

OPTIMAL+

Lifecycle analytics you can trust

Product lifecycle analytics

Solutions for Semiconductors

Presenter

Month 2019



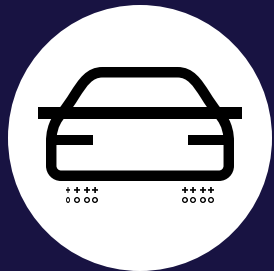
It's a changed world

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.

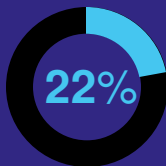




Automotive innovation reliability challenge



car innovations & new features are driven by electronics¹



warranty costs related to electronics & semiconductors²



car recall increase from 2014-2016 due to electronics³

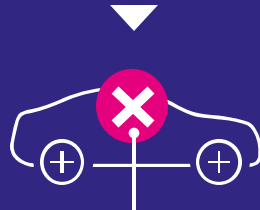


Ignition switch failure
Failure to park
Takata airbag recall

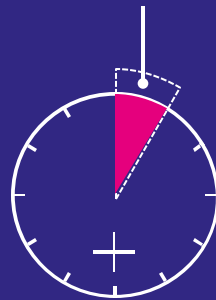


15x Drive per day⁴:
1.5hr traditional car vs.
22.5hr autonomous car

Audi says



1 car failure
every hour⁴



Reliable electronics is a must



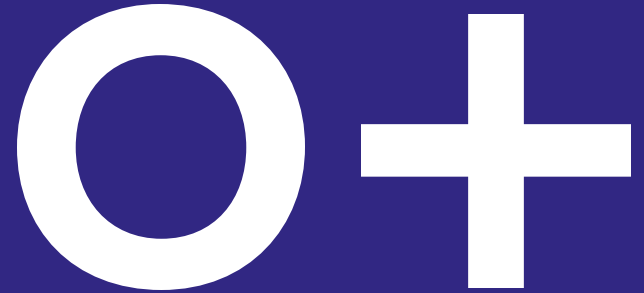
1) Automotive change drivers for the next Decade, EY, 2016
2) BMW - AEC Automotive electronics reliability workshop, 2017
3) NHTSA Recall Data
4) Audi, DVCon Munich, 2017

Our role

We deliver unprecedented manufacturing efficiency and reliability to the Automotive, Semiconductor and Electronics supply chains.

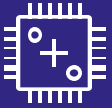
We provide actionable insights through unique data analytics to prevent bad products from reaching the market.

We call it **lifecycle analytics**



Analyzing huge volumes of data

100bn+
devices per year



Semiconductor



Automotive



Electronics



Trusted by leading brands

Customers



Supply chain



Providing innovative solutions

Customer 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

Collect

- Data harmonization
- Product, machine and process data

Detect

- Prescriptive analytics
- AI / Machine learning
- 24x7 analytics engine
- Real-time

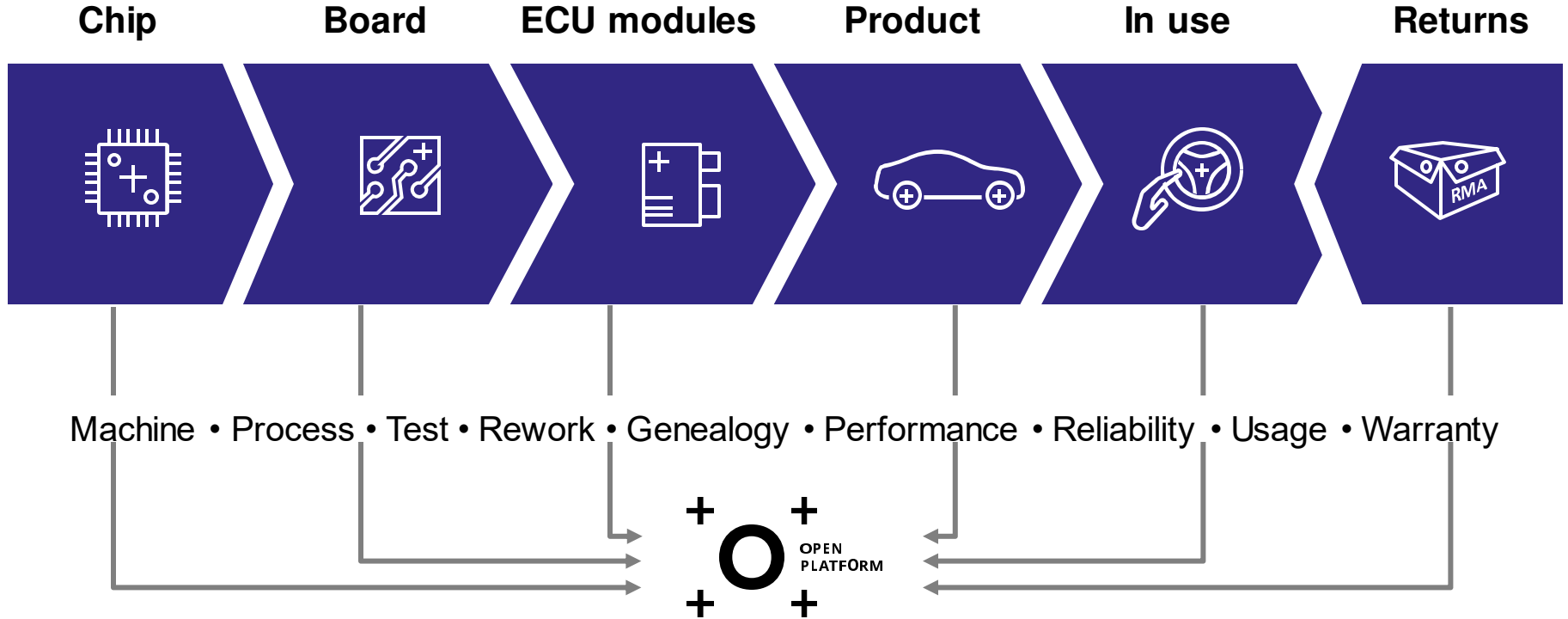
Act

- Automatic
- Distributed
- Controlled

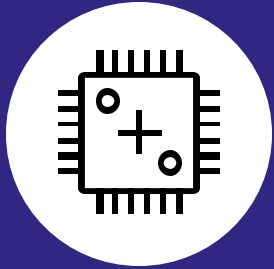
A unique, automated and proactive integrated solution



