Analytic Solutions For Semiconductor

May 2020

OPTIMAL+
is now NI

Through the acquisition of OptimalPlus, NI accelerates companies' digital transformation initiatives by coupling NI leadership in automated test with new advanced product analytics for enterprises.

"We're confident NI's enterprise software strategy unlocks the value of test data by embracing digital transformation and bringing it to the analog world."

Eric Starkloff

NI CEO AND PRESIDENT

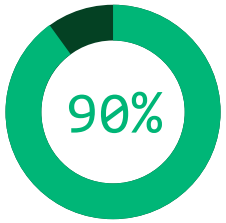
It's A Changed World

Technological innovation has transformed our lives.

Products and devices are more intelligent and connected.

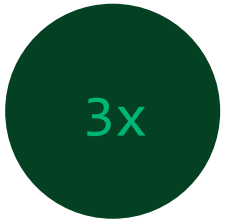
These products rely on thousands of electronic components that must be more reliable than ever before.

Automotive Innovation Reliability Challenge



Car innovations and new features are driven by electronics[1]

Warranty costs related to electronics and semiconductors[2]



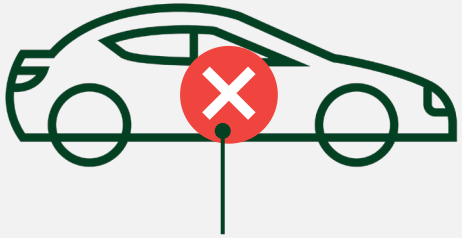
Car recall increase from 2014-2016 due to electronics[3]

Ignition switch failure
Failure to park
Takata airbag recall

15x Drive per day[4]:
1.5hr traditional car vs.
22.5hr autonomous car

1 Automotive change drivers for the next Decade, EY, 2016
2 BMW - AEC Automotive electronics reliability workshop, 2017
3 NHTSA Recall Data
4 Audi, DVCon Munich, 2017

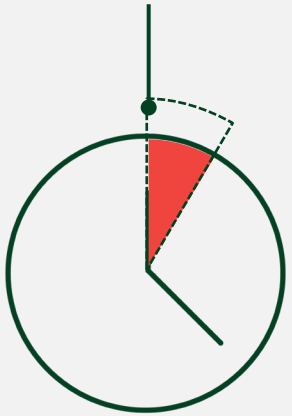
AUDI SAYS



1 CAR FAILURE

↓

EVERY HOUR[4]



Reliable electronics

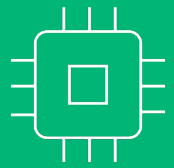
2005
FOUNDED

~230
EMPLOYEES

Analyzing huge volumes of data

100bn
DEVICES PER YEAR

ROI track record and loyal trusted partner



SEMICONDUCTOR

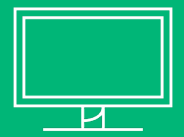
Big data analytics with expertise in manufacturing

Ready-made solutions for Automotive and Semiconductor industries

AUTOMOTIVE

Open innovation platform for edge deployment of real-time analytics and AI/ML

Lifecycle visibility across supply chains and industries



ELECTRONICS

Product-Centric approach taking I4.0 and IIoT to the next level

Cloud Or On-Prem
AWS (partner), Azure, GCP

Trusted By Leading Brands

Customers

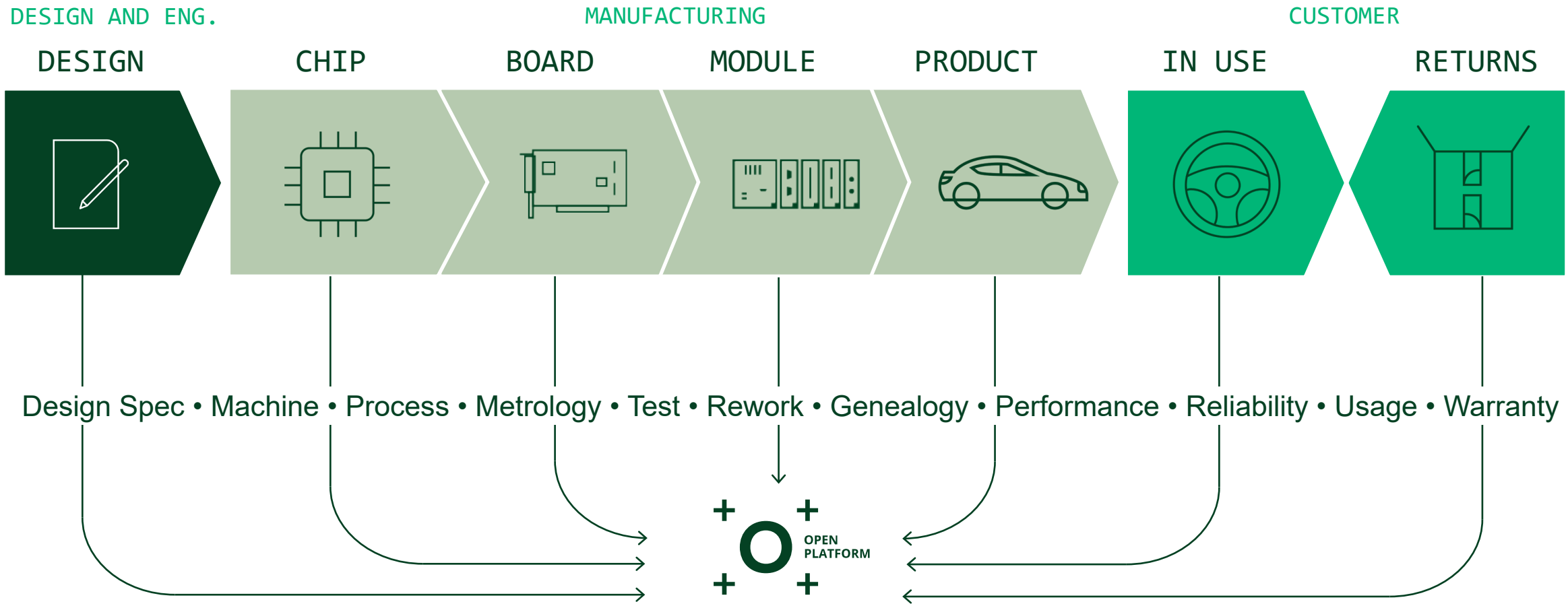

Supply Chain

Challenges We Address In The Semi Industry

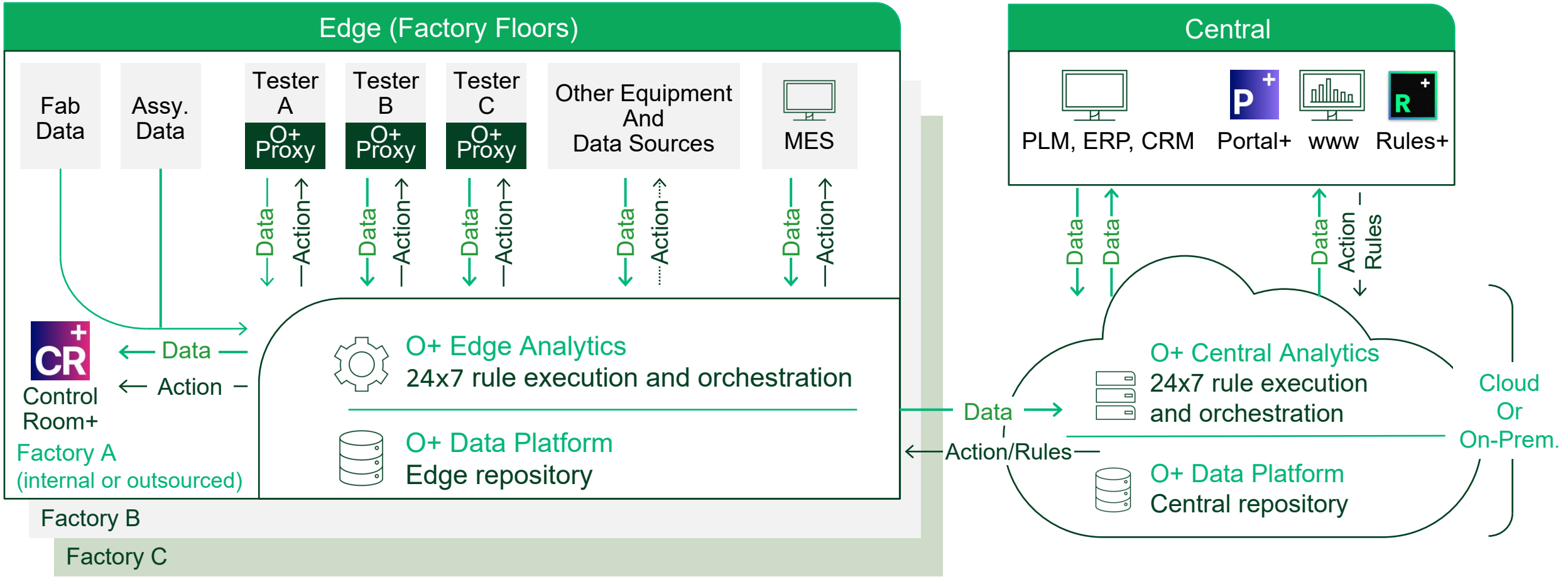
1. Growing chip complexity, including advanced materials, processes, and packages
2. Quality requirements get more demanding
3. Efficiently manage fragmented supply chains – suppliers, sites, equipment, systems
4. Need to improve time to market of new products
5. Continuous pressure on profitability
6. Where and how to use AI/ML to maintain competitiveness

Our Vision

Lifecycle Analytics Through Product-Centric Approach



System Architecture



Actionable Insights Across All Manufacturing And Test Processes

Semiconductor Solutions

Quality, Reliability and Brand Protection	Yield Analysis and Reclamation	Efficiency	Time To Market	Supplier Transparency

AI/ML Deployment For Manufacturing

Data Security

Data Lifecycle

Providing Innovative Solutions

Typical Methods

- Collect lots of data
- Use it primarily when there is a problem: Bad Yield, RMA (Returns), Etc.
- Find the problem but frequently not the root cause
- Process is often manual and reactive, not proactive
- Use of many tools, but not an integrated solution

O+ Solution

Collect	Detect	Act
• Lifecycle data harmonization of any type • Product, machine and process data • Data security	• Prescriptive analytics • AI / Machine Learning • 24x7 analytics engine • Real-time	• Automatic • Distributed • Controlled

A unique, automated and proactive integrated solution

The Value We Bring

Quality, Reliability and Brand Protection	Minimize excursions	Minimize RMAs	Analyze root cause	Protect your brand	Comply with automotive standards
Yield Analysis and Reclamation	Improve overall yield	Minimize site-to-site variations	Optimize re-test policy	Identify equipment performance issues	
Efficiency	Enable consistent tester availability and utilization	Avoid excessive index and pause times	Identify test time variations per tester	Ensure efficient retest policies and execution	
Time To Market	Shorten NPI time	Optimize balance between time, cost, and quality	Facilitate multi-team collaboration	Share learnings from NPI to HVM and back	
Supplier Transparency	Benchmark suppliers		Ensure supplier compliance with flows for every chip		

Proxy+

1 Real-Time Data Collection

- Runs on all major semiconductor test platforms
- Ensures consistent data quality and high-speed delivery
- Includes a wealth of information not provided in regular data logs for accurate OEE analysis and software/hardware validation
- Agnostic to, and supports all test programs

2 Real-Time Control

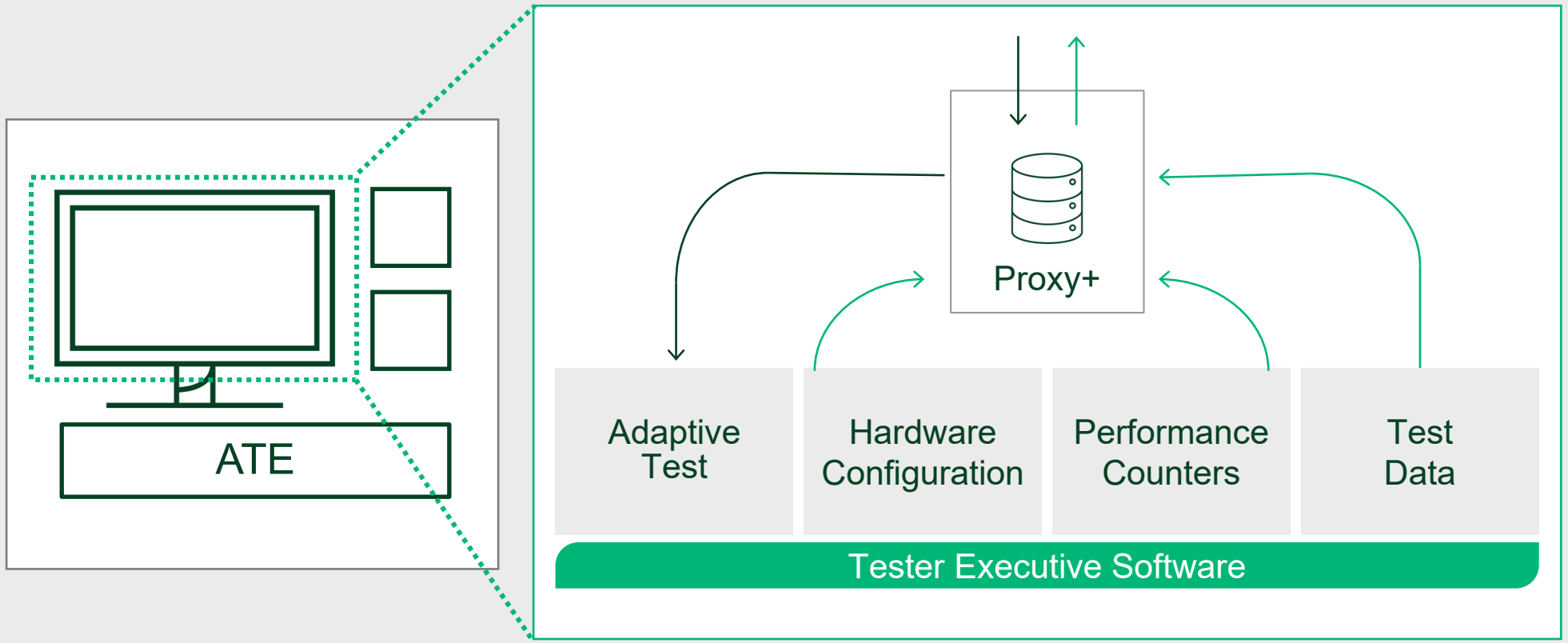
- Identifies issues as soon as they occur
- Alerts operators
- Pauses the tester

