

From Wafer to Strip to Reel – Analytics Across the Lifecycle

Michael Schuldenfrei, NI Fellow

Customer Challenges Where Genealogy Matters



Yield

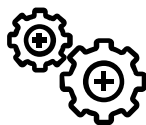
Fab process migrations (7, 5 & 3nm) enable increased IP integration

Advanced Packaging (2.5D & 3D) required to enable maximum system performance



Quality

Automotive and Data Center product quality demands driving additional system-level testing and burn in requirements



Efficiency

Increased integration drives increased test times

Customer Challenges – NI's Response



Yield

Fab process migrations (7, 5 & 3nm) enable increased IP integration

- *Add process information to enable yield analysis (e.g. PCM/eTest, Metrology/Inspection)*

Advanced Packaging (2.5D & 3D) required to enable maximum system performance

- *Include device genealogy for die traceability (e.g. MCM, Chiplet, CoWoS)*



Quality

Automotive and Data Center product quality demands driving additional system-level testing and burn in requirements

- *Virtual Operations for device grading to shorten (or even skip) operations without quality impact*

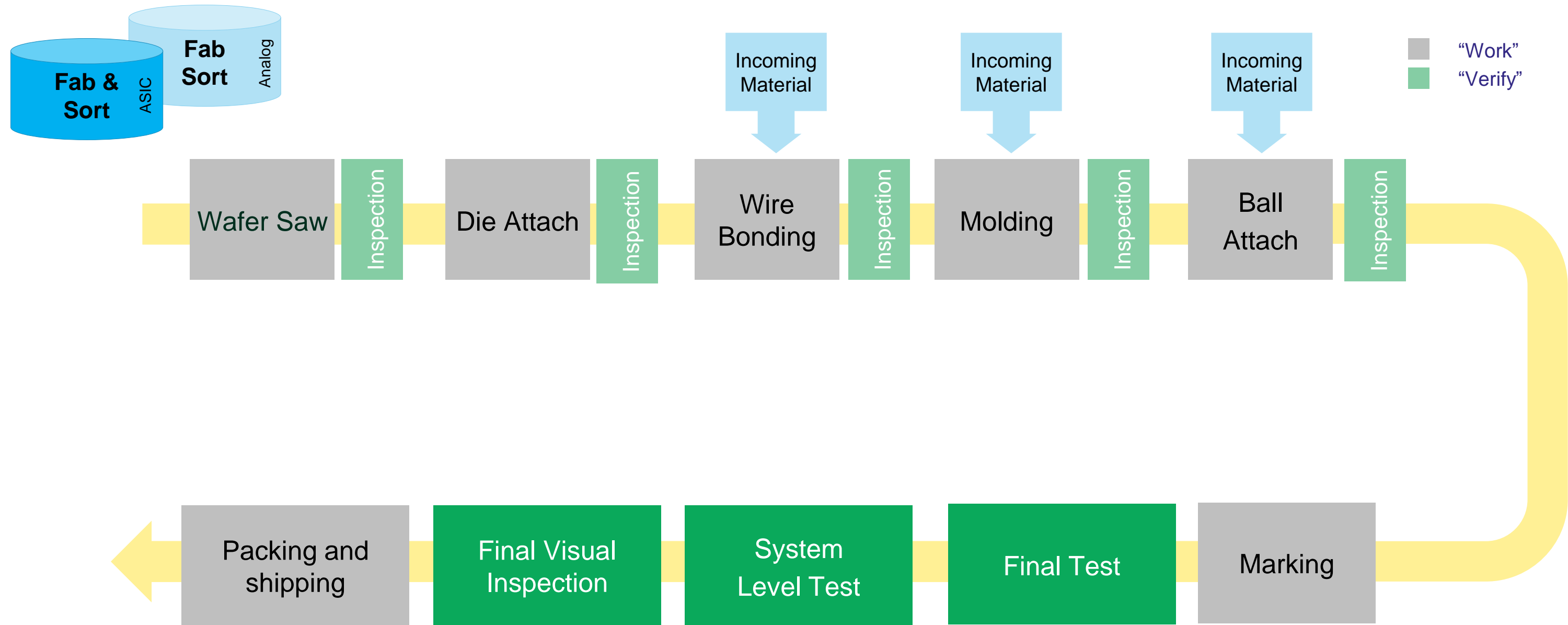


Efficiency

Increased integration drives increased test times

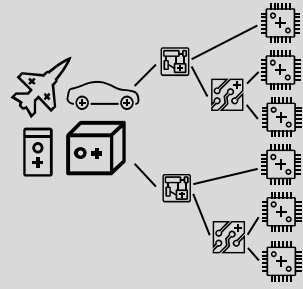
- *Adaptive testing based on previous test operations with AI/ML Models*

Example: MCM Assembly and Test Flow



The unified data platform enables Closed Loop Process Control analytics across the assembly line and the supply chain