Through the entire product lifecycle



Semiconductor solution overview



Semiconductor solutions



Quality & Reliability



Yield



Productivity & Efficiency



Ramp, NPI



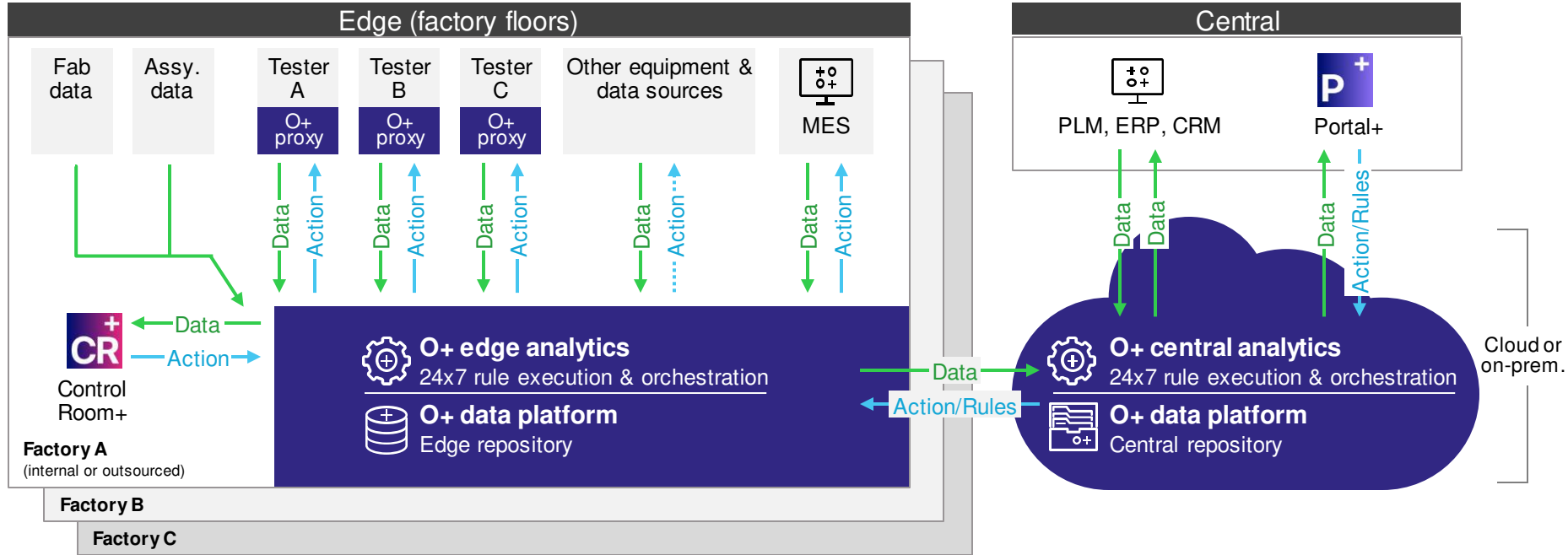
Open platform



Big data highway



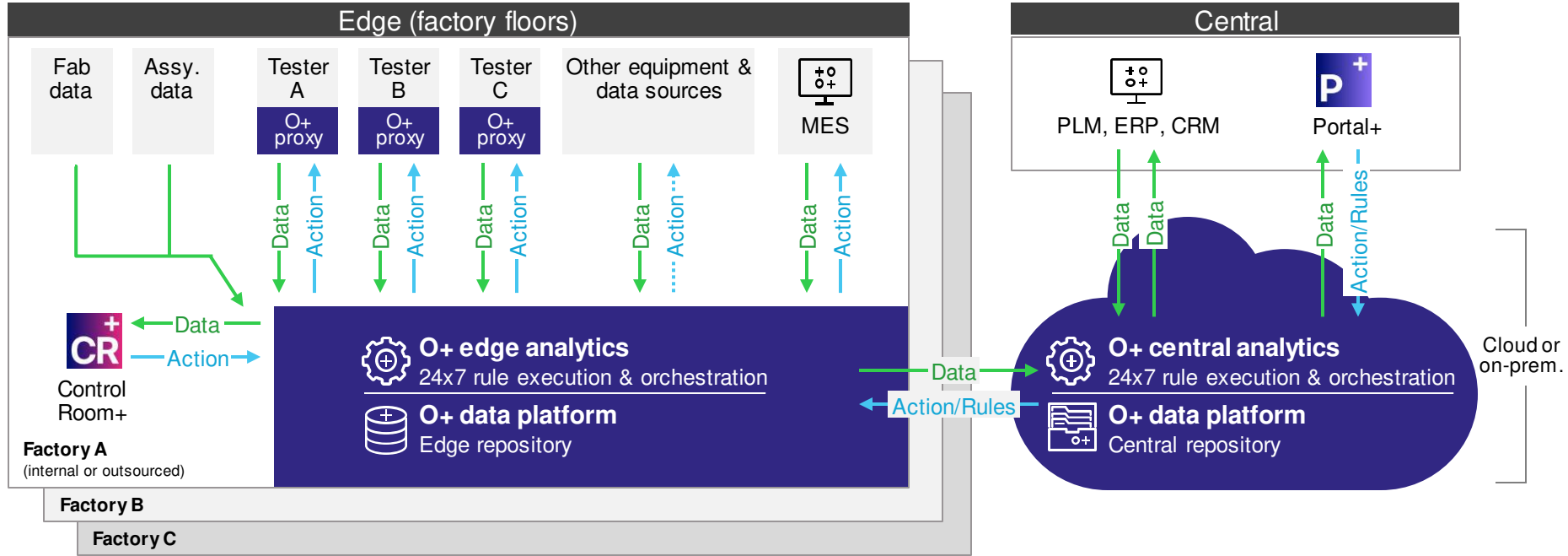
System architecture



Actionable insights across all manufacturing and test processes



System architecture



Actionable insights across all manufacturing and test processes



Common challenges we solve



Quality & Reliability

- Minimize excursions
- Eliminate RMAs
- Protect your brand
- Product safety net



Yield

- Overall yield
- Site-to-site yield
- Re-test policy
- Equipment & H/W performance issues



