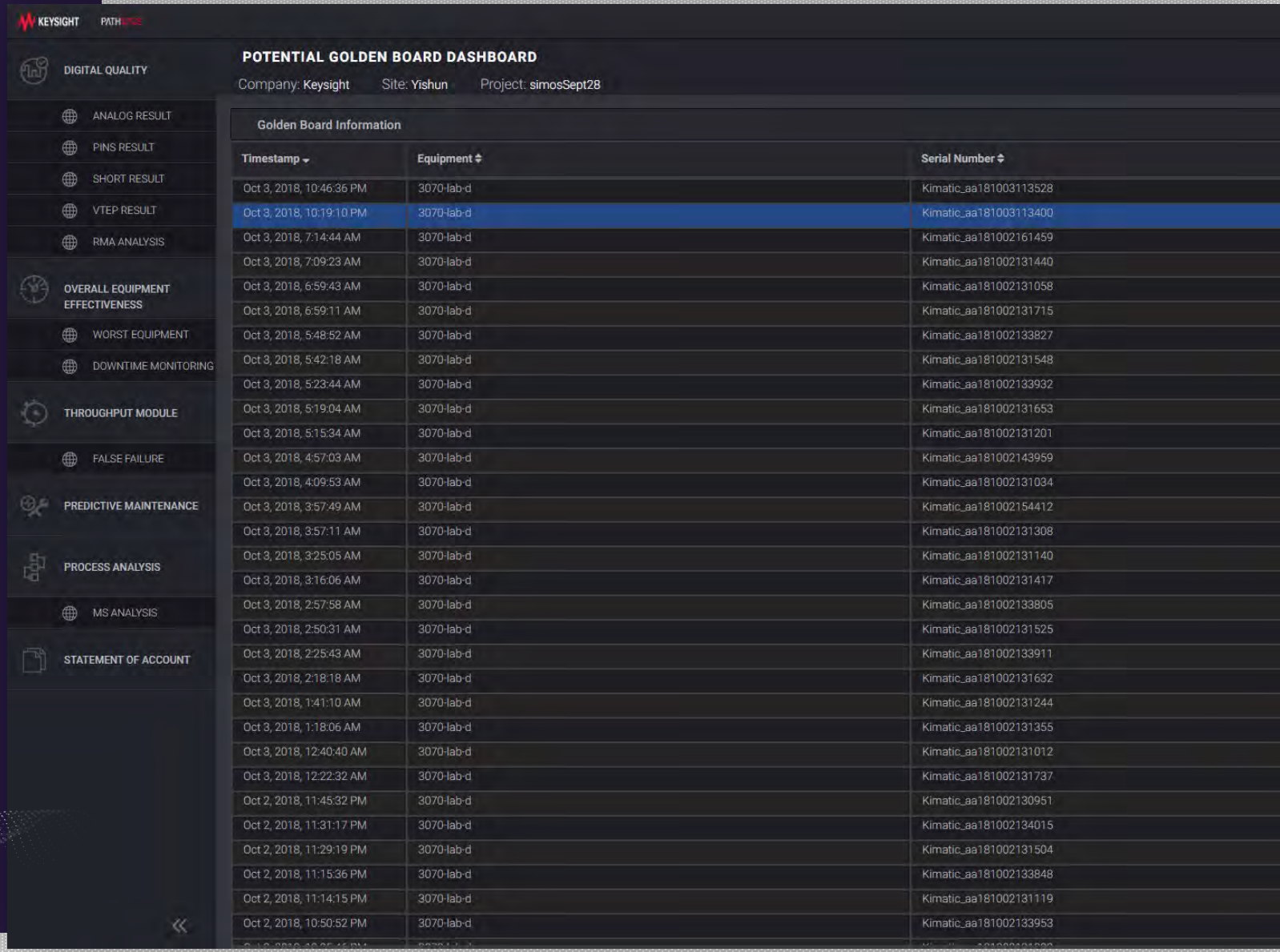


Power Consumption

- Continuous monitoring
- Real-time
- Sensor built-in Series 6 prime

Golden Unit Detection

- Fully automated
- World's 1st
- Alerts customers when potential golden unit detected in production