Genealogy in O+

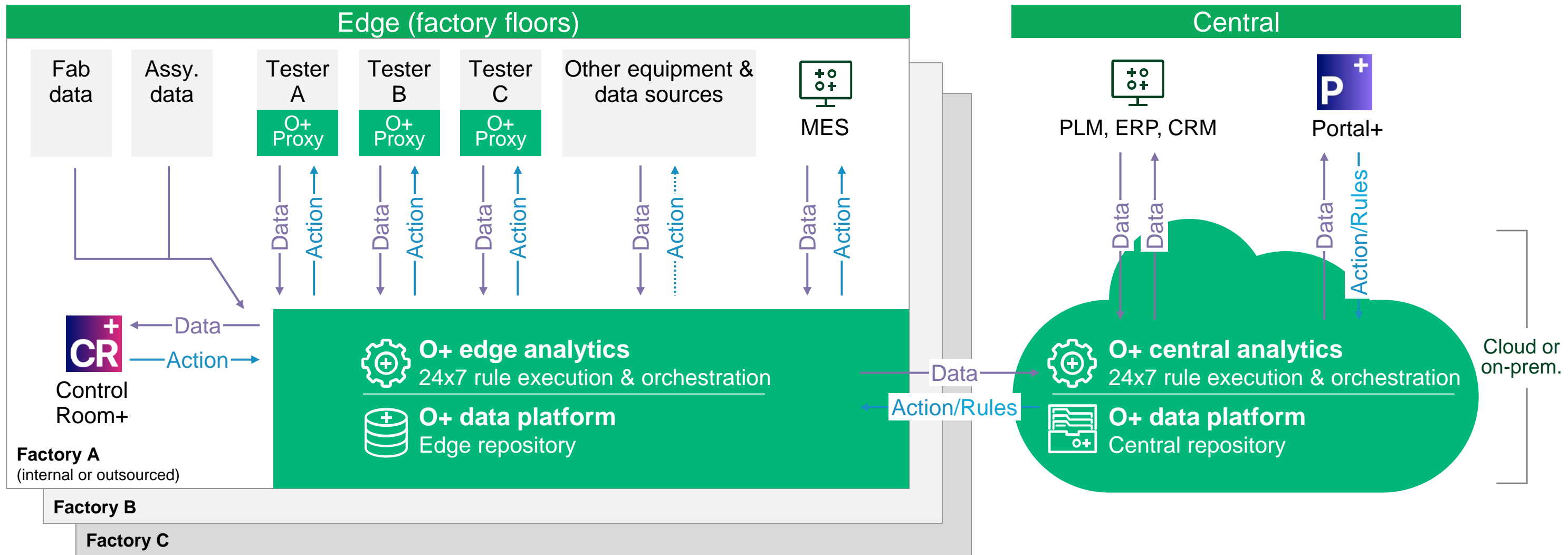


Genealogy & Assembly

- Asynchronous loading & connecting
- Unit traceability across all levels
- Efficient analyses
- Containment

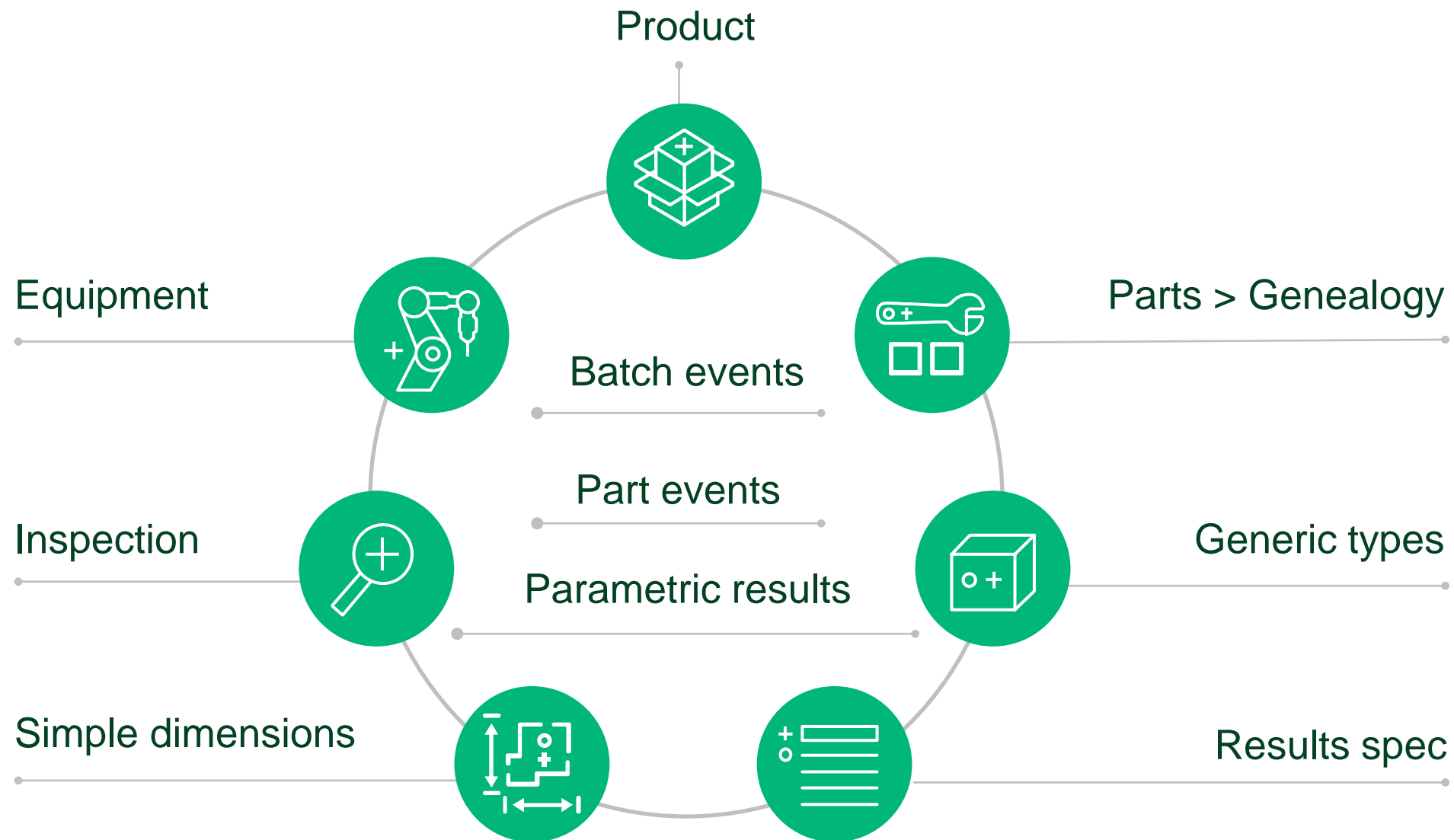
- Connects all levels of assembly
- Parametric data correlations across any operation
- Group or analyze data from any level
- Cross operation heat map analyses
- Wafer map reconstruction based on any level results