3 Platform For Real-Time Action

- Automated re-binning
- Adaptive test time reduction
- Drift detection
- Data-feed-forward
- and much more…

Proxy+ is an agent running on the tester, enabling real-time data collection, control and action

Proxy+ – Optimal+ Ambassador On The ATE



For:

Data collection

Adaptive testing and tester control

Rules

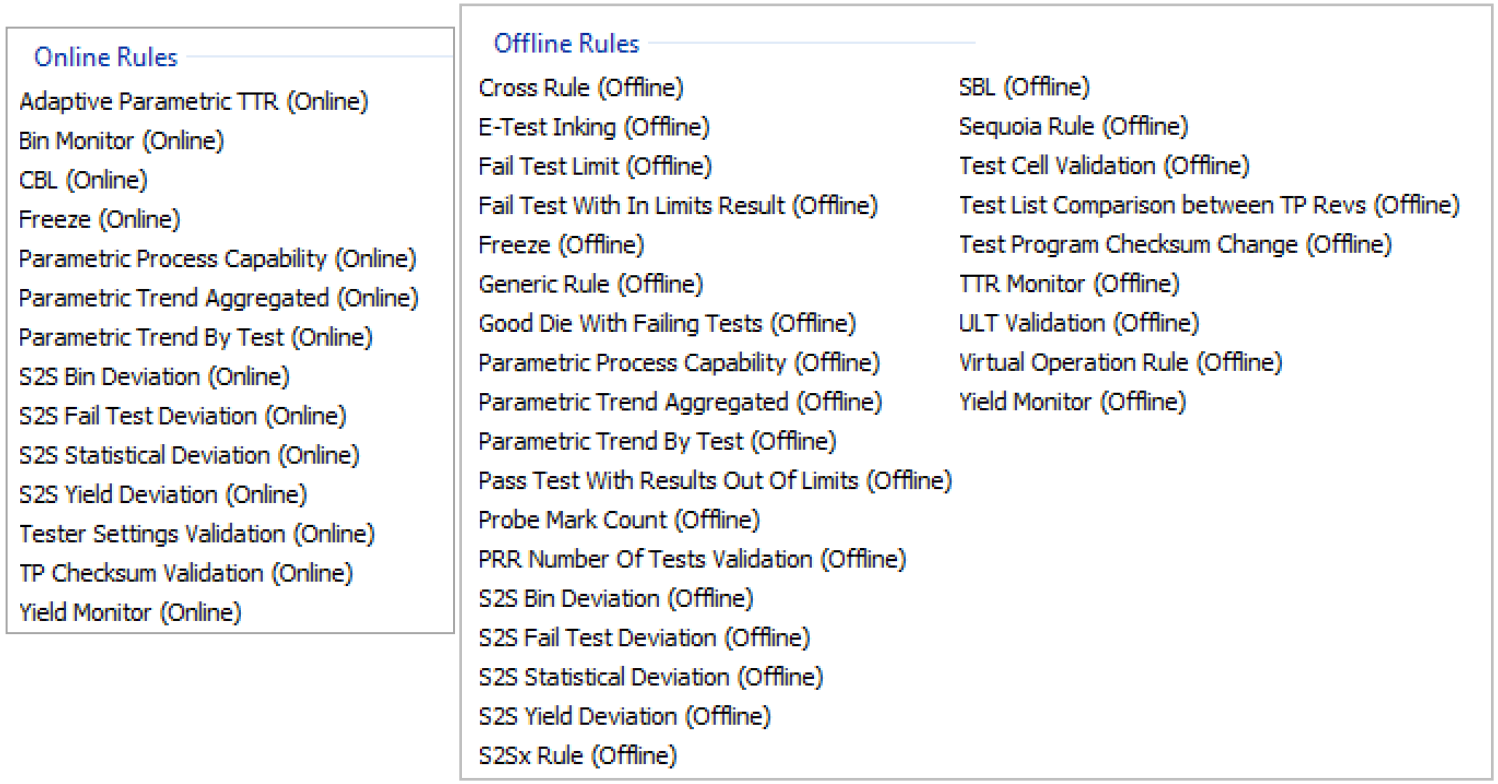
Targeting Challenges 24x7

Library of standard rules accommodate most the challenges faced by our industry

Custom rules available for unique monitors and actions including support for R and Python scripts

Deployed at any level of your supply chain (central vs edge)

Rules engine running 24x7



Rules Turning Challenges Into Actions

Action Categories

Equipment Actions	Pause	Engineering tool alert	
Process Actions	Put materials on hold	Re-binning	
Recipe Adjustments	Re-test skip/add	Adaptive testing	
Data Augmentation	Feed-forward	Feed-backward	Virtual operation
Alerts	Quality outlier alerts	Yield alerts	Predictive/ Anomaly alerts

Data Security Solution

1 End-to-end secure data lifecycle

- Authenticate with tester OS and test program (TP)
- Secure channel between Tester and Local Server
- Secure data at rest on tester and local server
- Secure transfer of data logs to HQ

2 Key exchange mechanism

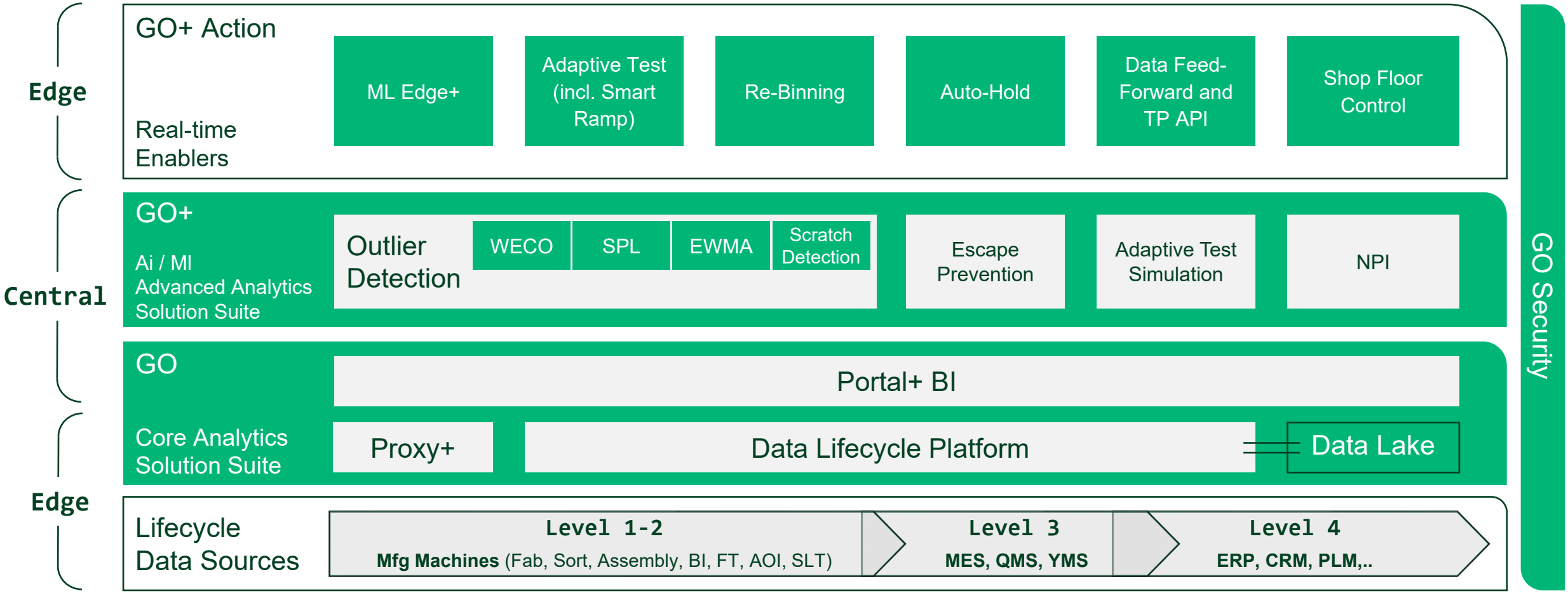
3 Offline mode for offline data logs and recovery

4 Sensitive data filtering to securely share data logs with suppliers

5 Allowing Real-time and offline rules without exposing sensitive data

6 Compatible with older TPs not implementing encryption

Our Marketecture



Solution Examples

Quality, Reliability and Brand Protection Solutions

Quality and Reliability

Minimize excursions

Minimize RMAs

Analyze root cause

Protect your brand

Comply with automotive standards

Outlier Detection

Escape Prevention

Special quality algorithms –
WECO, EWMA, SPL, Scratch Detection

Auto-hold (via MES)

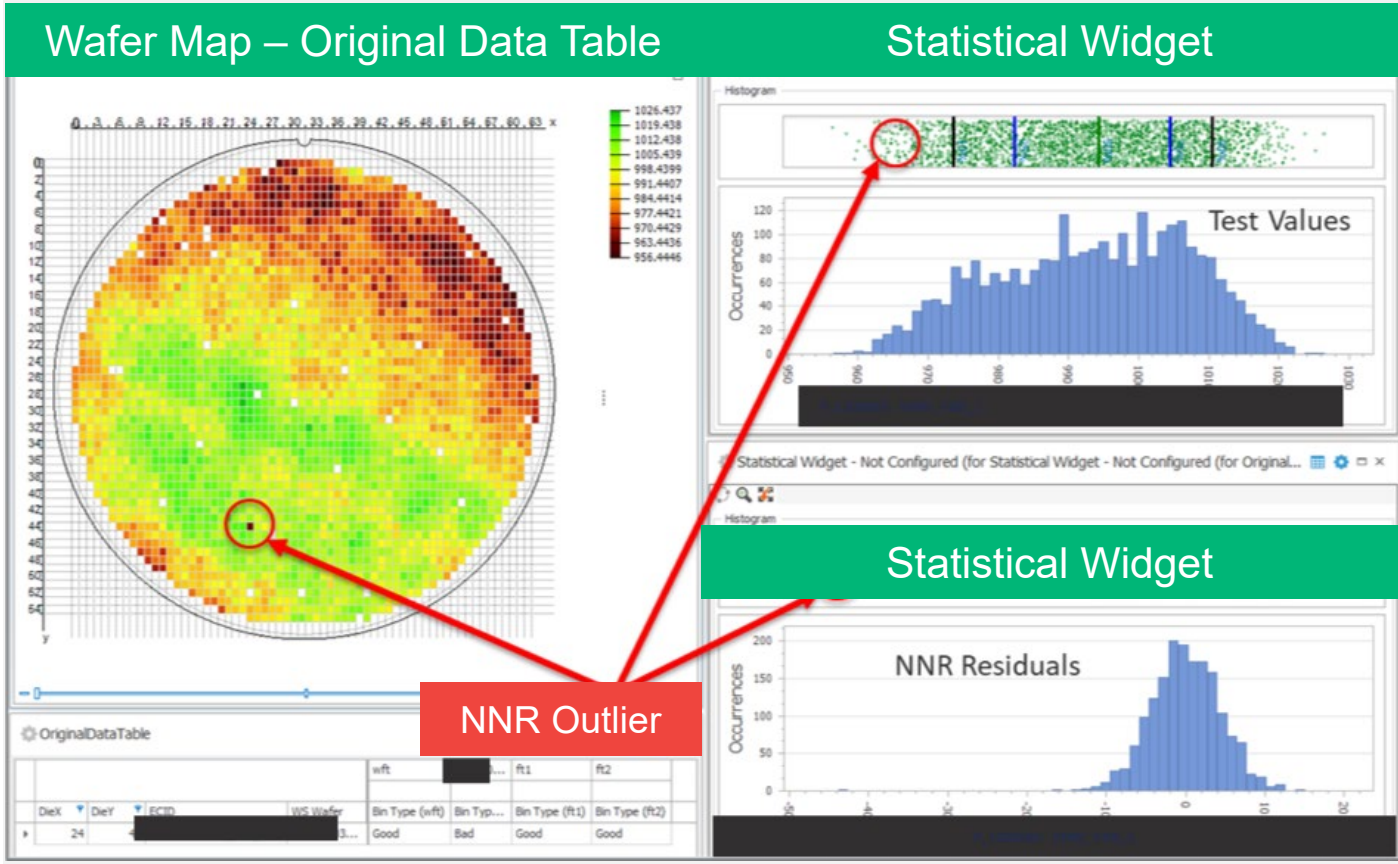
Re-bin (via MES)