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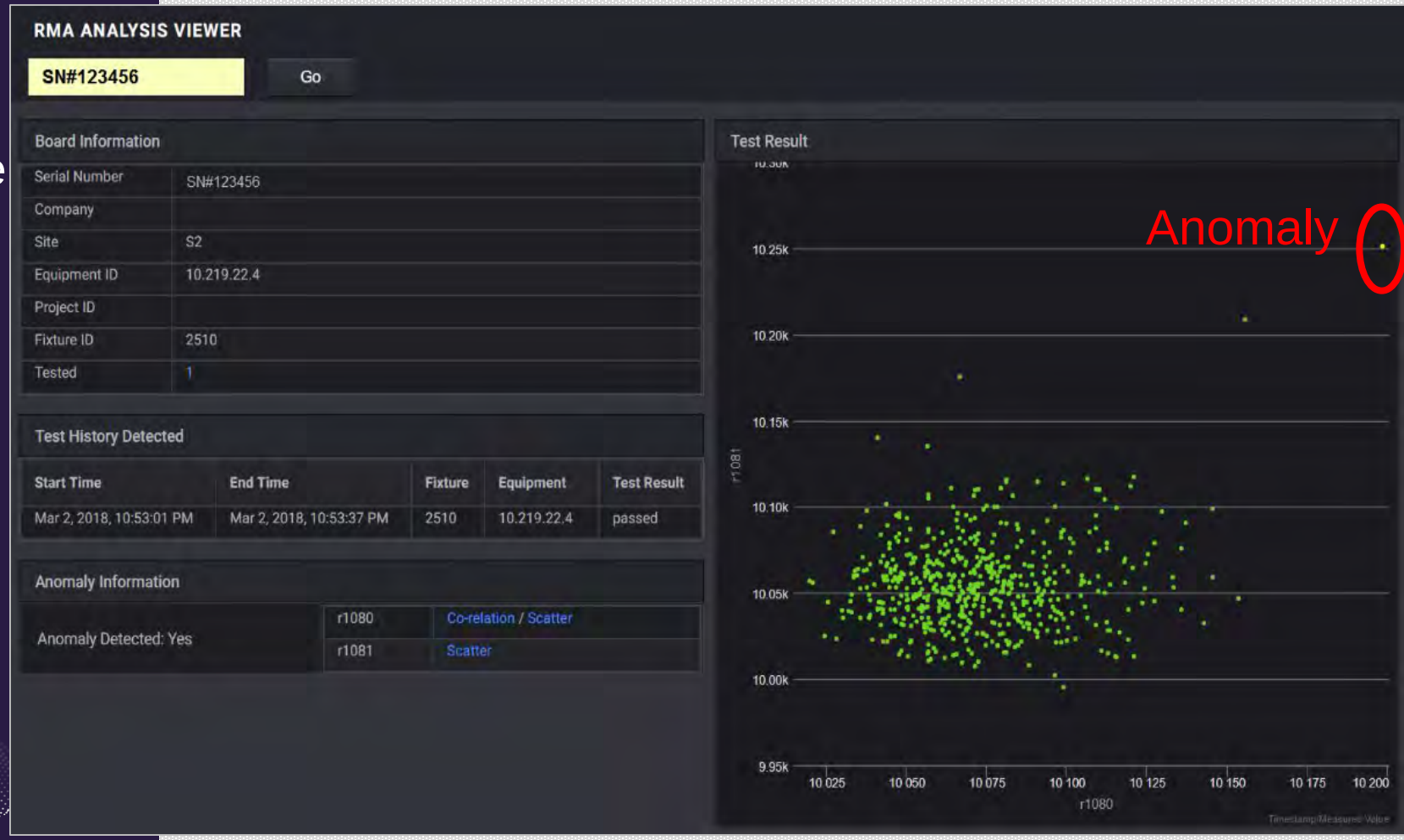
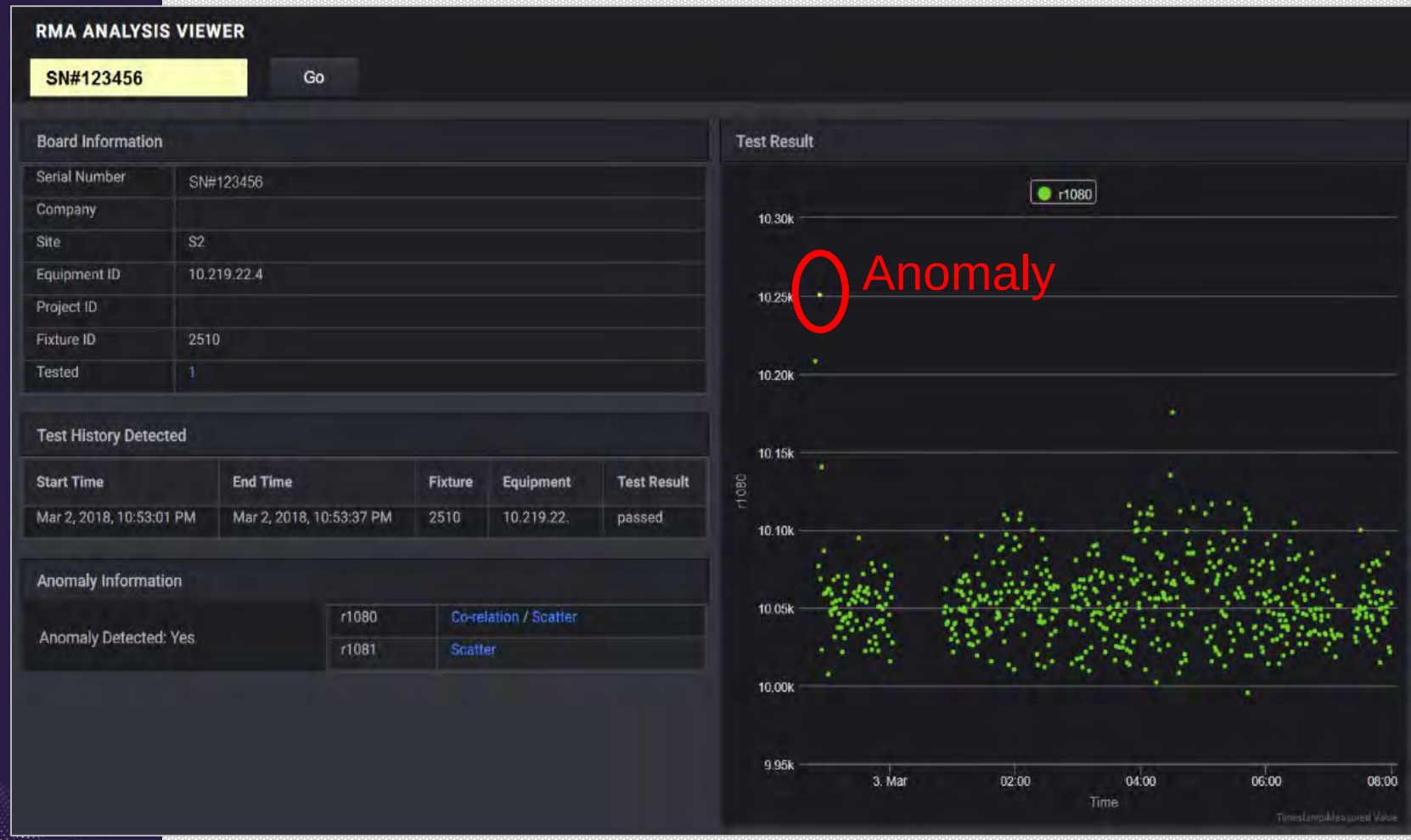
RMA Analysis
Multi-Component Correlation