Global Operations – “GO” – Architecture



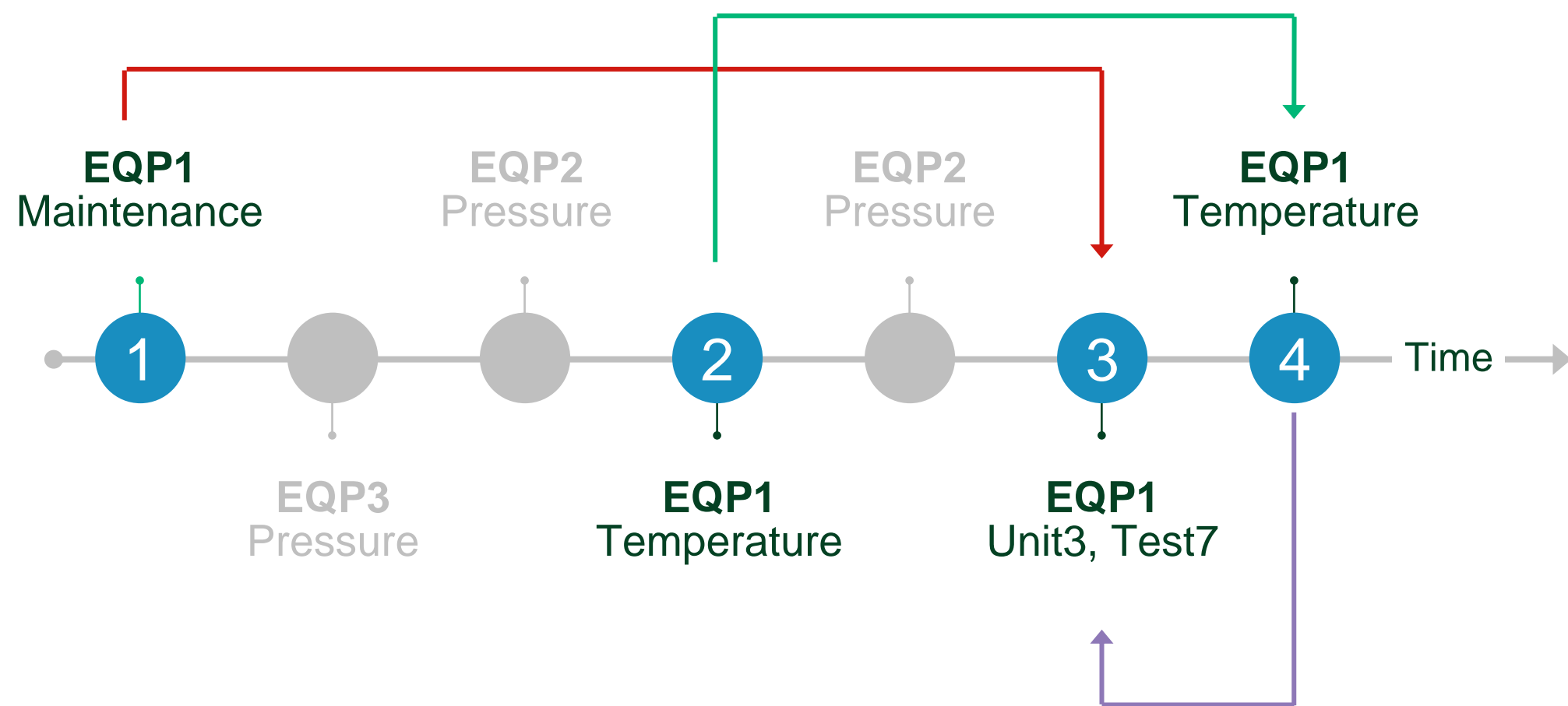
Actionable insights across all manufacturing and test processes

Unified Data Model (UDM)



- Generalization of events
- Generalization of parts
- Virtual batching
- Genealogy and traceability
- Asynchronous loading

Analyze Across Product, Process & Equipment

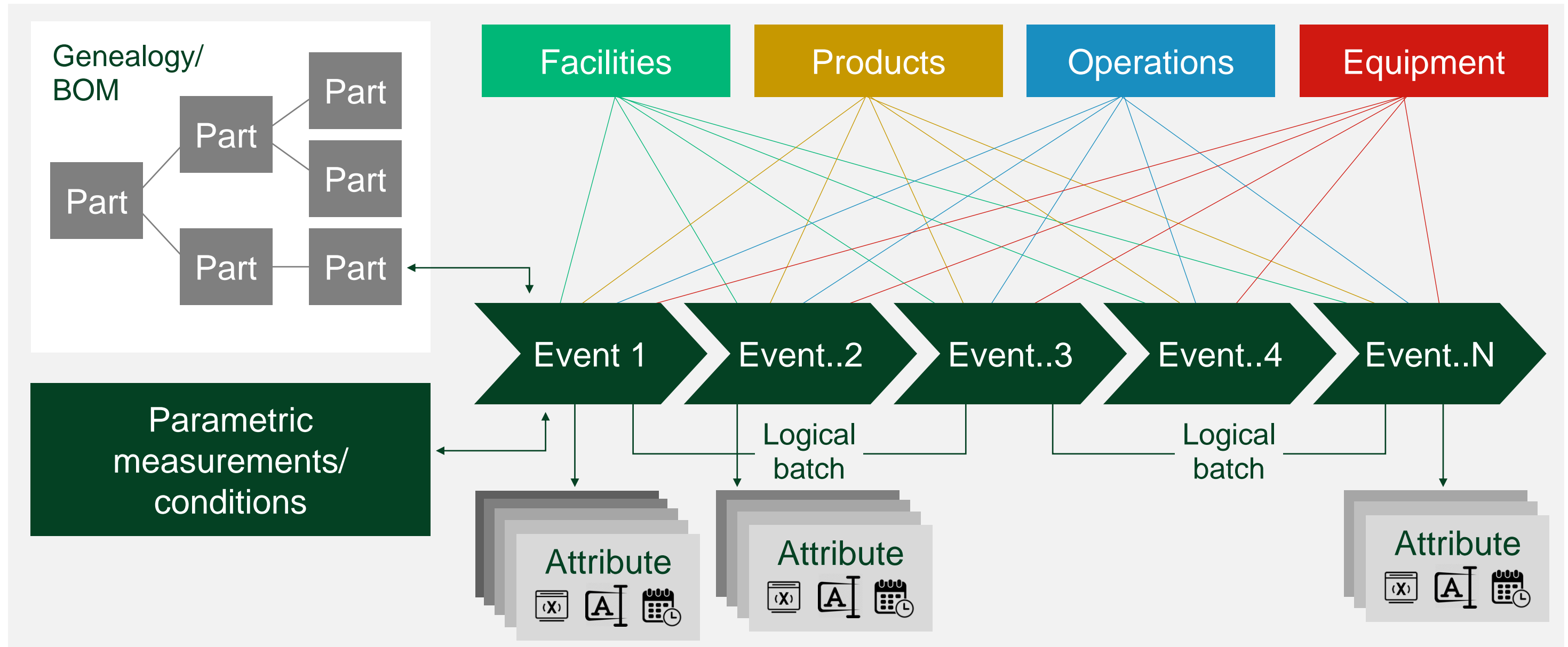


What was the equipment maintenance done **before** product event #3?