Data Feed Forward and Test Program API

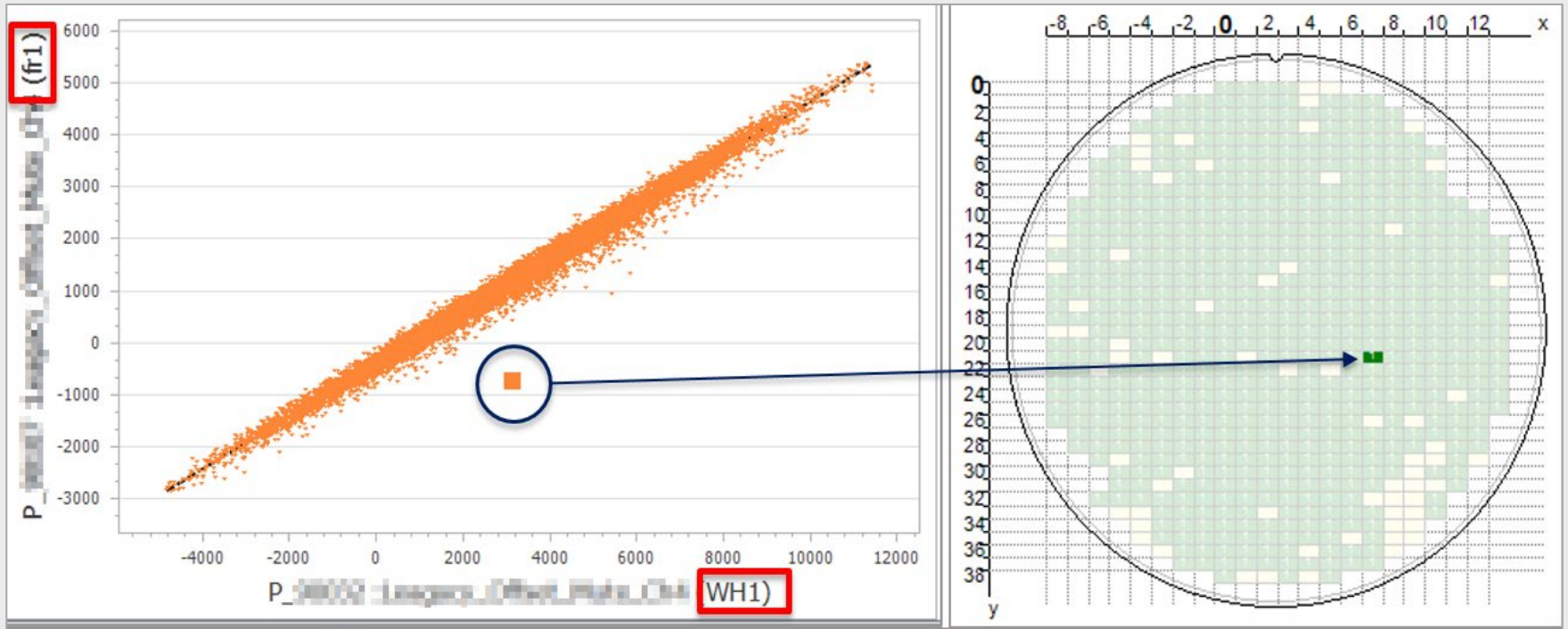
EXAMPLE

Outlier Detection

NNR (Near Neighbor Residual)



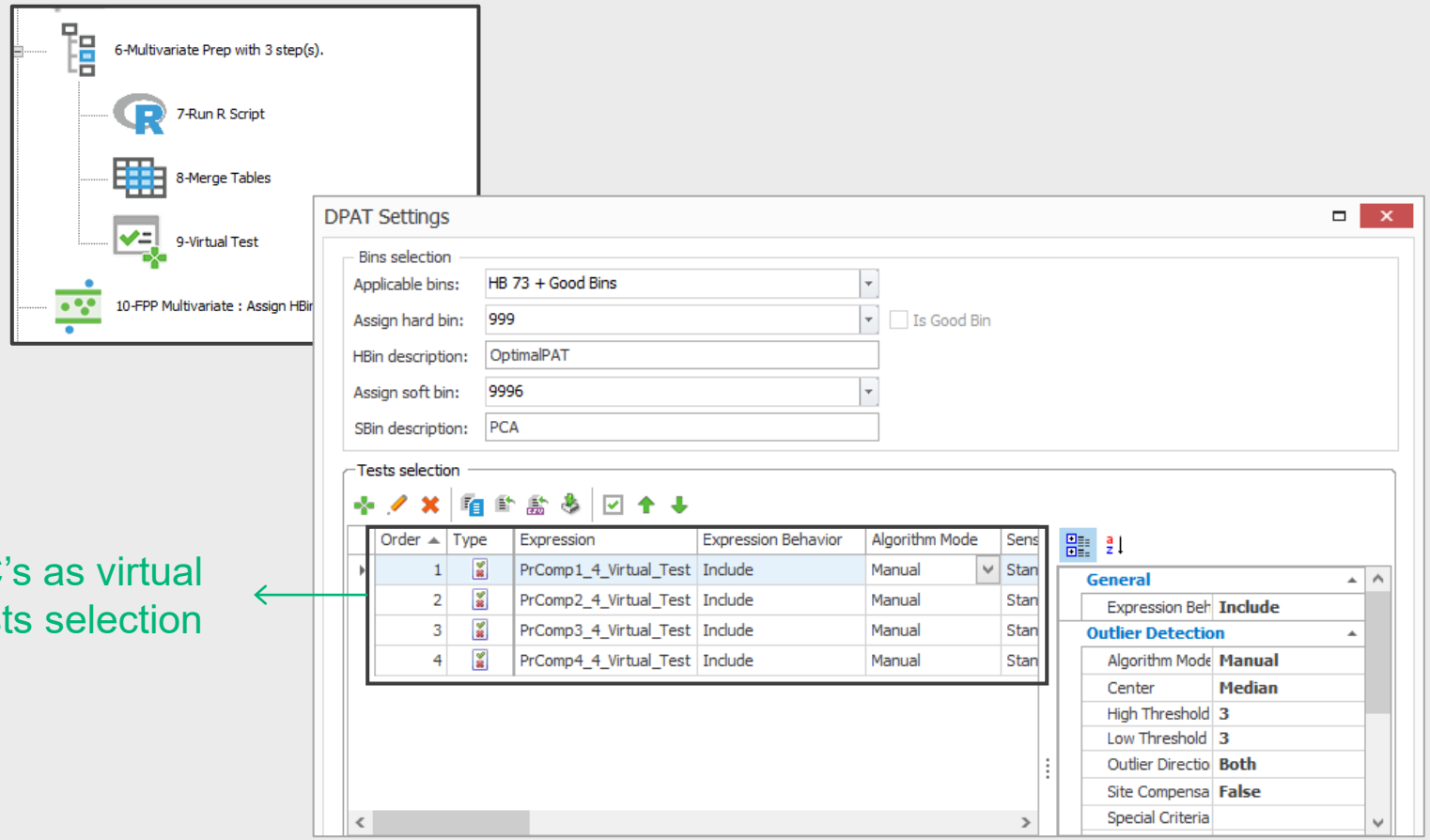
Bivariate Outlier Detection



				fr1				WH1			
							P_ (fr1)				P_
WS Wafer	DieX	DieY	ECID	Lot (fr1)	Hard Bin...	Soft Bin ...	Value (	Lot (WH1)	Hard Bin...	Soft Bin...	Value (P_
	7	21			1	1	-741.4802		1	1	3118.29

Bivariate outliers may be related to pairs of tests from the same or different operations

Multivariate Outlier Detection



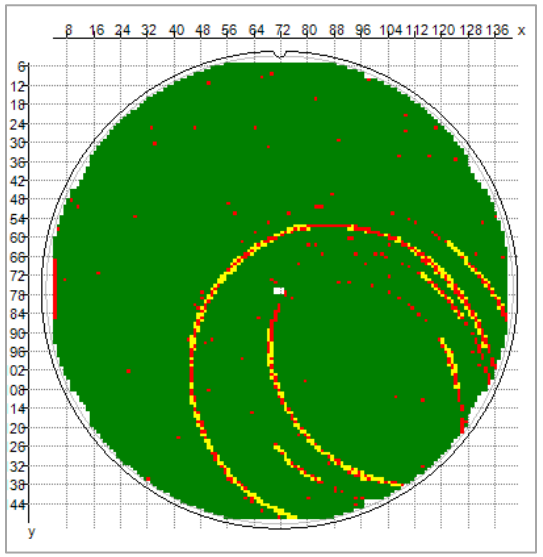
PC's as virtual tests selection

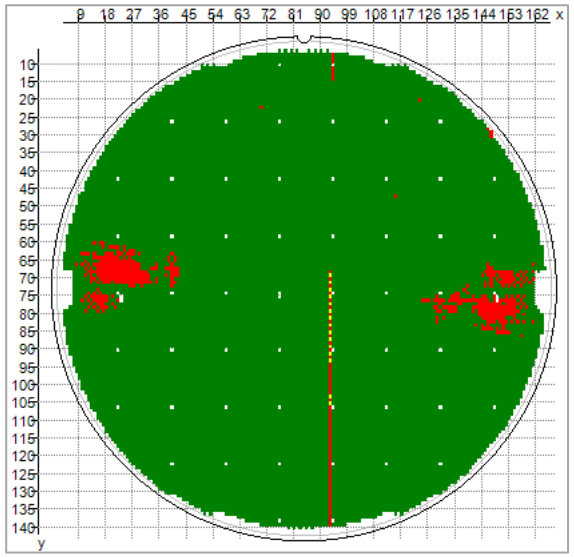
Several ML techniques can be used to screen multivariate outliers

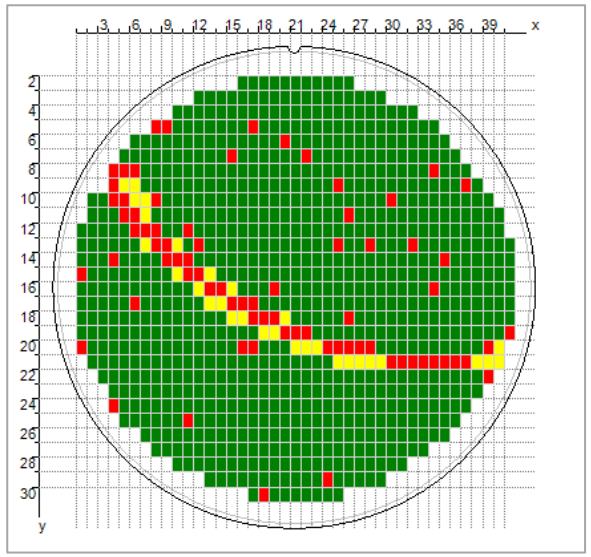
The methodology here is to use PCA (Principal Component Analysis) to define the main virtual tests, and then perform DPAT on such tests