Productivity & Efficiency

- Excessive index & pause times
- Test time variations per tester
- Inefficient retest policies & execution
- Inconsistent tester availability & utilization



Ramp, NPI

- Quality & consistency of data
- Minimize time to market
- No traceability
- Expensive mask costs

Rules – Targeting challenges 24x7

- Library of standard rules accommodate most of 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

Online Rules

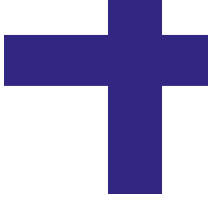
Adaptive Parametric TTR (Online)
Bin Monitor (Online)
CBL (Online)
Freeze (Online)
Parametric Process Capability (Online)
Parametric Trend Aggregated (Online)
Parametric Trend By Test (Online)
S2S Bin Deviation (Online)
S2S Fail Test Deviation (Online)
S2S Statistical Deviation (Online)
S2S Yield Deviation (Online)
Tester Settings Validation (Online)
TP Checksum Validation (Online)
Yield Monitor (Online)

Offline Rules

Cross Rule (Offline)
E-Test Inking (Offline)
Fail Test Limit (Offline)
Fail Test With In Limits Result (Offline)
Freeze (Offline)
Generic Rule (Offline)
Good Die With Failing Tests (Offline)
Parametric Process Capability (Offline)
Parametric Trend Aggregated (Offline)
Parametric Trend By Test (Offline)
Pass Test With Results Out Of Limits (Offline)
Probe Mark Count (Offline)
PRR Number Of Tests Validation (Offline)
S2S Bin Deviation (Offline)
S2S Fail Test Deviation (Offline)
S2S Statistical Deviation (Offline)
S2S Yield Deviation (Offline)
S2Sx Rule (Offline)
SBL (Offline)
Sequoia Rule (Offline)
Test Cell Validation (Offline)
Test List Comparison between TP Revs (Offline)
Test Program Checksum Change (Offline)
TTR Monitor (Offline)
ULT Validation (Offline)
Virtual Operation Rule (Offline)
Yield Monitor (Offline)



Rules turning challenges into actions

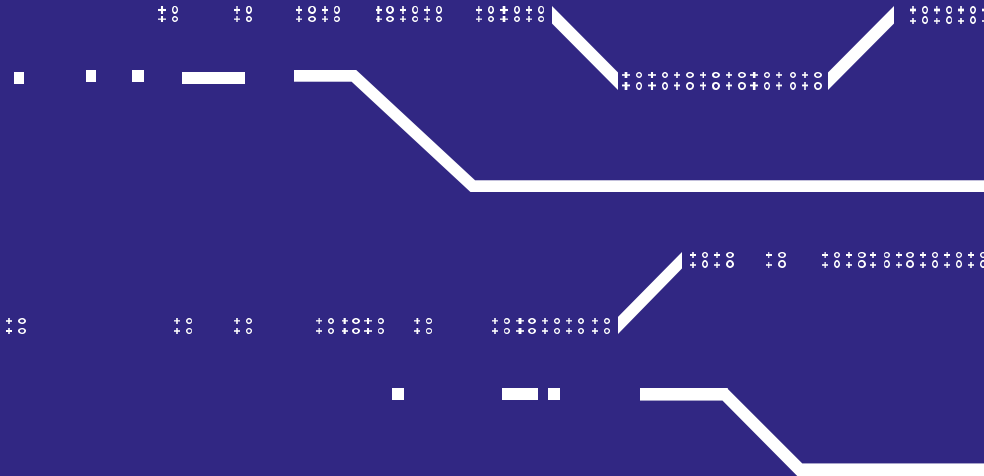


Action categories

Equipment actions	Process actions	Recipe adjustments	Data augmentation	Alerts
<ul style="list-style-type: none">• Pause• Engineering tool alert	<ul style="list-style-type: none">• Put materials on hold• Re-binning	<ul style="list-style-type: none">• Re-test skip/add• Adaptive testing	<ul style="list-style-type: none">• Feed-forward• Feed-backward• Virtual operation	<ul style="list-style-type: none">• Quality outlier alerts• Yield alerts• Predictive/ Anomaly alerts



Solutions Details



Quality & Reliability – Solutions



Quality & Reliability

- Minimize excursions
- Eliminate RMAs
- Protect your brand
- Product safety net

- Outlier Detection
- Adaptive testing using Machine Learning
- Escape Prevention
- Test data reliability

Driving quality improvements

Approaches

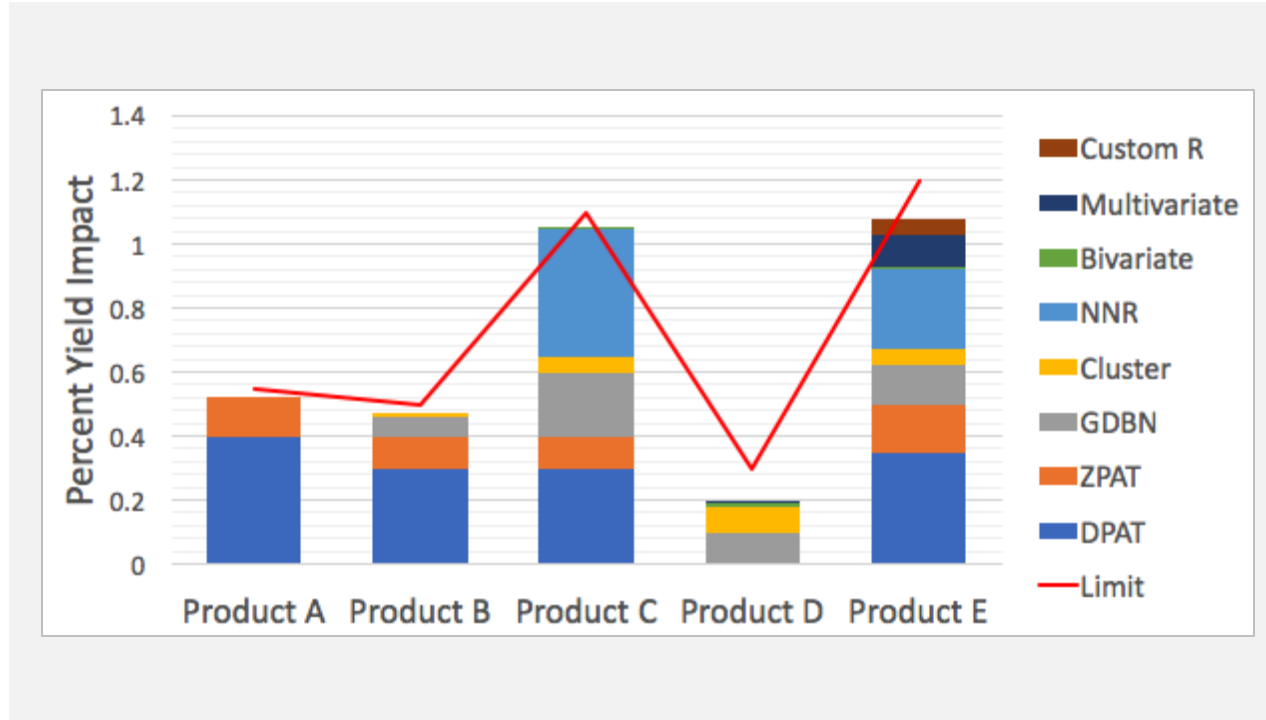
- Yield impact budget
Proactive outlier screening
- Cycles of learning
RMAs