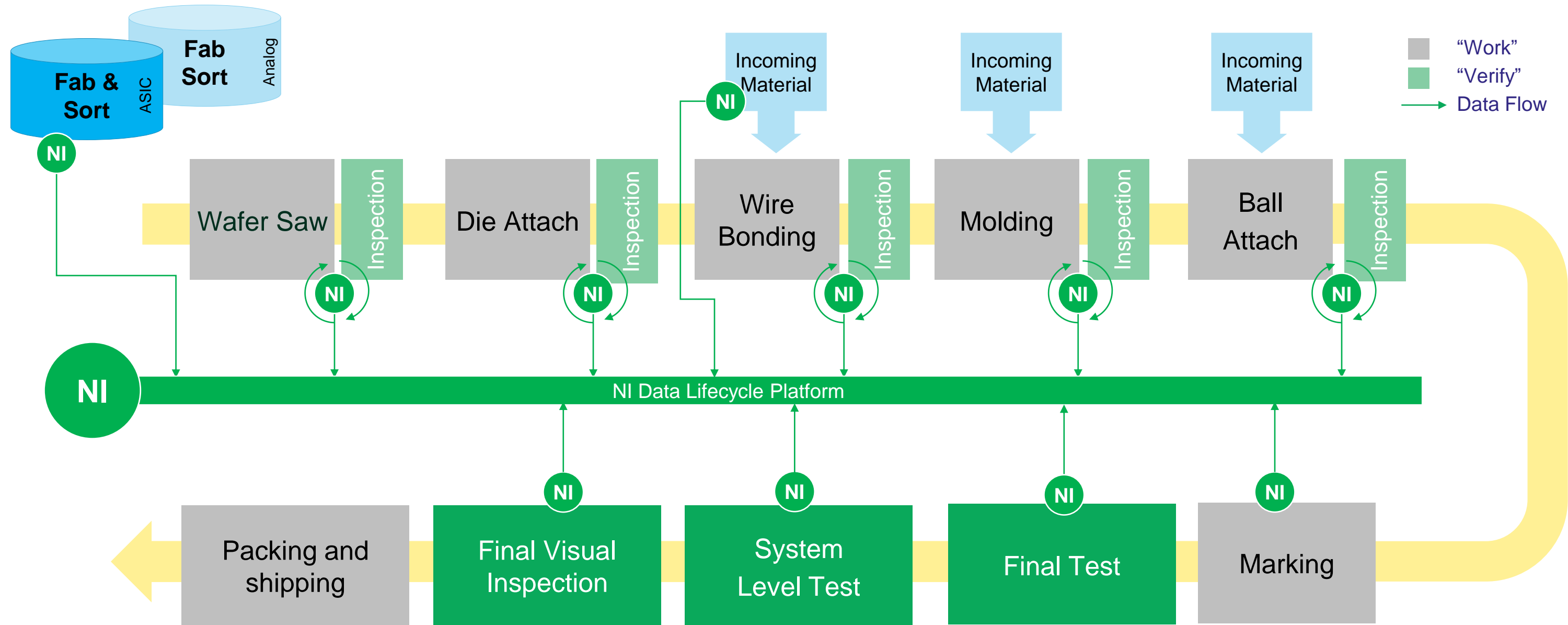
What is the **closest** equipment temp measurement event to product event #3?

What is the equipment temp **average** around product event #3?

Unified Data Model (UDM) for Any Type of Data

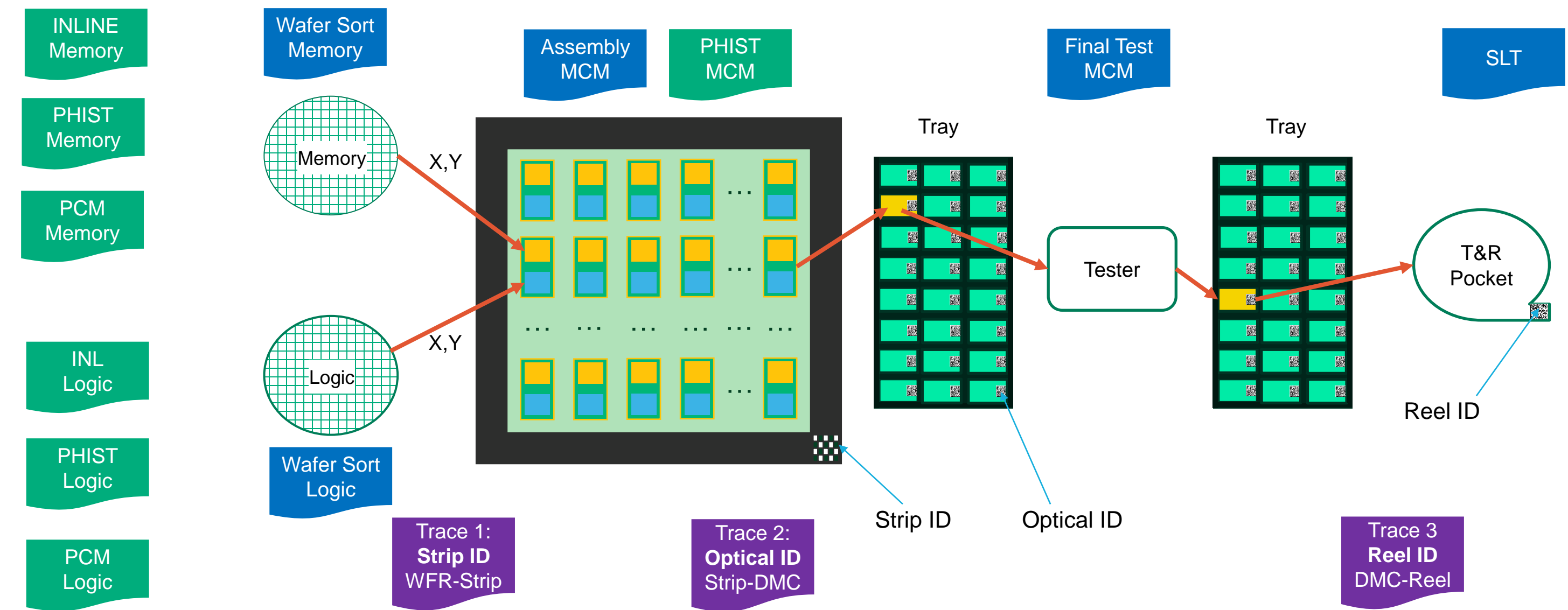


Example: MCM Assembly and Test Flow



The unified data platform enables Closed Loop Process Control analytics across the assembly line and the supply chain