Specialty Algorithm Example

Scratch Detection



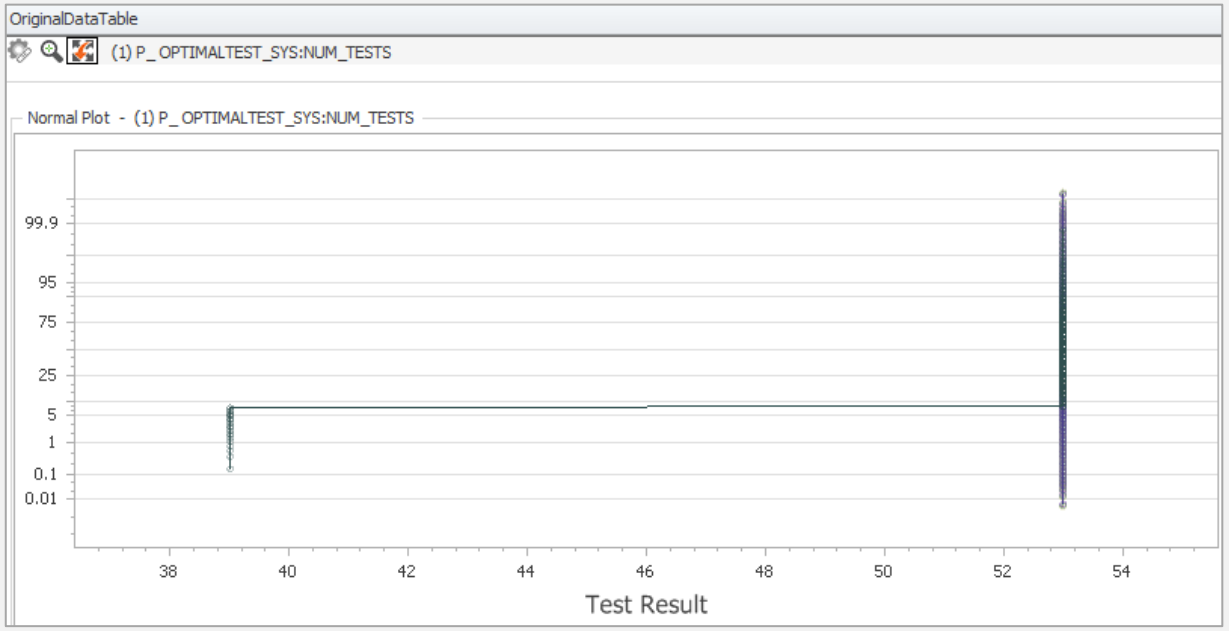




Patent pending

Escape Prevention Example

Not Enough Tests Performed On Parts



Standard PRR (53 tests)	Low PRR (39 tests)
PIR:1|5	PIR:1|1
PTR:200000|1|5|-0.549067|P|||LH	PTR:200000|1|1|-0.547264|P|||LH
PTR:200001|1|5|-0.520031|P|||LH	PTR:200001|1|1|-0.507356|P|||LH
PTR:200002|1|5|-0.520361|P|||LH	PTR:200002|1|1|-0.509317|P|||LH
PTR:200003|1|5|-0.647235|P|||LH	PTR:200003|1|1|-0.646587|P|||LH
PTR:200004|1|5|-0.638282|P|||LH	PTR:200004|1|1|-0.637824|P|||LH
PTR:200005|1|5|-0.514767|P|||LH	PTR:200005|1|1|-0.512531|P|||LH
PTR:90000000|1|5|0|P|||LH	PTR:90000000|1|1|1|P|||LH
PTR:10000000|1|5|0.793171|P|||LH	
PTR:10000001|1|5|18|P|||LH	
PTR:10000002|1|5|0.798799|P|||LH	
PTR:20000000|1|5|4.5|P|||LH	
PTR:30000000|1|5|0.408345|P|||LH	
PTR:30000001|1|5|2.30645|P|||LH	
PTR:40000000|1|5|500000|P|||LH	
PTR:50000000|1|5|523959|P|||LH	
PTR:50000001|1|5|2|P|||LH	
PTR:50000002|1|5|477160|P|||LH	
PTR:60000000|1|5|0|P|||LH	
PTR:62000000|1|5|8e-008|P|||LH	
PTR:70000000|1|5|1|P|||LH	
PTR:71000000|1|5|1|P|||LH	
PTR:400001|1|5|1.44211e-005|P|||LH	PTR:400001|1|1|1.32674e-005|P|||LH
PTR:500001|1|5|0.00185048|P|||LH	PTR:500001|1|1|0.00178691|P|||LH
PTR:600001|1|5|0.0136838|P|||LH	PTR:600001|1|1|0.0138471|P|||LH
PTR:800001|1|5|0.798832|P|||LH	PTR:800001|1|1|0.799737|P|||LH
PTR:900001|1|5|475881|P|||LH	PTR:900001|1|1|502445|P|||LH
PTR:1000002|1|5|0.934878|P|||LH	PTR:1000002|1|1|0.934067|P|||LH
PTR:1000003|1|5|0.0562721|P|||LH	PTR:1000003|1|1|0.0742091|P|||LH
PTR:1200002|1|5|1.32|P|||LH	PTR:1200002|1|1|1.32|P|||LH
PTR:1300000|1|5|4.7439|P|||LH	PTR:1300000|1|1|5.75846|P|||LH
PTR:1300001|1|5|0.840529|P|||LH	PTR:1300001|1|1|1.02042|P|||LH
PTR:1300002|1|5|3.72793|P|||LH	PTR:1300002|1|1|3.59691|P|||LH
PTR:1400000|1|5|4.4|P|||LH	PTR:1400000|1|1|4.4|P|||LH
PTR:1400001|1|5|4.1|P|||LH	PTR:1400001|1|1|4.1|P|||LH
PTR:1400002|1|5|0.3|P|||LH	PTR:1400002|1|1|0.3|P|||LH
PTR:1600000|1|5|-1.82428e-005|P|||LH	PTR:1600000|1|1|-1.83854e-005|P|||LH
PTR:1600001|1|5|2.02591e-005|P|||LH	PTR:1600001|1|1|1.95853e-005|P|||LH
PTR:1600002|1|5|0.000213899|P|||LH	PTR:1600002|1|1|0.000210948|P|||LH
PTR:1700008|1|5|0.147186|P|||LH	PTR:1700008|1|1|0.146048|P|||LH
PTR:1700009|1|5|0.712|P|||LH	PTR:1700009|1|1|0.712|P|||LH
PTR:1700010|1|5|0.726|P|||LH	PTR:1700010|1|1|0.726|P|||LH
PTR:1700011|1|5|0.876|P|||LH	PTR:1700011|1|1|0.876|P|||LH
PTR:1700012|1|5|0.862|P|||LH	PTR:1700012|1|1|0.862|P|||LH
PTR:1700013|1|5|1|P|||LH	PTR:1700013|1|1|1|P|||LH
PTR:2000000|1|5|97.5345|P|||LH	PTR:2000000|1|1|101.71|P|||LH
PTR:2100000|1|5|22.8233|P|||LH	PTR:2100000|1|1|23.6104|P|||LH
PTR:2300000|1|5|0.0048847|P|||LH	PTR:2300000|1|1|0.00450245|P|||LH
PTR:3300000|1|5|-1.46336e-010|P|||LH	PTR:3300000|1|1|-1.5416e-010|P|||LH
PTR:3300001|1|5|-9.45279e-009|P|||LH	PTR:3300001|1|1|-6.4442e-010|P|||LH
PTR:3300002|1|5|1.28664e-009|P|||LH	PTR:3300002|1|1|1.37676e-009|P|||LH
PTR:3300003|1|5|1.37701e-007|P|||LH	PTR:3300003|1|1|1.26581e-007|P|||LH
PTR:3300004|1|5|2.92561e-010|P|||LH	PTR:3300004|1|1|6.0502e-010|P|||LH
PTR:3300005|1|5|4.87588e-010|P|||LH	PTR:3300005|1|1|4.02279e-010|P|||LH
PRR:1|5|6|53|P|1|1|-1|-1|||3917	PRR:1|1|1|39|P|1|1|-1|-1|||2739

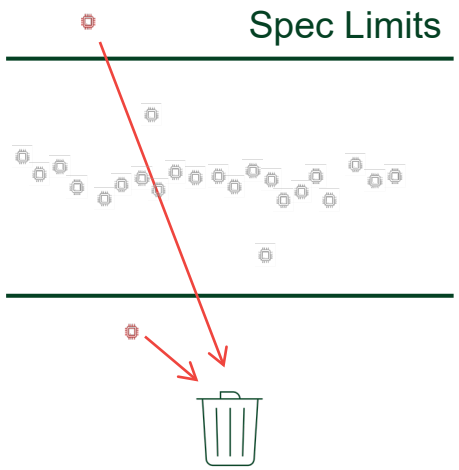
MISSING TESTS

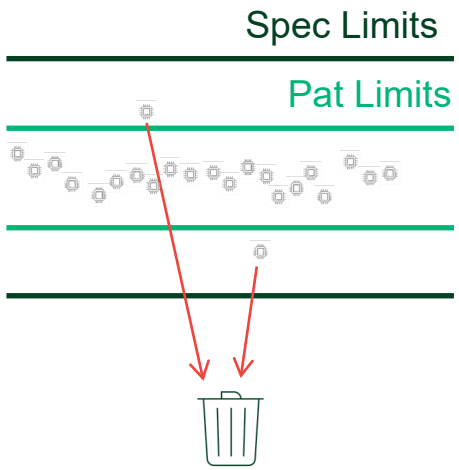
- Chart shows that the number of tests for a good device is 53 tests
- 5% of the units on one lot have 39 tests
- Automated rule detects this in production and prevents the parts from shipping

PAT For Packaged Units (FT PAT)

Skip next testing for units marked as ‘outlier’ bins

* Requires ECID





Defectivity Index (I-PAT) Correlation To Sort

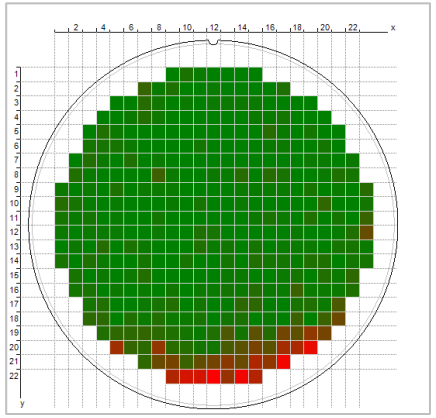
Better screening using both test and defectivity data

Applying I-PAT defect outlier recognition

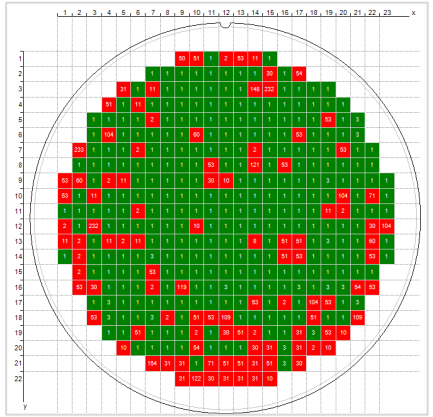
Using G-PAT to detect clusters using combination of test and I-PAT data

I-PAT can identify individual statistical outlier die, and drill down to root cause

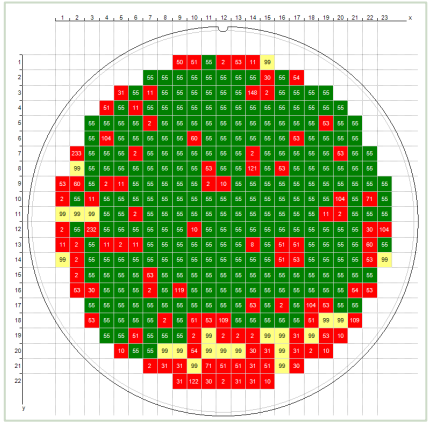
Smart I-PAT Map



Bin Map

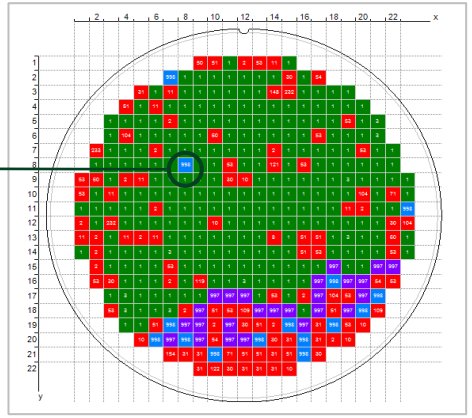


Bin Map Post
Standard Outlier Detection



HB99 → G-PAT
(test only)

Bin Map Post
Enhanced Outlier Detection



HB998 → I-PAT Static PAT
HB997 → G-PAT outliers
(test and defectivity)

Image Processing Flow

SAM inspection generates board image (jpg)

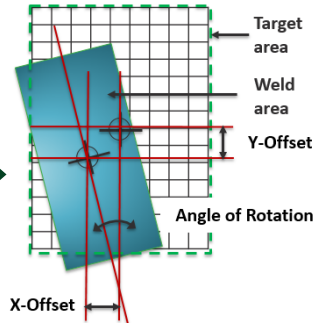
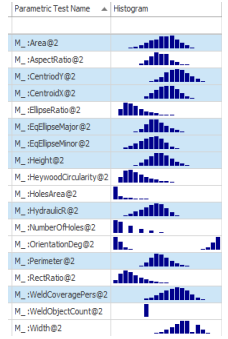
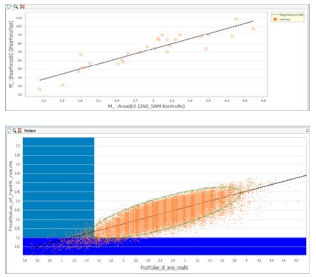


Image algorithm analyzes each welding location (pin) on the board



18 parameters are generated for each pin on the board (instead of just one parameter previously collected – the welding area)



Parameters are loaded into O+ to allow analytics, rules and correlations to machine/product data