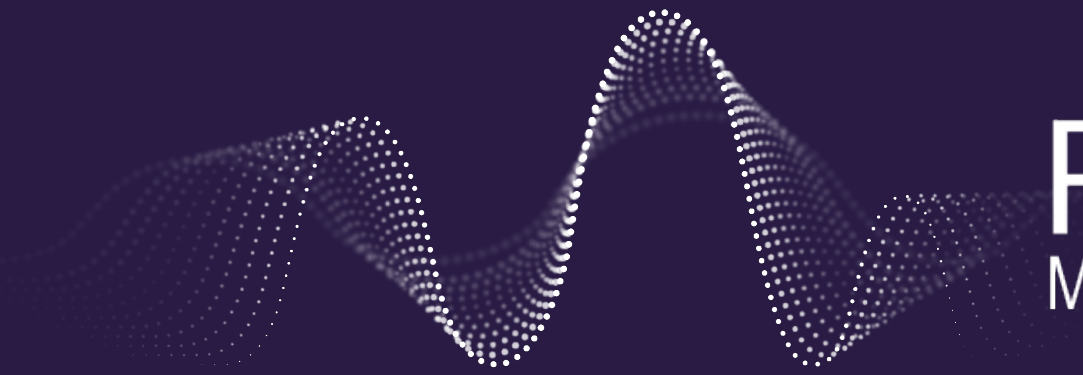
- Compare results from different components on same board type
- Automatically generated from historical data



RMA Analysis
Multi-Board Correlation

- Compare results from same board type and results from the same component
- Automatically generated from historical data





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