Example: MCM Data Files



Data Sources for Traceability

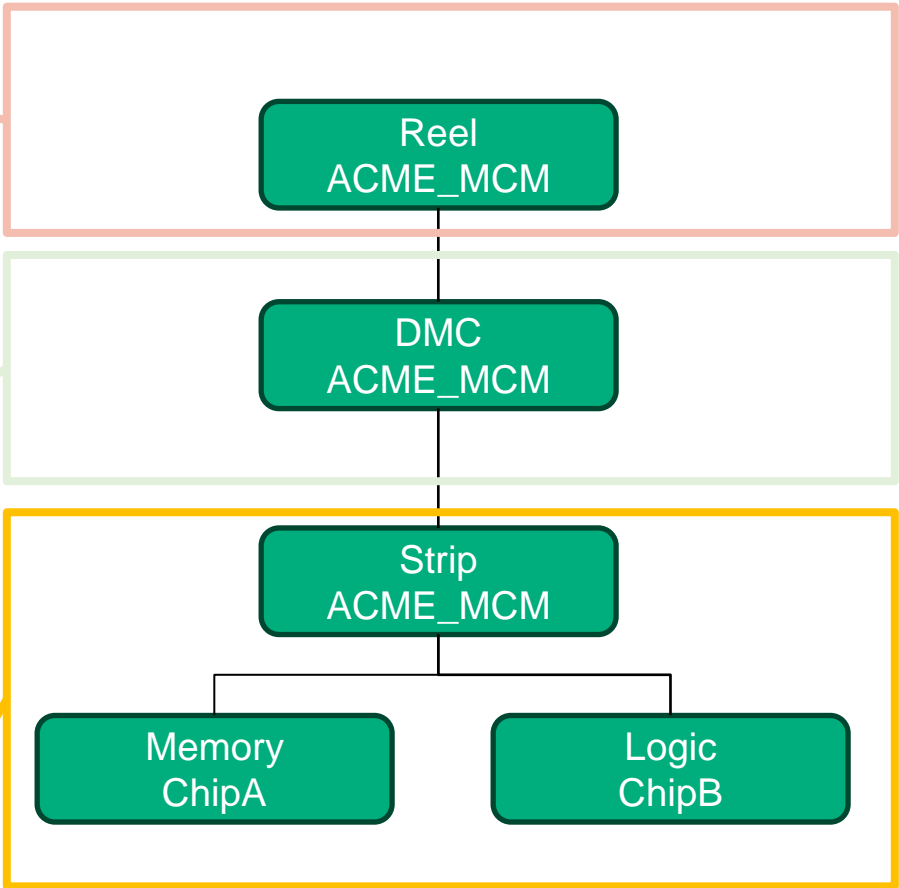
Data Source	Notes
STDF / OTDF	<ul style="list-style-type: none">• Common for test processes• For devices with Electronic Chip ID (ECID), contains relationship between Wafer-X-Y to ECID (typically at WS)• Can also contain Optical IDs read on tester• May require extraction of IDs from parametric tests, text records, etc.
E142	<ul style="list-style-type: none">• Common for assembly processes• Contains mapping between Wafer-X-Y to location on strip or reel
Other	<ul style="list-style-type: none">• Various text and binary formats generated by non-standard equipment or processes

How Genealogy Data is Modeled

Parent Level (-1)		Component Level (0)		
Product	Unit ID	Product	Unit ID	Location / Socket
ACME_MCM	ReelNBC_P4	ACME_MCM	AB15453Z	Reel DMC
ACME_MCM	ReelNBC_P18	ACME_MCM	AB15454X	Reel DMC
...				
ACME_MCM	ReelNBC_P42	ACME_MCM	AB16243N	Reel DMC
ACME_MCM	ReelNBC_P94	ACME_MCM	AB16244Q	Reel DMC

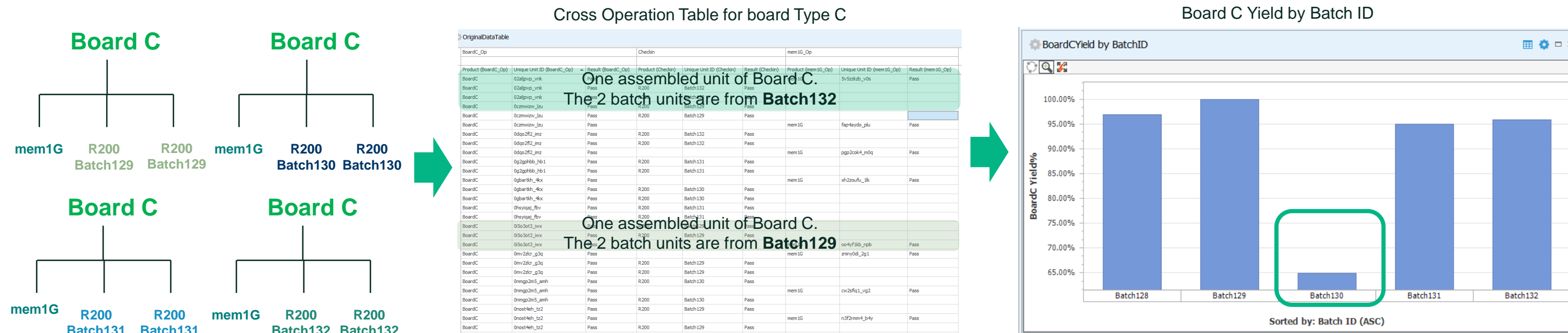
Parent Level (0)		Component Level (1)		
Product	Unit ID	Product	Unit ID	Location / Socket
ACME_MCM	AB15453Z	ACME_MCM	STR141_X0_Y0	Strip DMC
ACME_MCM	AB15454X	ACME_MCM	STR141_X1_Y0	Strip DMC
...				
ACME_MCM	AB16243N	ACME_MCM	STR141_X50_Y10	Strip DMC
ACME_MCM	AB16244Q	ACME_MCM	STR141_X50_Y10	Strip DMC