Yield Analysis and Reclamation Solutions

Yield

Overall yield

Site-to-site yield

Re-test policy

Equipment and hardware performance issues

Baseline yield and SBL monitoring

Test equipment performance

Test and retest policies and execution

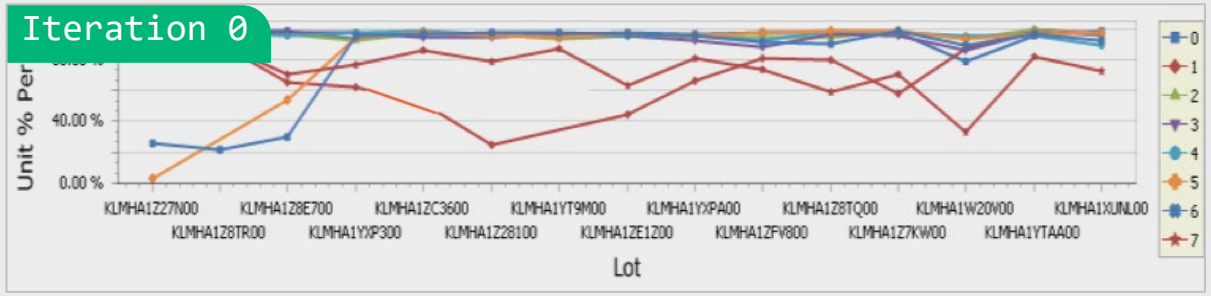
Tests limits validation

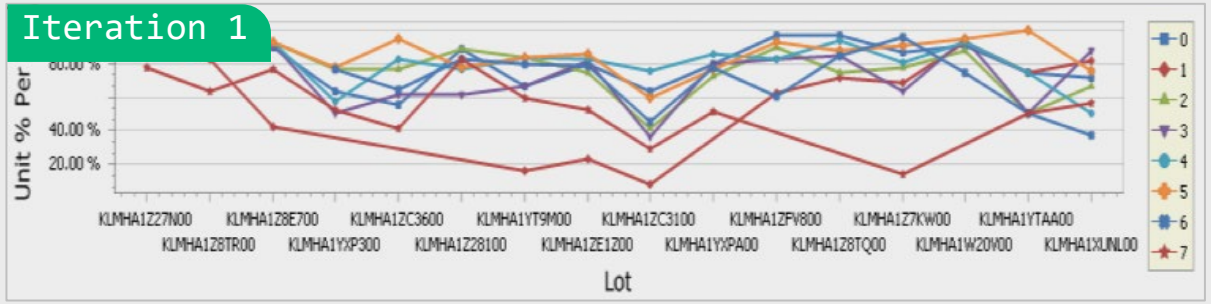
Cross-operation correlation

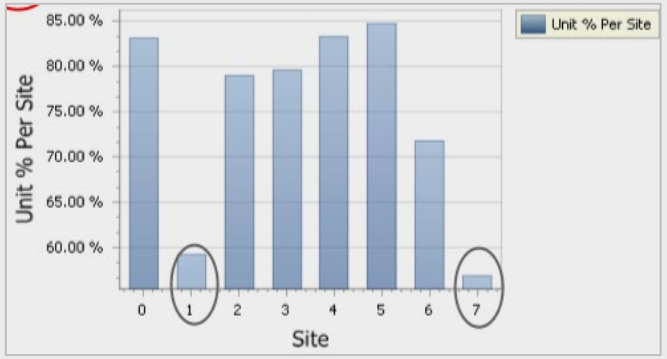
Targets against any measure/KPI

Customer Use Case: Operational Yield

Site Issue







Device:
Network

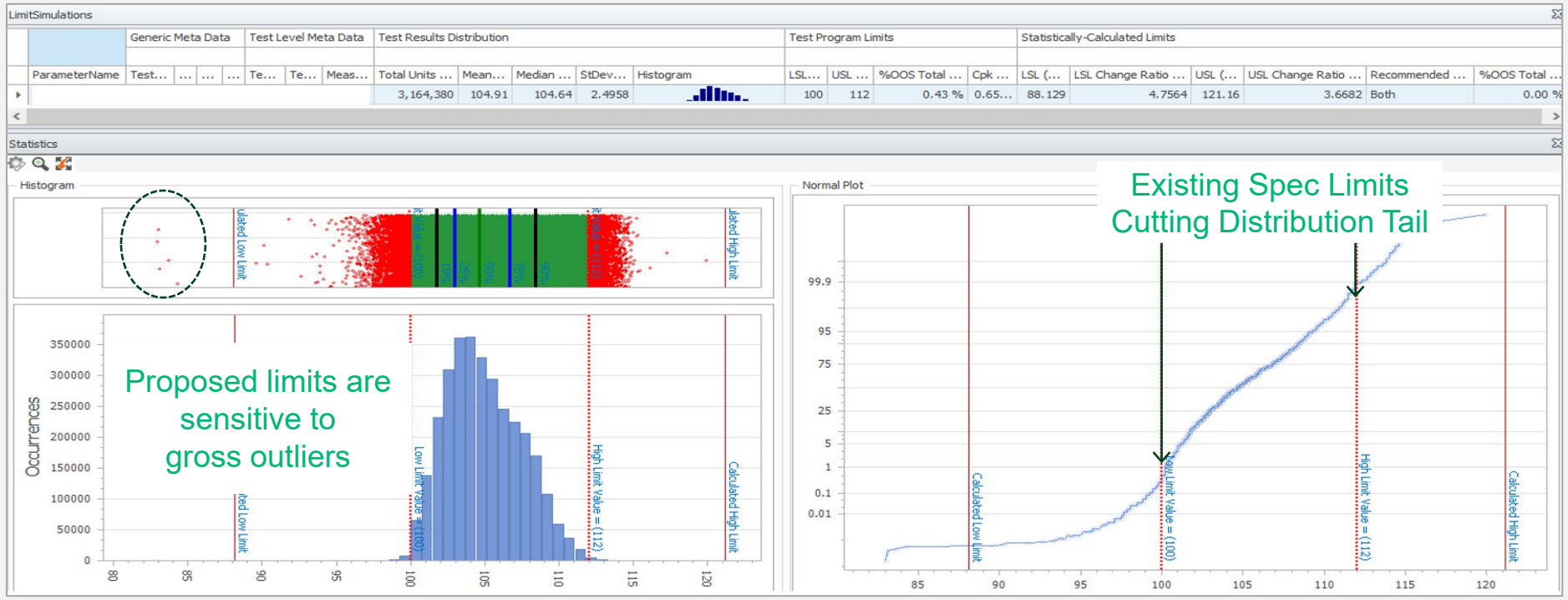
Problem:
Yield loss

Issue:
Yield by tester varies

Standard O+ Rules Found
With no monitoring – Site-Site issue not detected – This case is 16 lots

Yield Improvement Example

Tight Spec Limits



- Current test limits are too tight, causing 0.4% yield loss
- Proposed test limits will reduce yield loss without impacting product quality

Efficiency Solutions

Efficiency

Inconsistent tester availability and utilization

Excessive index and pause times

Test time variations per tester

Inefficient retest policies and execution

Adaptive Testing using Machine Learning

Test equipment performance

Test and retest policies and execution

Testers availability and utilization (OEE analysis)

Classical Test Time Reduction (TTR analysis, ROA)

Adaptive Test Time Reduction (ATTR)

Cross-operation correlations

Shop Floor Control

Test Efficiency Opportunities

Better resolution of time during test

Actual test time maximization (vs. index time)

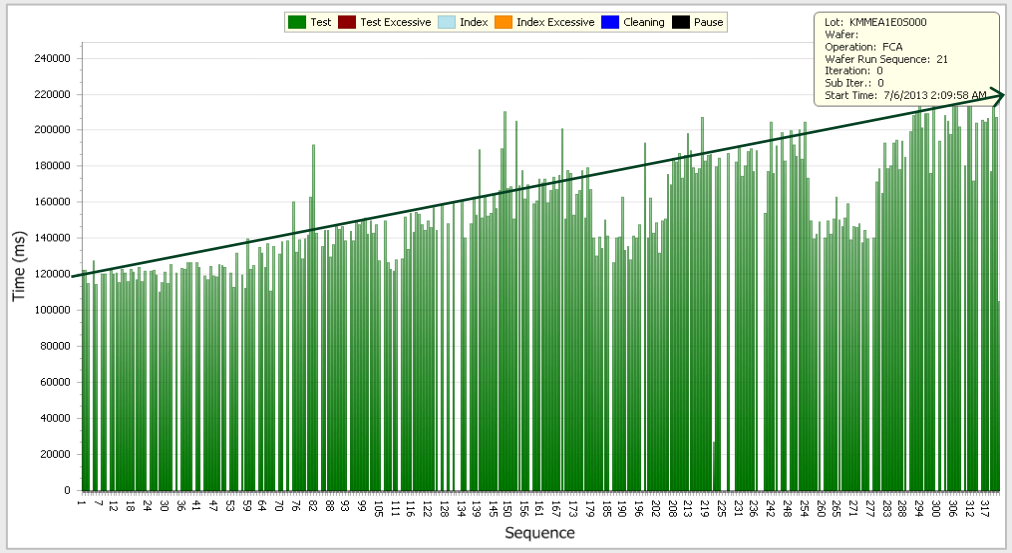
Retest optimization

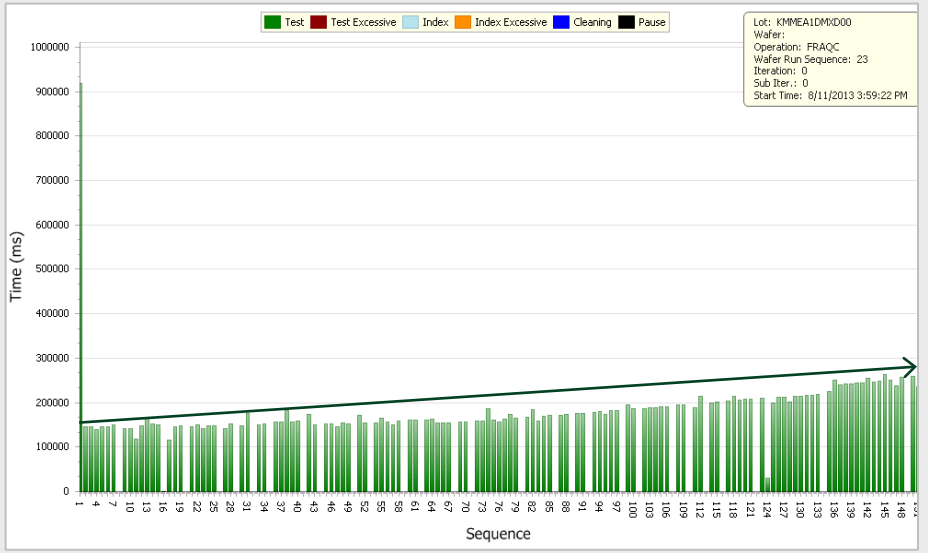
Test time consistency

Tester utilization – owned, consigned or paid for

Customer Use Case: Efficiency Problem

Increasing Test Time





Standard O+ rules found
Testers had different throughputs
Test Time Increasing from 120 Sec to 300 Sec

Result: Saved 8 test stations = $12M in CapEx and OpEx Savings

Device:
Microcontroller with flash

Problem:

Capital avoidance Issue: Needed 10 more test stations

Problem Discovered:

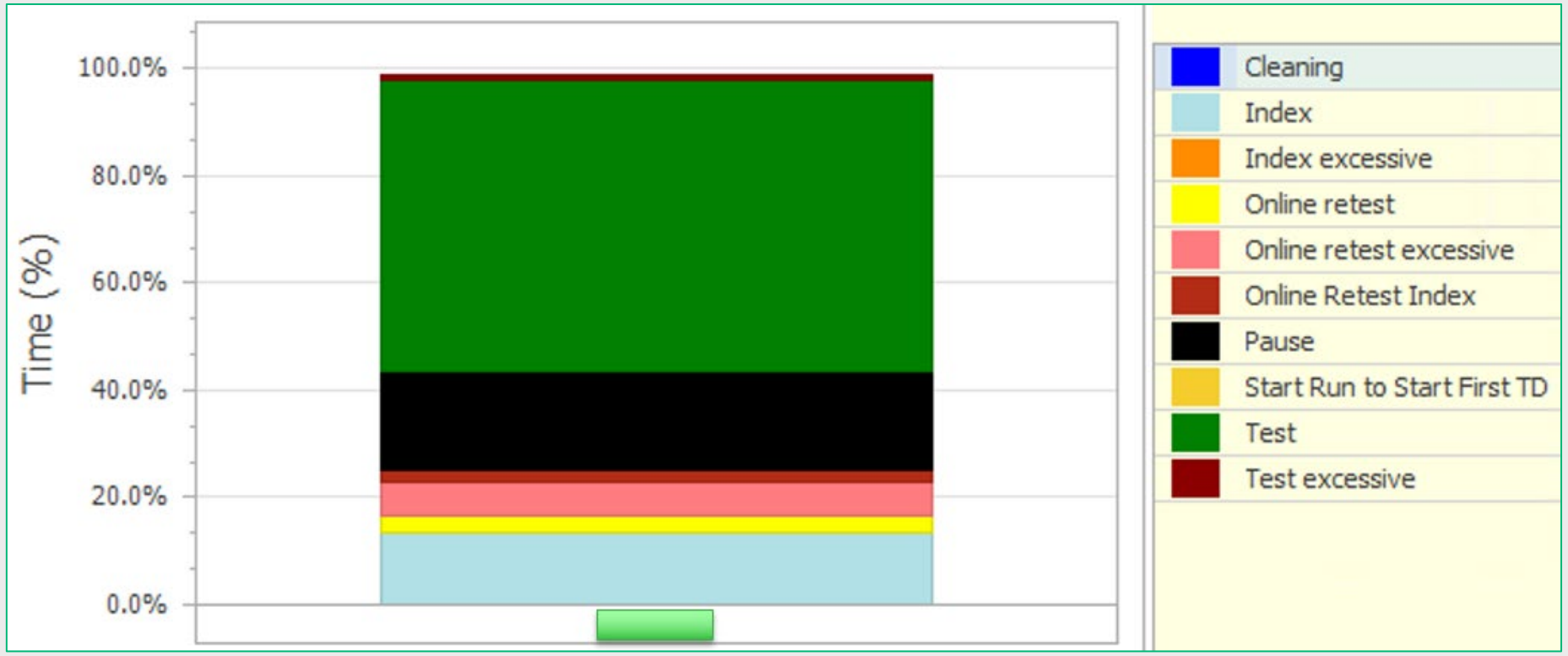
Issue with test program

Fix:

Improved O+ rule for monitoring for all future testers/devices

Overall Equipment Efficiency

Tester Usage Breakdown By Category



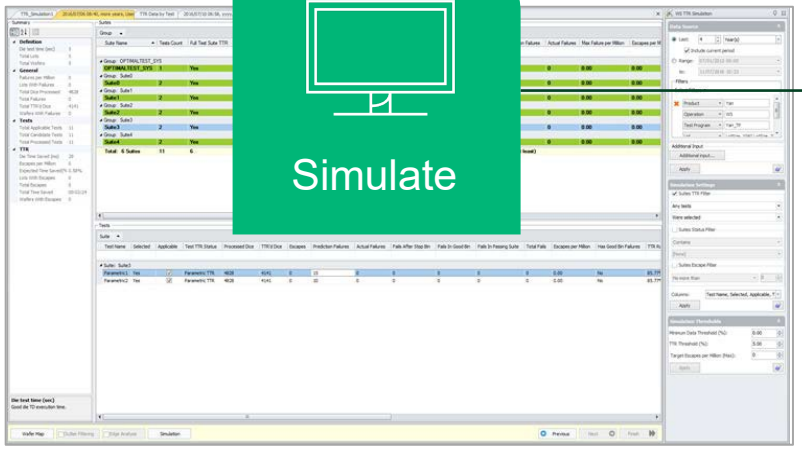
O+ collects detailed data on tester operation

Tester usage statistics allow to perform in-depth productivity analyses (e.g. OEE) which help eliminate wasted time

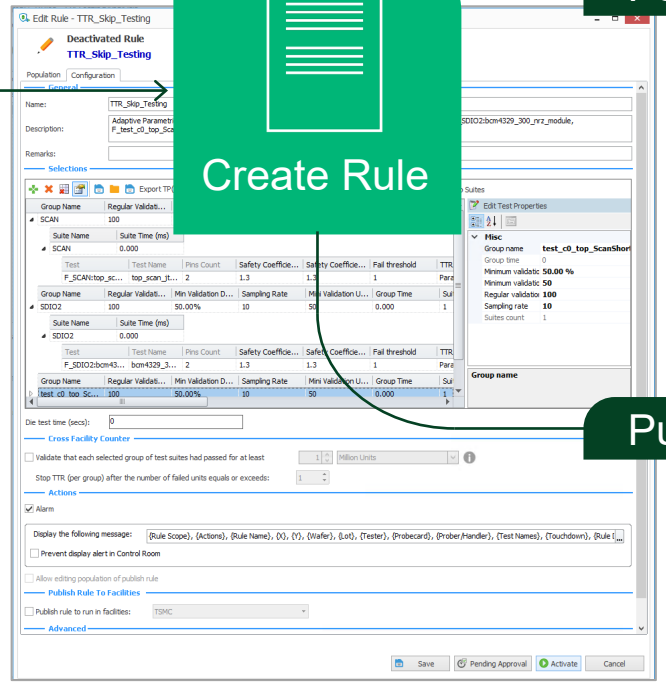
Customer Use Case

Test Time Reduction

HQ



Simulate



Publish

Publish

Facility A

MES

Proxy/ Server

Tester/Proxy

Facility B

MES

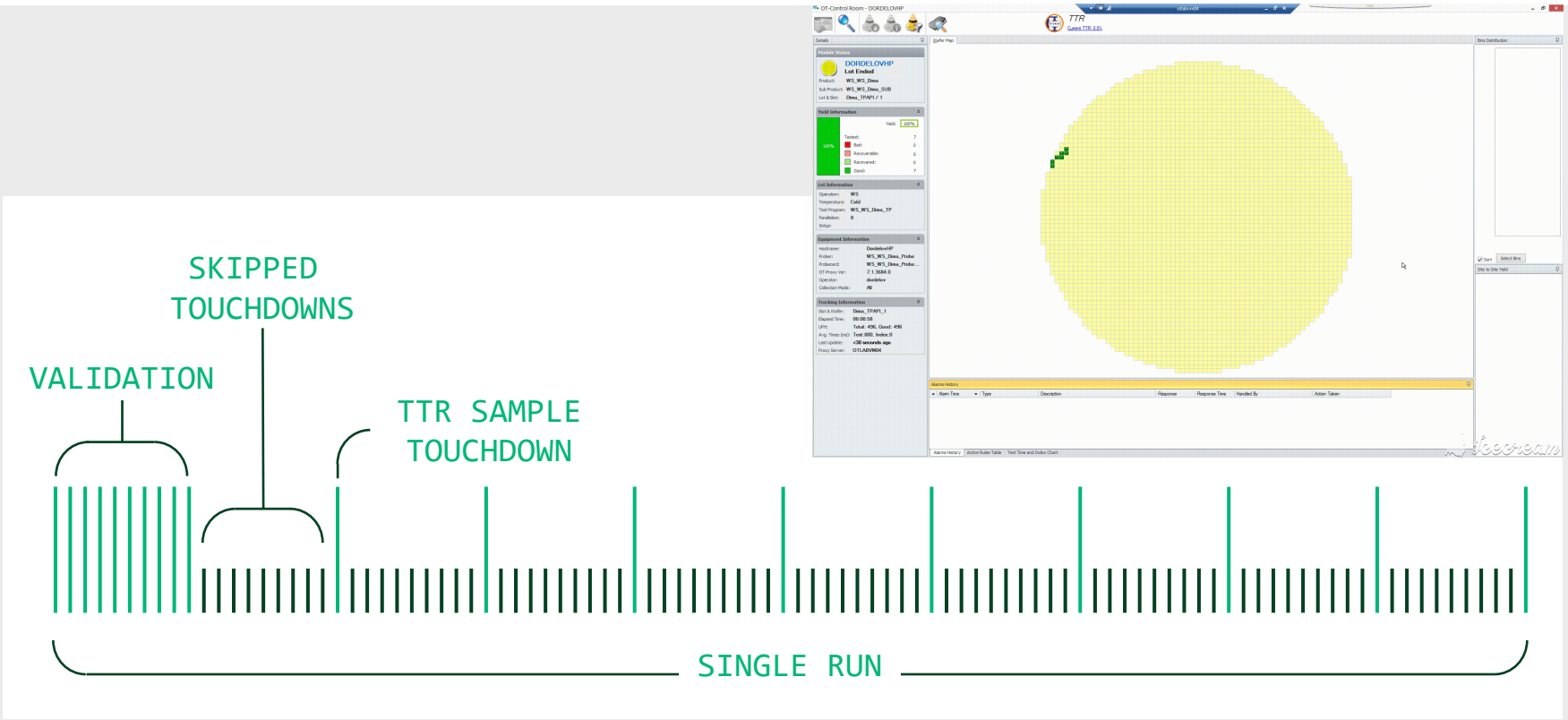
Proxy/ Server

Tester/Proxy

Identify tests that can be skipped, create rules and publish to the testers, wherever they are

Adaptive Test Time Reduction

Example Run Showing TTR Element



Sampling

Zero fails validation (before skipping tests) in each run

Time-To-Market Solutions

Time-To-Market

Shorten NPI time

Optimize balance between time, cost, and quality

Facilitate multi-team collaboration

Share learnings from NPI to HVM and back

Adaptive test (reduction or augmentation) and smart ramp

Data loading rules

Load and create conditions

Sandbox to edit metadata

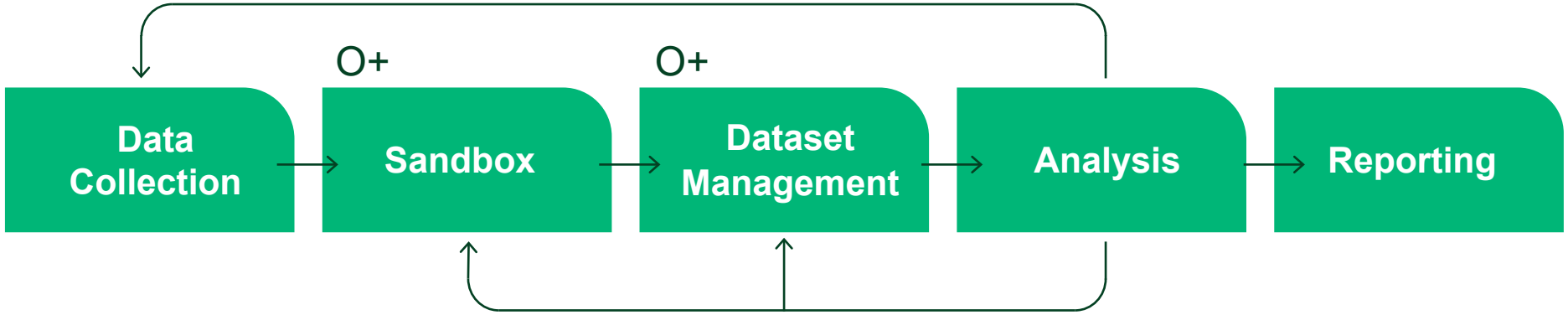
Datasets

- Virtual “workbench”
- Shared analyses and data augmentation
- Full chain of custody