Best practices

- Escape prevention
Deterministic
- Outlier detection
Geographical & Statistical
- Quality index
Die “goodness” score
- Data feed forward
Drift detection & ML scoring
- Auto-Hold



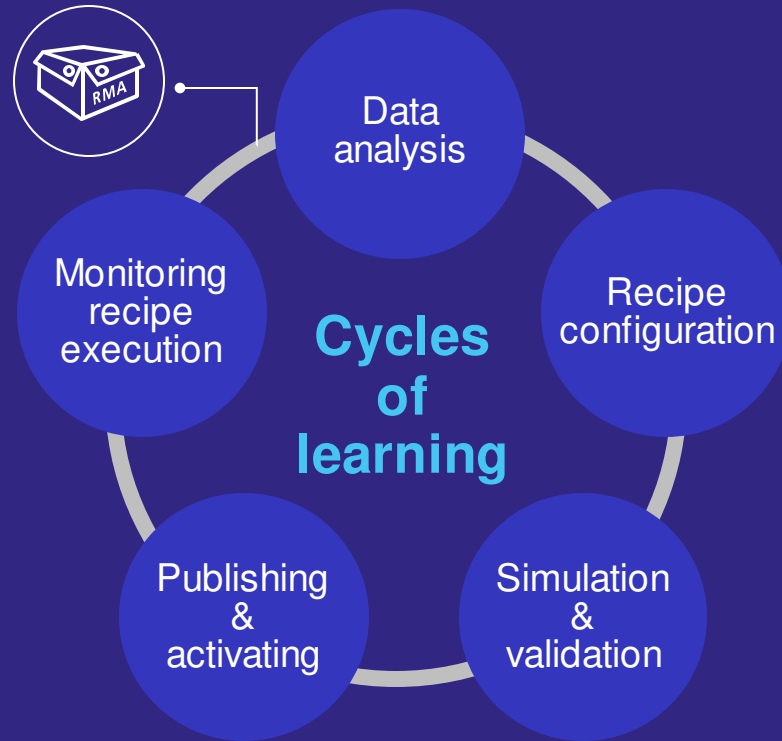
Yield impact budget – Balancing quality and yield



- Comprehensive and flexible library of algorithms, supporting R & Python
- Can be applied and adjusted to meet yield/quality targets
- Results are saved in the database which allows you to visualize and monitor the impact



RMA/Quality cycles of learning



Customer Use Case: Quality monitoring – Test escapes

Test Name	Measuring Unit	Lot	W...	Q0	Q10	Q25	Q50	Q75	Q90	Q100	Mean	StDev	Count	SSD	CPk	Variance	IQR	Skewness	Entropy
P_OPTIMALTEST_SYS:NUM_TESTS		DE31268	05	2460	2461	2461	2461	2461	2462.6	2503	2461.8048	4.3458581	333	False	N/A	18.886483	0	8.3093633	0.67306061
P_OPTIMALTEST_SYS:NUM_TESTS		DE31525	05	2460	2461	2461	2461	2461	2462	2499	2461.4836	2.9234066	366	False	N/A	8.5463059	0	11.722425	0.64161228
P_OPTIMALTEST_SYS:NUM_TESTS		DE31527	05	2460	2461	2461	2461	2461	2464	2506	2461.9972	4.8753014	351	False	N/A	23.768563	0	8.4619773	0.76214211
P_OPTIMALTEST_SYS:NUM_TESTS		DE31533	05	2459	2461	2461	2461	2461	2464	2512	2461.8917	5.0492767	360	False	N/A	25.495195	0	8.7492243	0.69627057
P_OPTIMALTEST_SYS:NUM_TESTS		DE31535	05	2460	2461	2461	2461	2461	2461	2506	2461.6794	4.3579026	340	False	N/A	18.991315	0	8.7243468	0.43184948
P_OPTIMALTEST_SYS:NUM_TESTS		DE31538	05	2460	2461	2461	2461	2461	2464	2506	2461.6377	3.4840626	345	False	N/A	12.138692	0	10.352822	0.53501383
P_OPTIMALTEST_SYS:NUM_TESTS		DE32568	05	2460	2461	2461	2461	2461	2463	2502	2461.5854	3.0820135	369	False	N/A	9.498807	0	11.172164	0.61114124
P_OPTIMALTEST_SYS:NUM_TESTS		DE32820	05	363	2462	2462	2462	2464	2468.1	2519	2364.7569	453.44839	288	False	N/A	205615.45	2	-4.2142947	1.675823

12 devices

Die X	Die Y	Retest	Hard Bin	Soft Bin	Die Test Time (...)	Site	Touchdown Seq...	First Fail Test	Last Fail Test	Is Good Bin	E...	Operation	P_OPTIMAL...
22	7	1	55	55	167751	2	14	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
8	7	4	55	55	167751	7	14	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
2	7	0	55	55	5662	1	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
3	8	0	55	55	5662	5	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
2	8	0	55	55	5662	6	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
4	8	0	55	55	5662	7	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
1	9	0	55	55	5662	8	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
2	9	0	55	55	5662	9	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
3	9	0	55	55	5662	10	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
4	9	0	55	55	5662	11	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
1	10	0	55	55	5662	12	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
2	10	0	55	55	5662	13	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
3	10	0	55	55	5662	14	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363
4	10	0	55	55	5662	15	15	F_1110100 Fla...	F_1110100 Fla...	True		PRB	363