Parent Level (1)		Component Level (2)		
Product	Unit ID	Product	Unit ID	Location / Socket
ACME_MCM	STR141_X0_Y0	ChipA	XY123456-05_x20_y15	Memory Socket 0
ACME_MCM	STR141_X0_Y0	ChipB	AB987654-12_x12_y24	Logic Socket 1
....				
ACME_MCM	STR141_X50_Y10	ChipA	BN132457-04_x19_y11	Memory Socket 0
ACME_MCM	STR141_X50_Y10	ChipB	GS529475-18_x05_y28	Logic Socket 1



Batch Level Genealogy

- Build a more complete genealogy tree by loading parts that don't have unique unit ID's ("Passives")
- Parts will get the ID of the batch from which they were taken
- Allows analysis of:
 - Module performance across all the components assembled to it
 - Batch performance across the different devices it was assembled on



Searching for Failing Units

Unit Level Data Wizard

Step 1 of 6 - Population
Select a date range and population

☐ Use Dataset:
Name: Snapshot: ☐ Use Date Range

Date range:
☒ Last: 11 Year(s)
☒ Include current period
☐ Range: 1/ 6/2014 12:00 AM to: 5/ 8/2024 9:41 AM

Additional settings:
☒ Retain in Job Manager
☐ Show tests on rows
☐ Show units with no test results
☐ Open in new page
Primary Operation final result vs Secondary Operation final result

Main filters:

Product	WS_103764
Sub Product	[Not filtered]
Project	[Not filtered]
Facility	[Not filtered]
Test Program	[Not filtered]
Test Program Revision	[Not filtered]
Area	[Not filtered]
Operation	WS

☒ Perform cross operations

Additional filters:
Add field
☒ ECID ReelNBC_P4,ReelNBC_P18,ReelNBC_P42,ReelNBC_P94

Save Export Data to Python

Include Wildcard Match

ECID

- ☒ ReelNBC_P18
- ☒ ReelNBC_P4
- ☒ ReelNBC_P42
- ☒ ReelNBC_P94

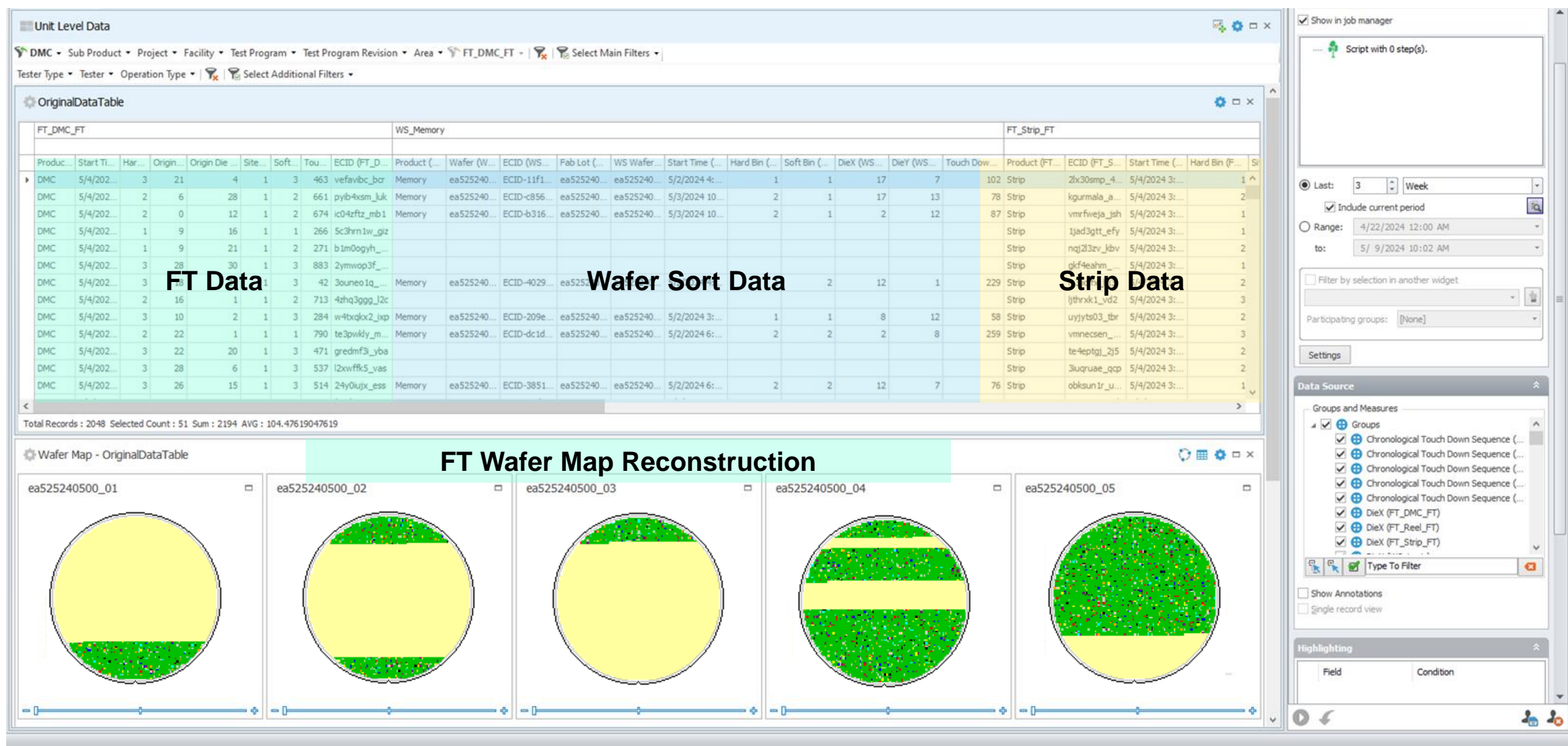
Selected 4 of 4.