Limits, Correlation and GR&R Applications

Report generation

NPI Areas Of Focus and Flow



- Proxy
- Drop Box
- STDF

- OTDF
- SAF

- Data Cleansing
- Mapping
- Validation

- Association
- Augmentation
- Attributes
- Templates

- PVT Analysis
- Correlation App
- Limits App
- GRR App

- Static/Scheduled
- Flexible
- Intuitive
- Customized

Minimize time to market

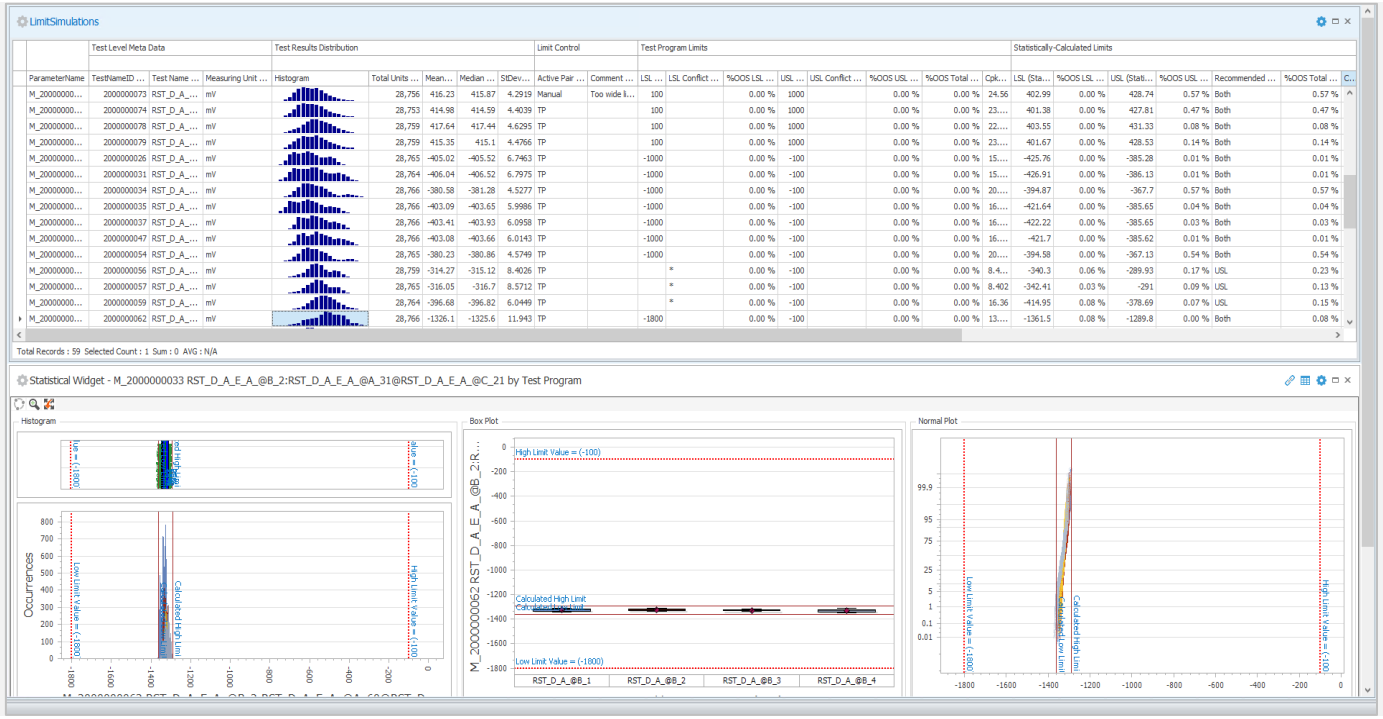
Analyze split lots

Determine production limits

Identify design sensitivities

Customer Use Case: Time-To-Market

Limit Simulation App



Device:
Cell phone

Problem:
Limits not optimized

Issue:
Would not fail questionable measurements

Fix:
Run analysis using limits application

O+ standard tools found: Limits too wide

Result: Immediate feedback = Faster product launch

Supplier Transparency Solutions

Supplier Transparency

Benchmark suppliers

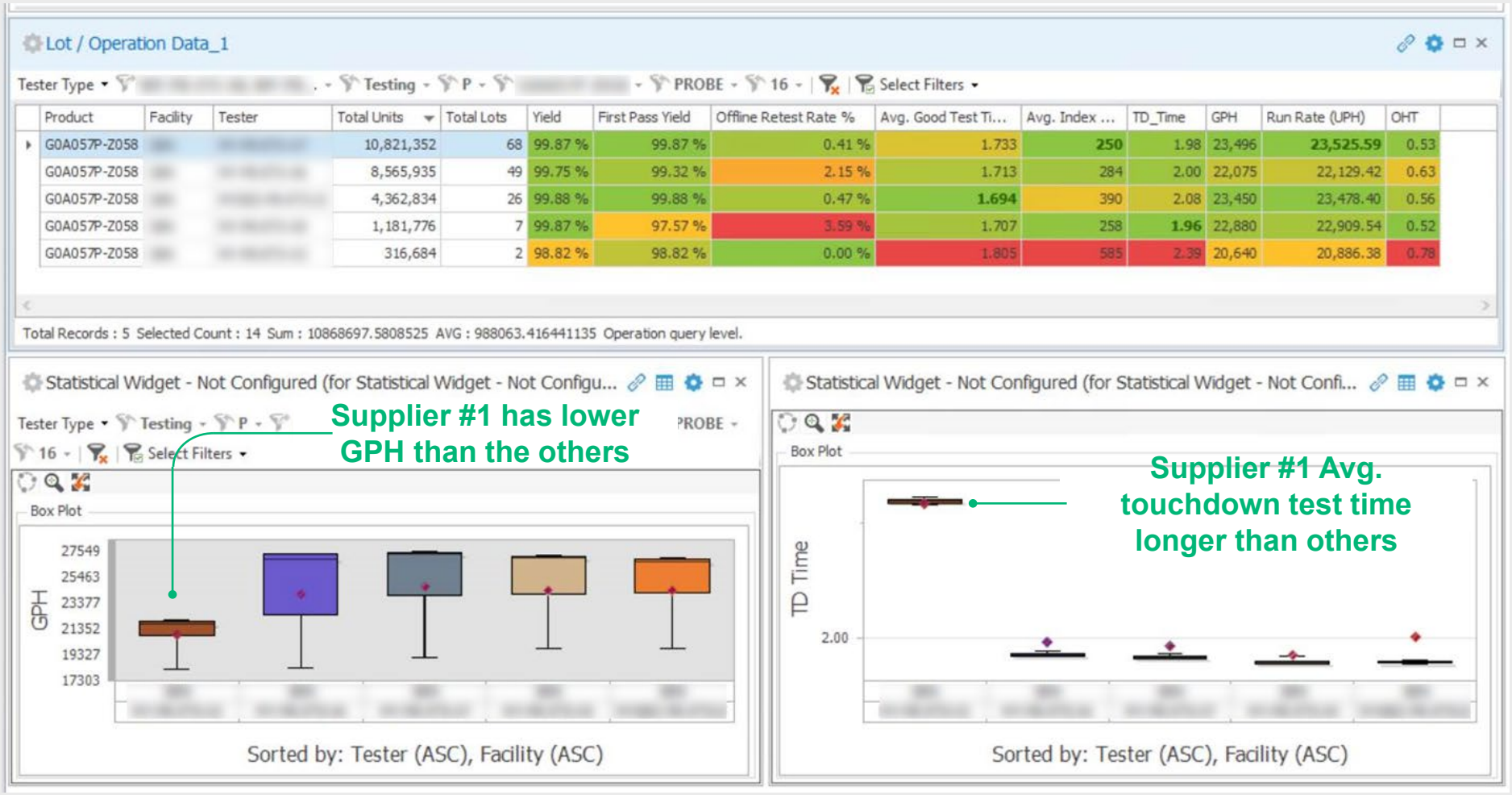
Ensure supplier compliance with flows for every chip

Site to site comparison

Supplier to supplier comparison

Customer Use Case

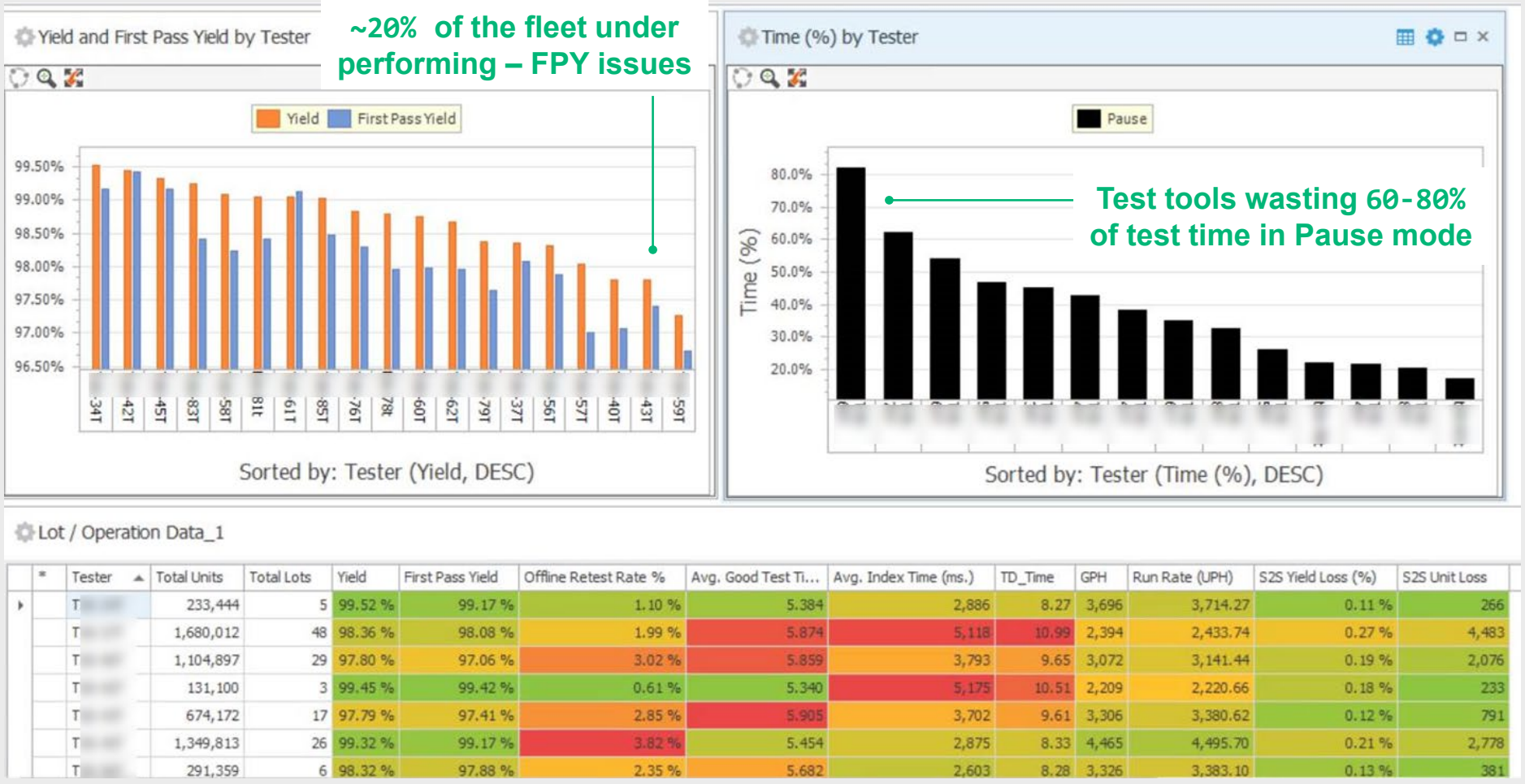
Suppliers Benchmark Dashboard For Key KPIs



- Provides consolidated views of operations across all suppliers mfg. sites
- Enables objective benchmarking of suppliers
- Highlights KPIs that require attention
- Enables drilldown for root-cause analysis

Customer Use Case

Supplier Transparency Into Consigned Test-Fleet Performance



Lot / Operation Data_1

Tester	Total Units	Total Lots	Yield	First Pass Yield	Offline Retest Rate %	Avg. Good Test Ti...	Avg. Index Time (ms.)	TD_Time	GPH	Run Rate (UPH)	S2S Yield Loss (%)	S2S Unit Loss
T	233,444	5	99.52 %	99.17 %	1.10 %	5.384	2,886	8.27	3,696	3,714.27	0.11 %	266
T	1,680,012	48	98.36 %	98.08 %	1.99 %	5.874	5,118	10.99	2,394	2,433.74	0.27 %	4,483
T	1,104,897	29	97.80 %	97.06 %	3.02 %	5.859	3,793	9.65	3,072	3,141.44	0.19 %	2,076
T	131,100	3	99.45 %	99.42 %	0.61 %	5.340	5,175	10.51	2,209	2,220.66	0.18 %	233
T	674,172	17	97.79 %	97.41 %	2.85 %	5.905	3,702	9.61	3,306	3,380.62	0.12 %	791
T	1,349,813	26	99.32 %	99.17 %	3.82 %	5.454	2,875	8.33	4,465	4,495.70	0.21 %	2,778
T	291,359	6	98.32 %	97.88 %	2.35 %	5.682	2,603	8.28	3,326	3,383.10	0.13 %	381

- Provides consolidated view of 100s-1000s fleet tools
- Enables real time and consistent equipment sets benchmarking
- Highlights KPIs require attention
- Enables drilldown for root-cause analysis

Partner with us to enhance your big data strategy with our open platform

Synergetic With Any Data Lake | Cloud and On-Premise | Accessible Optimized Schema | AI and Machine Learning | Collect and Act Anywhere | Enhance Data Scientist Productivity

Data Platform Needs

Voice of the Market

"How can I combine, and do more with my siloed data systems?"

"I know we need to do ML, we just don't know how to get started."

"My teams are proficient in Python or R and I want to leverage this."

"We already have a corporate license of Tableau, can we use this to visualize O+?"

"Our data retention is at least 10 years for our automotive products."

"How can we store old data so it doesn't take so long to reload and use?"

"Can we have programmatic access to O+ data?"

"I want to leverage fab/assembly data (i.e. defect and inspection) to improve my quality."

Consolidated Challenges

CTO/CIOs and IT Professionals	Concerned about enterprise TCO (Total Cost of Ownership)
Product, Quality and Yield Engineering Teams	Need a solution providing analytics that scale
Data Scientists and Engineering Teams	Need a collaborative ecosystem

Platform Goals

1. Support bi-directional data integration with any customer data lake
2. Enable easy consumption of OptimalPlus data by 3rd parties and BI tools
3. Integrating with machine learning data science frameworks, leveraging OptimalPlus deployed infrastructure
4. Boost developer's innovation by leveraging OptimalPlus rich API's, algorithms and infrastructure
5. Data security and encryption