Result: Insurance and improvement reports to customer

Device:

Automotive

Problem: Possible quality returns

Issue: Penalties from customer

Problem discovered: No PRR monitoring & 12 possible test escapes

Fix: Rules & special binning



Yield – Solutions

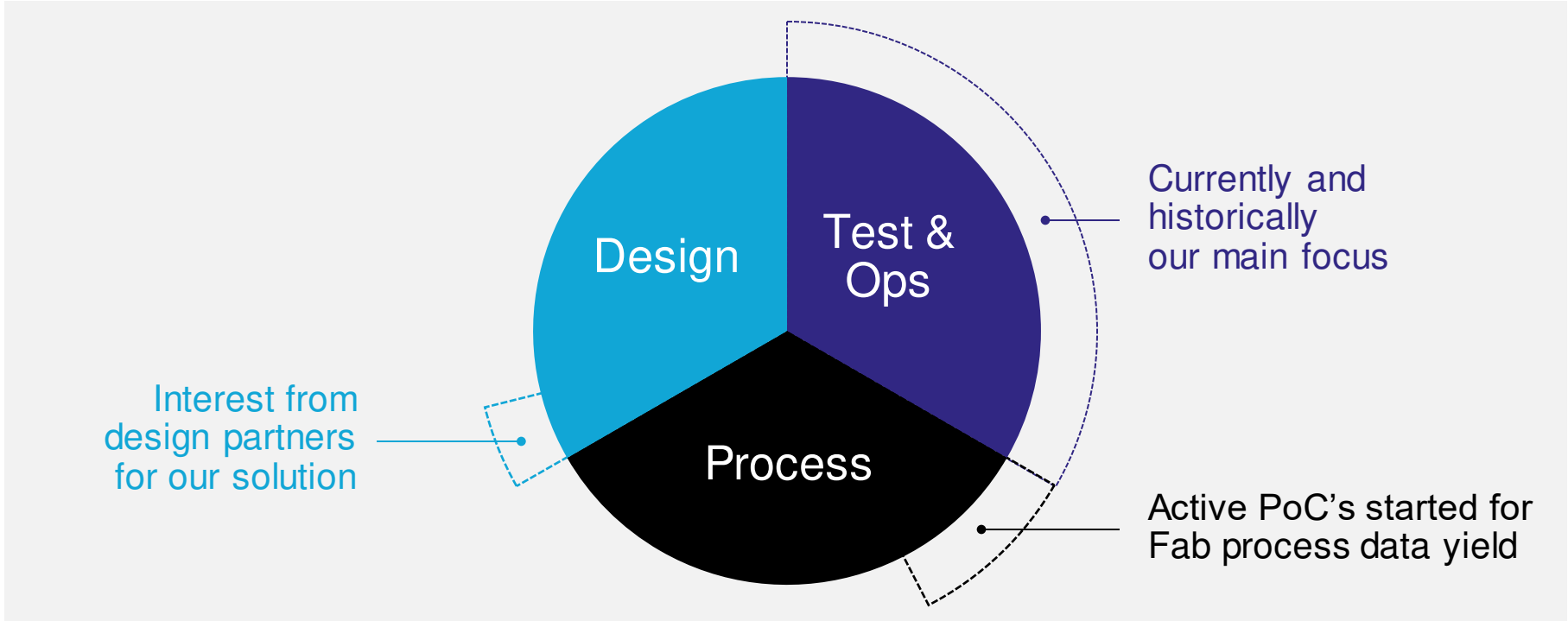
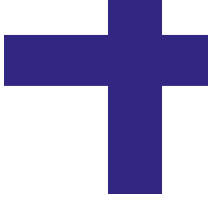


Yield

- Overall yield
- Site-to-site yield
- Re-test policy
- Equipment & H/W performance issues

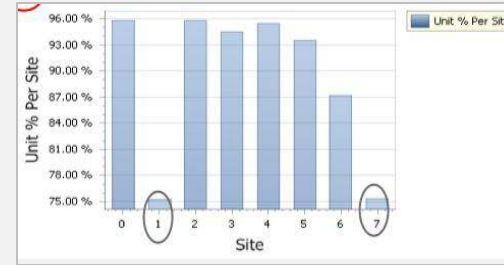
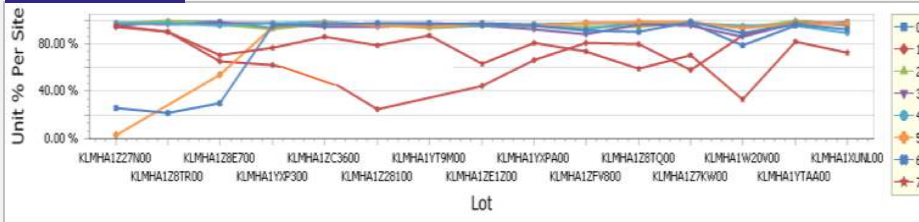
- Baseline yield & SBL monitoring
- Test equipment performance
- Test and retest policies and execution
- Tests limits validation
- Cross-operation correlation
- Targets against any measure/KPI

Overall yield contributors

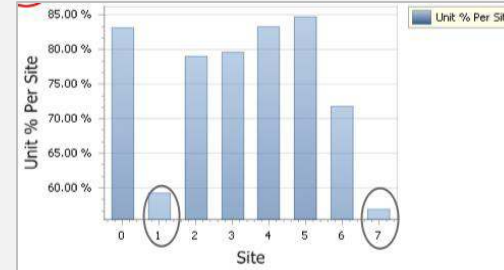
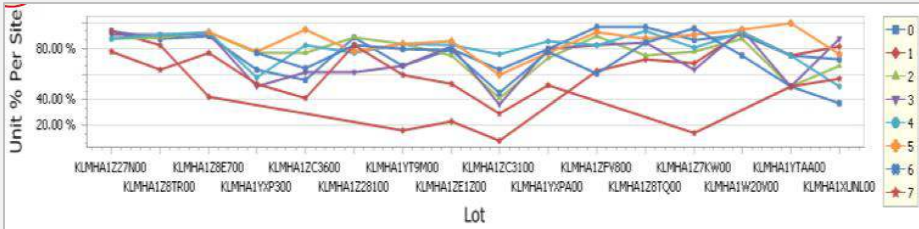