Type to filter:

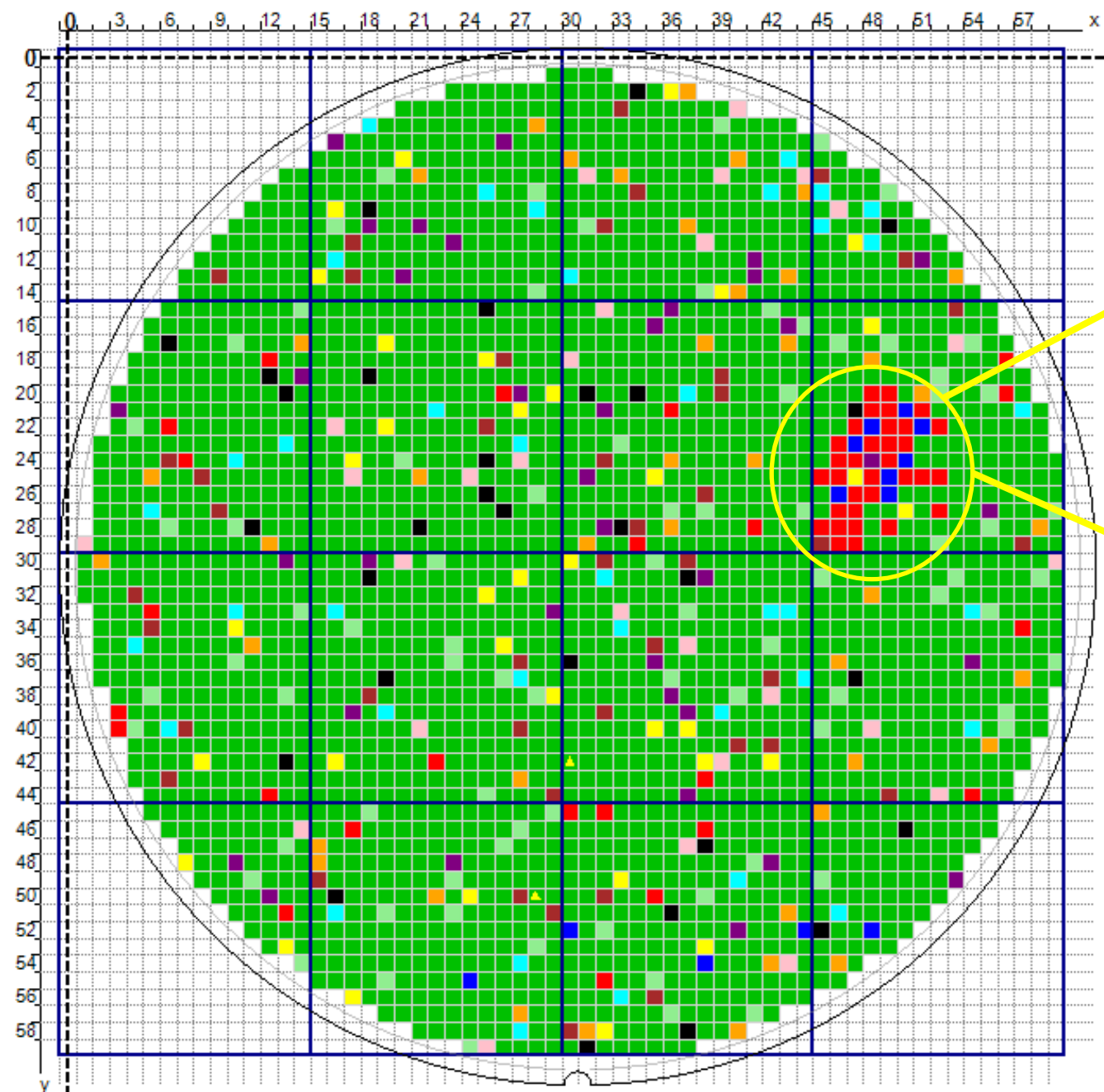
☐ Always show selected values

OK Cancel

Wafer Map Reconstruction



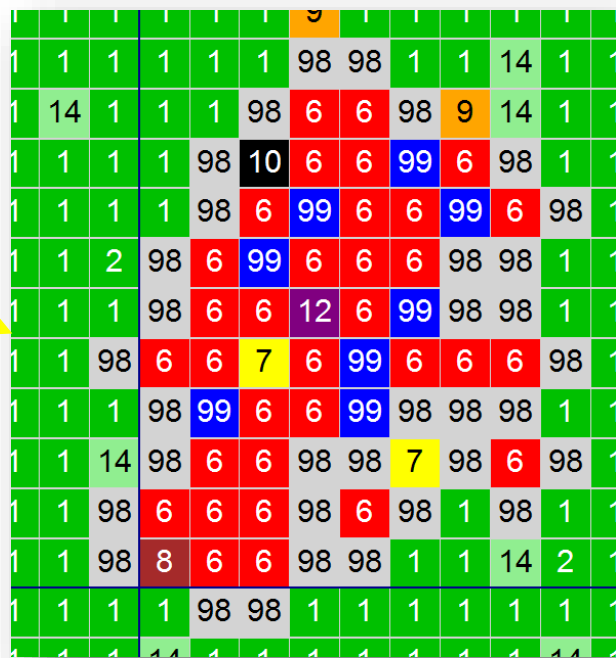
Tracing Package Test Failures