Industry Focused Open Platform

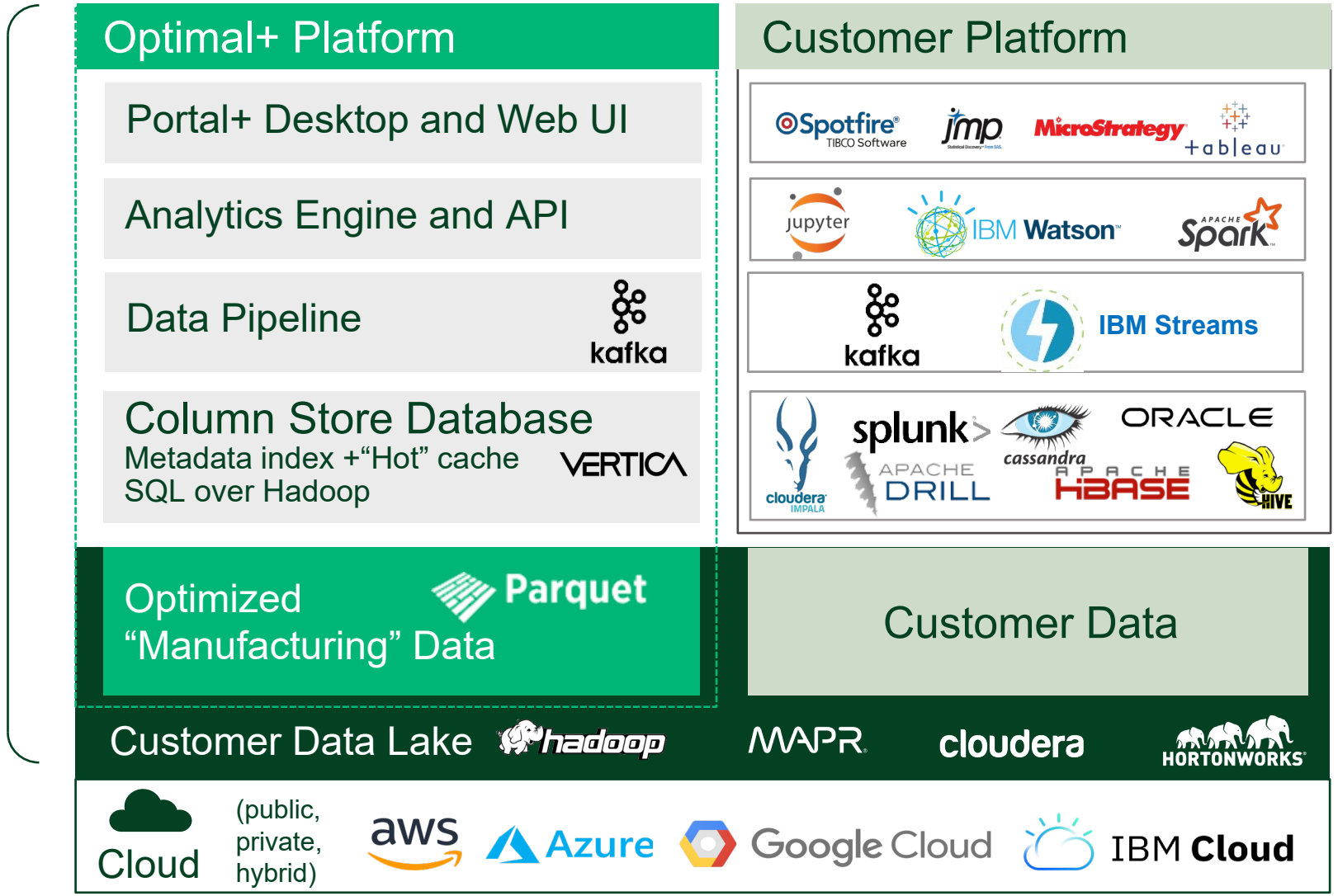
Synergetic with any big data strategy

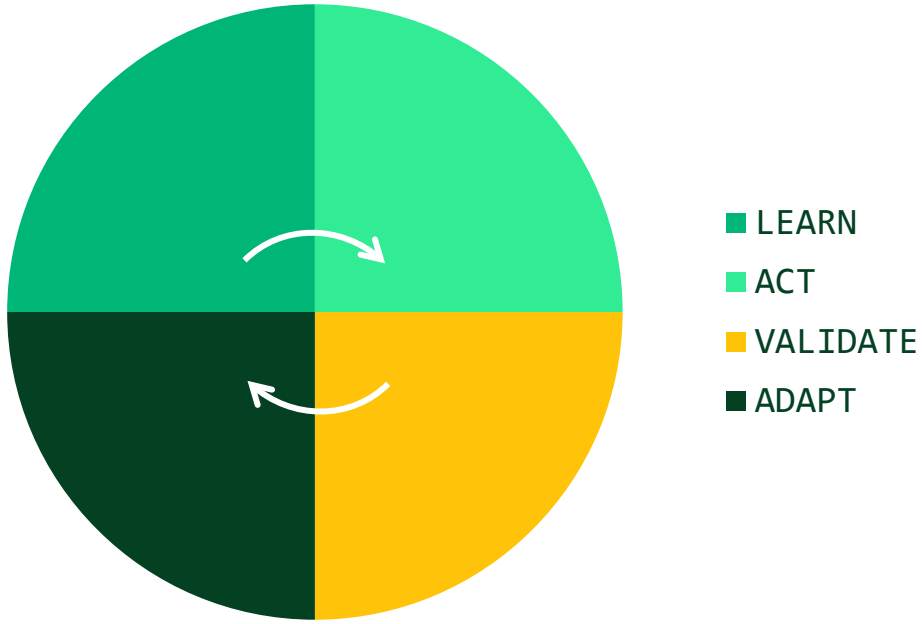
Connected to existing infrastructure

Open for all kinds of data

Accelerates innovation

Extensible through both data and algorithms





The Full Machine Learning Lifecycle

Learn from data and evaluate business value

Deploy and act upon the model

Monitor data and model performance to identify changes

Understand changes and update model/process

AI/ML Deployment Challenges

Learn

Getting data
Data scientists waste time getting and organizing data

Feature extraction
It is difficult to extract complex features from the data set

Freedom of choice
Data scientists want to use their favorite tools and the latest-and-greatest algorithms

Act

Complex “plumbing”
Data scientists waste time dealing with the “plumbing” associated with getting a model into production

Actionability
Taking action requires integration with equipment and systems

Distributed mfg.
Issues compounded in distributed, outsourced mfg.

Validate

Ongoing validation
Production models need to be validated all the time

Ongoing data collection
Data collection becomes an ongoing concern

Technical debt
Data scientists end up spending time monitoring “old” projects instead of investing in new ones

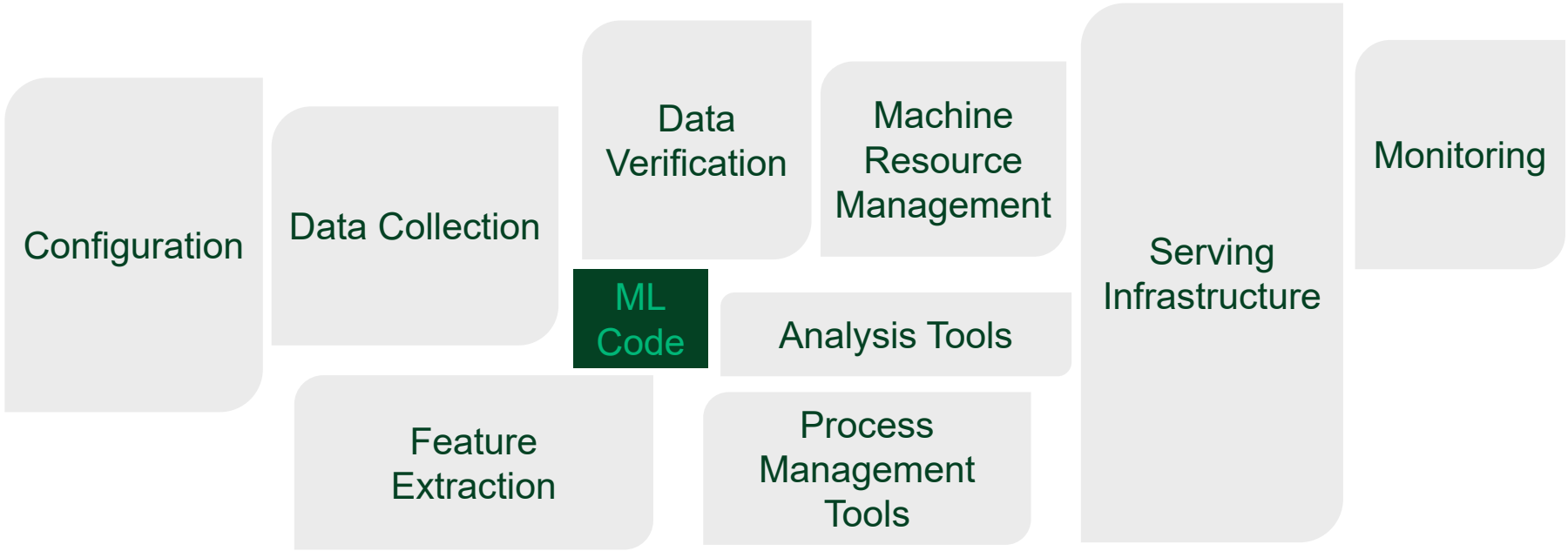
Adapt

Stale models
Production changes inevitably cause models to go stale

Relearning
Model relearning is often manual

Hidden Complexity

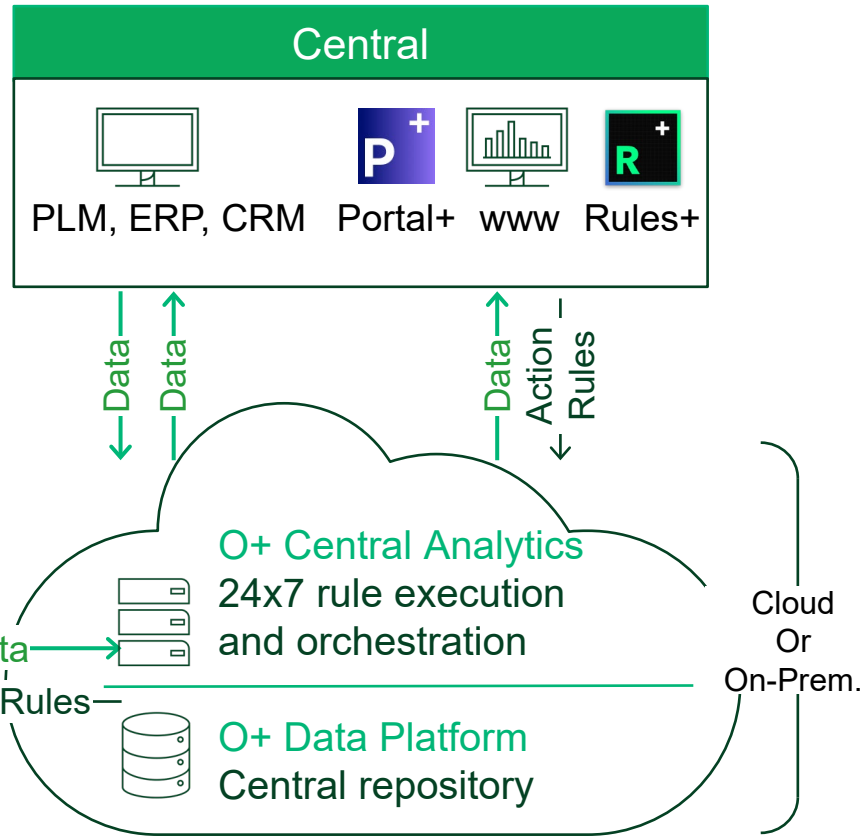
The Google View

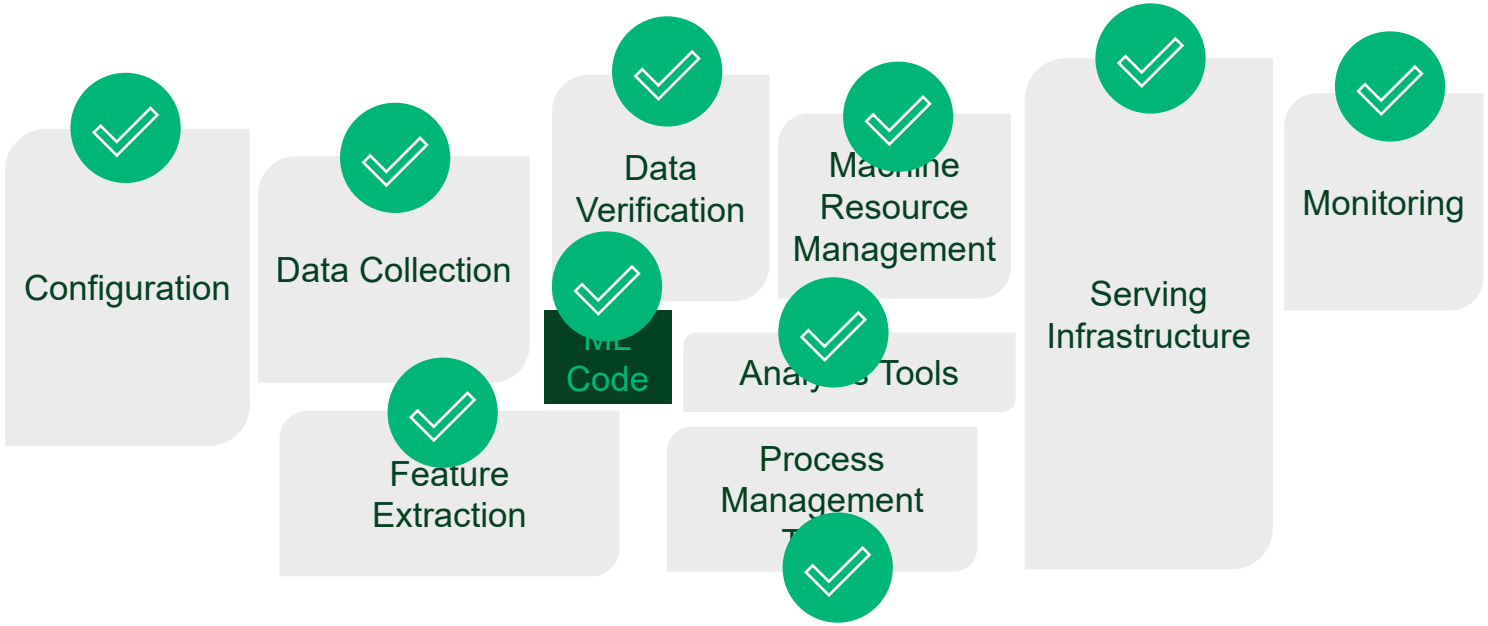


It's all about the infrastructure

Source: Google article from 2014: Hidden Technical Debt in Machine Learning Systems
https://papers.nips.cc/paper/5656-hidden-technical-debt-in-machine-learning-systems.pdf

Optimal+ Covers The Entire Lifecycle





Optimal+ covers the full scope all the way through ML deployment

Source: Google article from 2014: Hidden Technical Debt in Machine Learning Systems
https://papers.nips.cc/paper/5656-hidden-technical-debt-in-machine-learning-systems.pdf

Summary

Lifecycle Analytics Solutions	turning data into actions or immediate ROI
Product-Centric Approach	for improved quality and reliability and operational efficiency
AI/ML	support digital transformation in manufacturing
Open Platform	industry focused for seamless integration with any big data strategy
End-To-End Supplier Transparency	across operations and industries
Domain Expertise	applying data science to solve industry challenges

Significant Business Impact

Quality, Reliability and Brand Protection	50% case avoidance
Yield Analysis and Reclamation	increase up to 10% NPI 2% HVM
Efficiency	up to 25% test cost savings
Time To Market	from weeks to days NPI, TTM, RCA
Supplier Transparency	Consistency and compliance

Ask Our Customers

"Escape Prevention enables us to identify specific manufacturing and test issues that drive advanced quality screening and comprehensive product management."

QUALCOMM

Michael Campbell

SENIOR VP OF ENGINEERING

"Optimal+ gives us real-time visibility of our test operations, enabling us to monitor every critical parameter to ensure that every product is of the highest quality and performs as expected."

NVIDIA

Keith Katcher

VP OF OPERATIONS ENGINEERING

"Global Ops for Electronics enables us to rapidly identify and respond to the source of any PCB and systems manufacturing issue, down to an operation, facility, line or station."

XILINX

Vincent Tong

SENIOR VP OF GLOBAL OPERATIONS AND QUALITY

"We see Optimal+ as a strategic partner. Their open architecture enables us to create synergy across different tools and systems across the globe and accelerate innovation"

NXP

David Reed

EXECUTIVE VP OF TECHNOLOGIES AND OPERATIONS

Thank You