Customer Use Case: Operational yield – Site issue

Iteration 0



Iteration 1



Standard O+ rules found

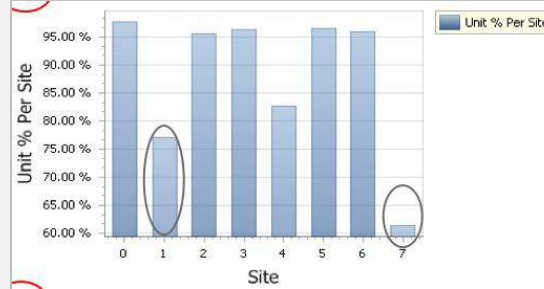
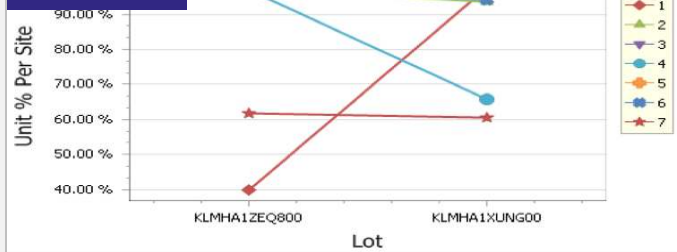
With no monitoring – Site-Site issue not detected – This case is 16 lots

Device:
Network
Problem:
Yield loss
Issue:
Yield by tester varies

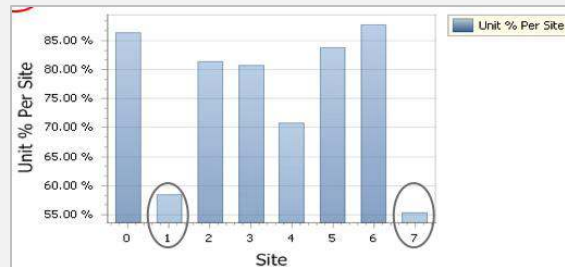
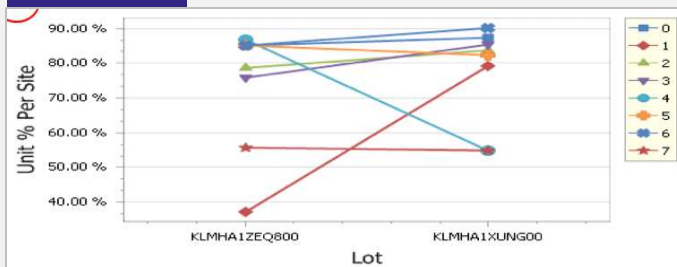


Customer Use Case: Operational yield – Site issue (continued)

Iteration 2



Iteration 3



Result: Increased overall Yield by 2%

Operation issue: Same-site problem over 4 re-tests
Problem discovered: Potential Good devices tested as Bad
Fix: Rules monitoring catches issues on 1st pass



Productivity & Efficiency – Solutions

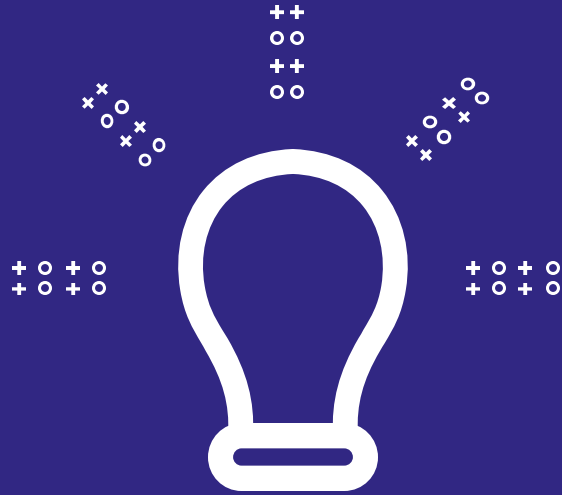


Productivity & Efficiency

- Excessive index & pause times
- Test time variations per tester
- Inefficient retest policies & execution
- Inconsistent tester availability & utilization

- Adaptive Testing using Machine Learning
- Test equipment performance
- Test and retest policies and execution
- Testers availability & utilization (OEE analysis)
- Classical Test Time Reduction (TTR analysis, ROA)
- Adaptive Test Time Reduction (ATTR)
- Cross-operation correlations

Productivity & Efficiency opportunities



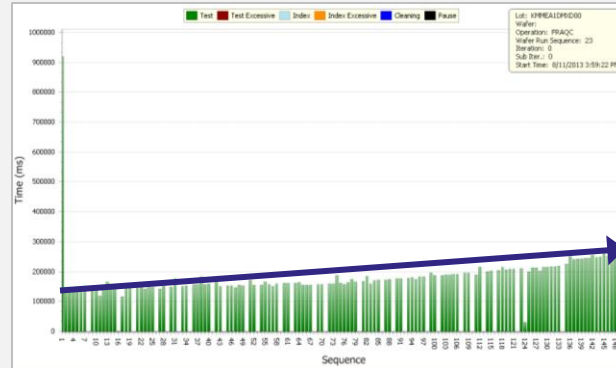
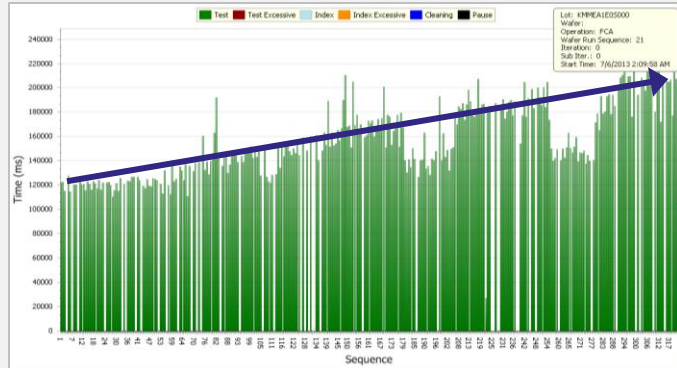
Better resolution of time during test

Retest optimization

Test time consistency

Tester utilization

Customer Use Case: Productivity & Efficiency – 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 & 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



Ramp, NPI – Solutions

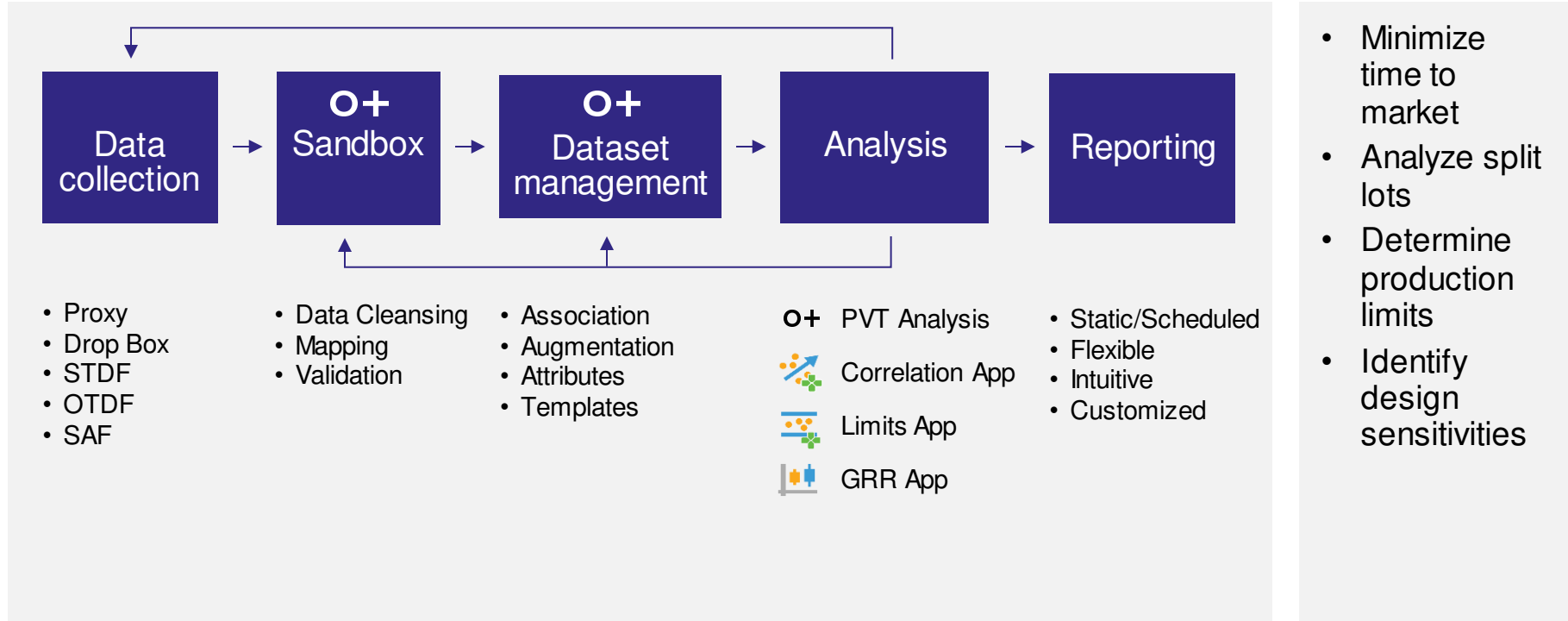


Ramp, NPI

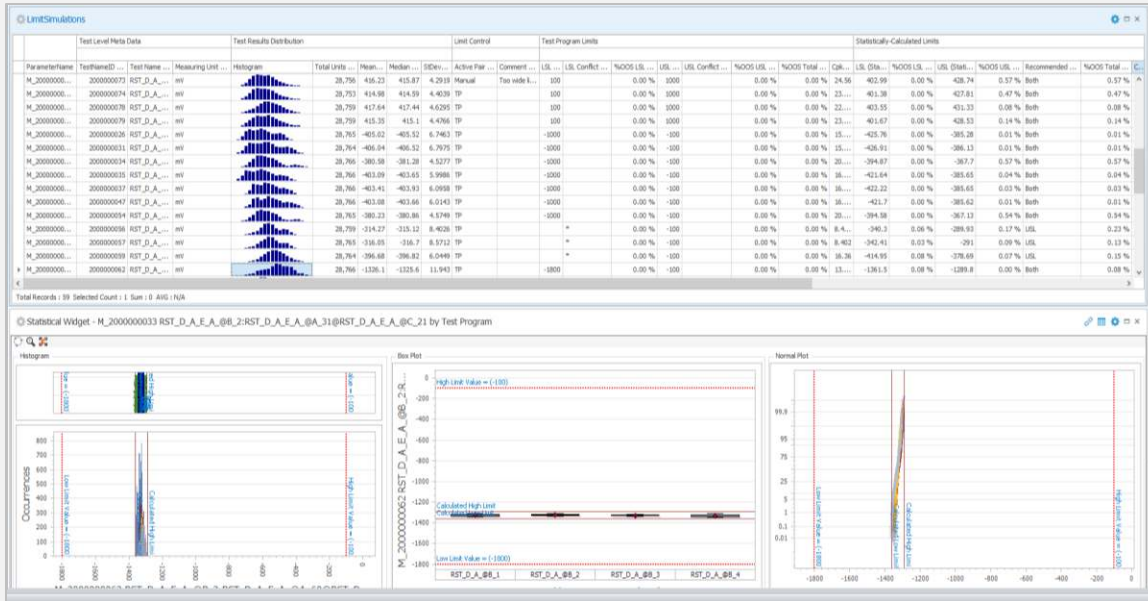
- Quality & consistency of data
- Minimize time to market
- No traceability
- Expensive mask costs

- 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 & GR&R Applications
- Report generation

NPI areas of focus and flow



Customer Use Case: Ramp, NPI – Limit Simulation App



O+ standard tools found: Limits too wide

Result: Immediate feedback = Faster product launch

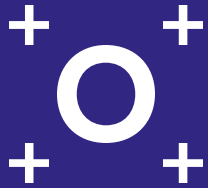
Device:
Cell phone

Problem:
Limits not optimized

Issue:
Would not fail questionable measurements

Fix:
Run analysis using limits application





Partner with us to enhance your Big data strategy with our **open platform**

Synergetic with any data lake | Cloud & on-premise | Accessible optimized schema |
AI & machine learning | Collect & act anywhere | Enhance data scientist productivity



Voice of the market



“How can I **combine**, and do more with my siloed data systems?”

“Our **data retention** is at least 10 years for our **automotive** products.”

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

“I know we need to do **ML**, we just don't know how to get started”

“How can we store old data so it doesn't take so long to **reload & use?**”

“Can we have **programmatic access** to O+ data?”

“My teams are proficient in **Python** or **R** and I want to leverage this”

“I want to leverage **fab/assembly** data (i.e. defect & inspection) to improve my quality”



Consolidated challenges

CTO/CIOs & IT professionals

Concerned about enterprise TCO (Total Cost of Ownership)

Product, Quality & Yield Engineering teams

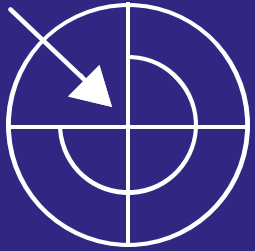
Need a solution providing analytics that scale

Data Scientists & 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 developers innovation by leveraging OptimalPlus rich API's, algorithms and infrastructure

Industry focused open platform

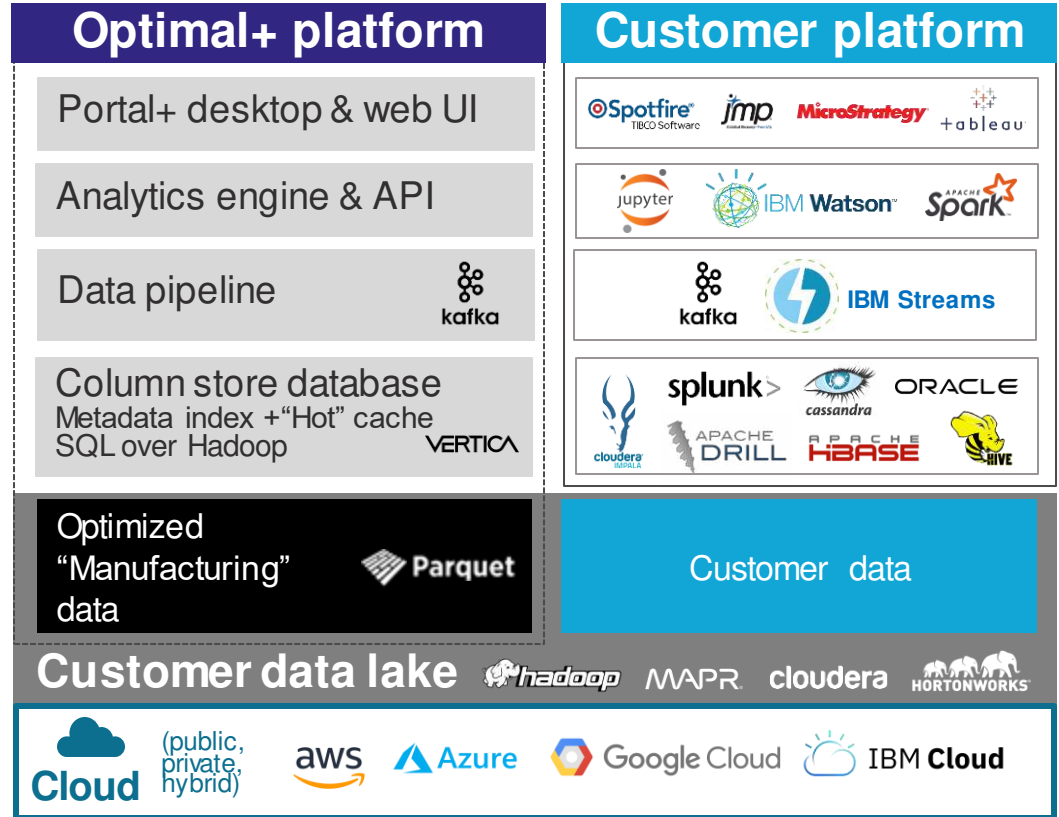
Synergetic with any big data strategy

Connected to existing infrastructure

Open for all kinds of data

Accelerates innovation

Extensible through both data and algorithms



Summary



Lifecycle analytics solutions

turning data into actions for immediate ROI



Product-centric approach

for improved quality & reliability and operational efficiency



End-to-end supply chain visibility

across operations and industries



Open platform

industry focused for seamless integration with any big data strategy



Domain expertise

applying data science to solve industry challenges

Significant business impact



Quality &
Reliability

50%
case avoidance



Yield

increase up to
10% NPI
2% HVM



Productivity &
Efficiency

up to 25%
cost savings



Ramp, NPI

from weeks
to days
NPI, TTM, RCA

Ask our customers



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

– **Michael Campbell**
Senior VP of 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.”

– **Keith Katcher**
VP of Operations
Engineering



“We went from ‘We can’t afford to do this [Optimal+] to ‘We can’t afford not to do this [Optimal+]”

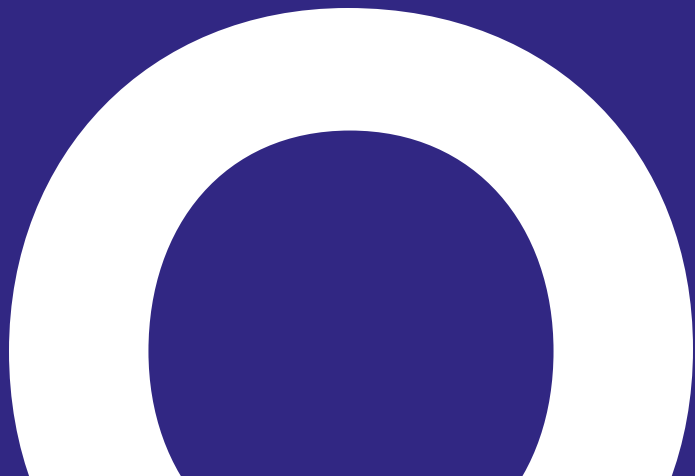
– **Carl Bowen**
AMD Fellow



“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.”

– **Vincent Tong**
Senior VP,
Global Operations & Quality





Thank you

OPTIMAL+
Lifecycle analytics you can trust