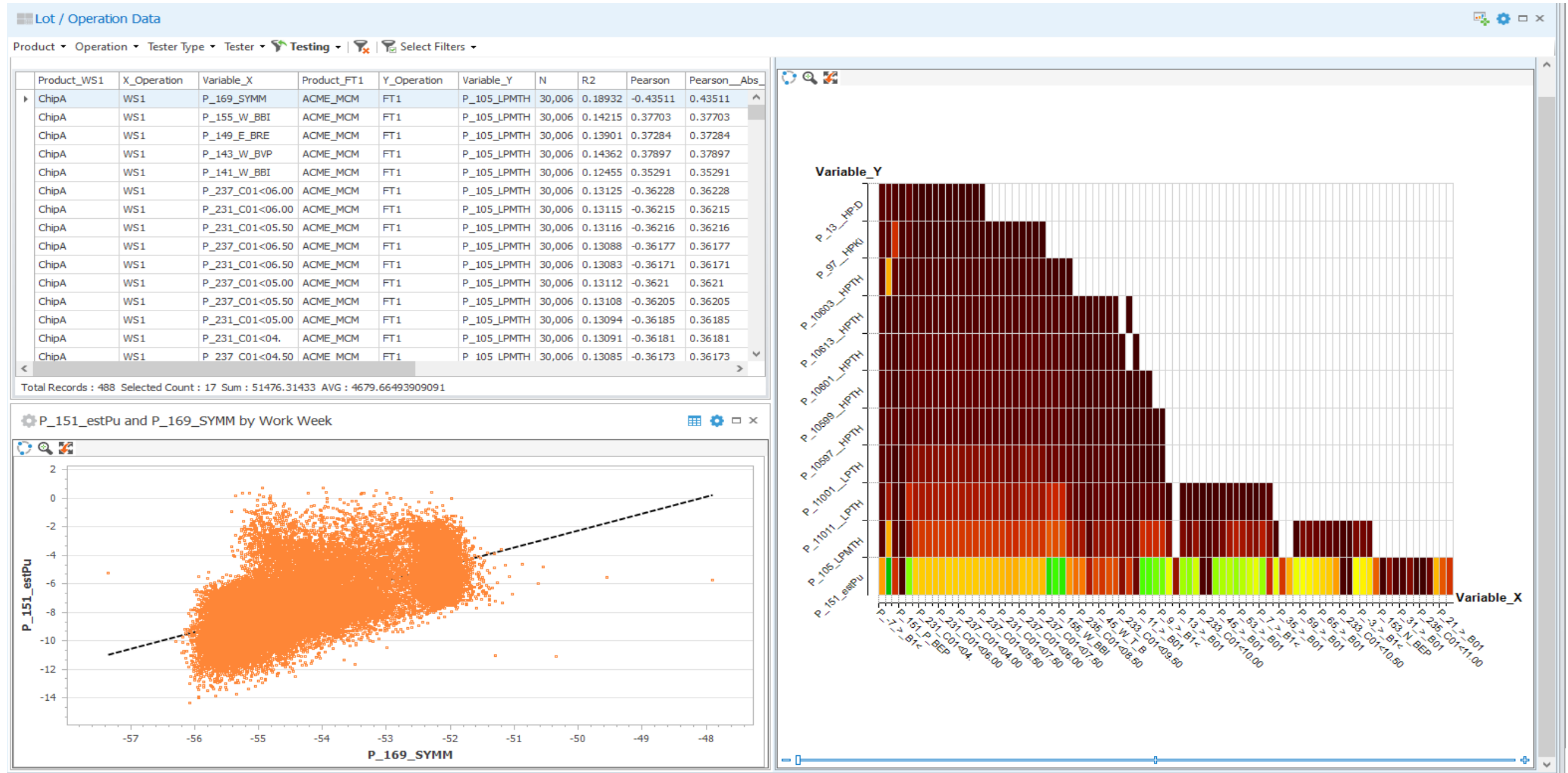
Legacy PAT algo



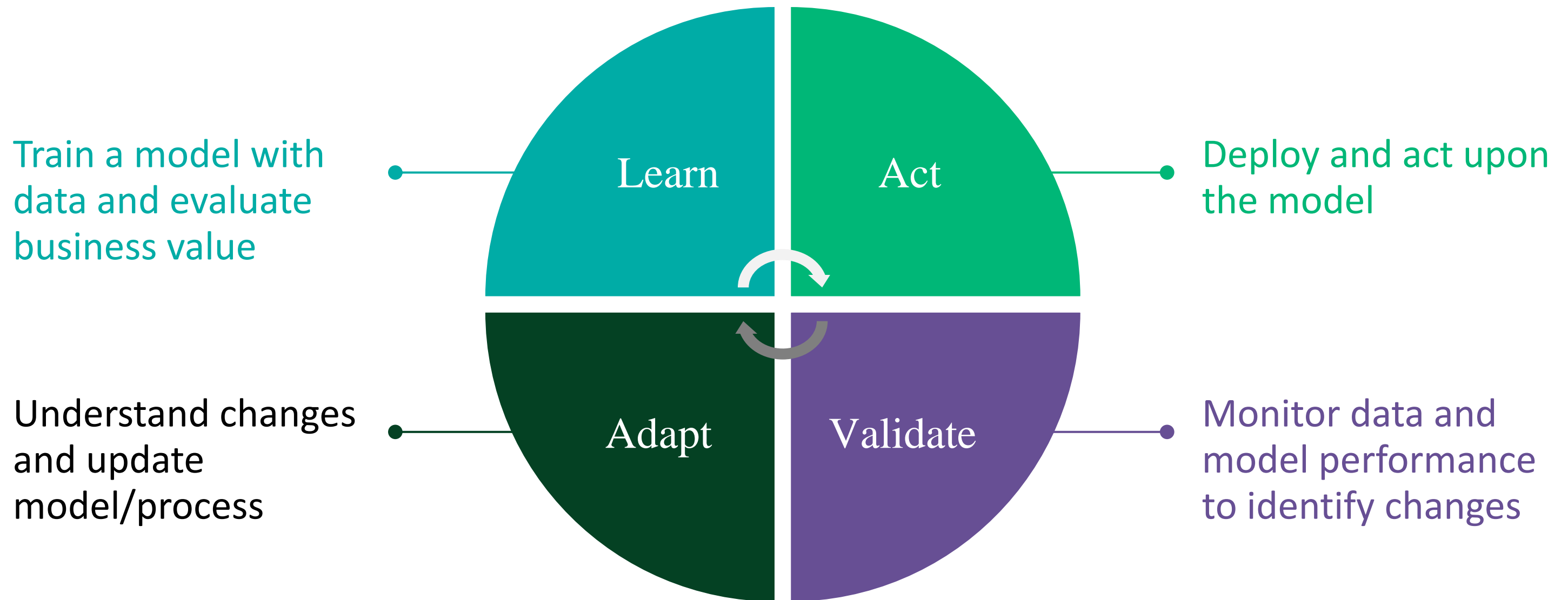
Cluster PAT algo



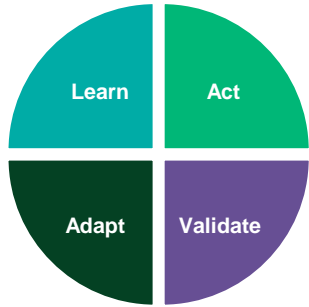
Cross-Operation Correlation



The Full Machine Learning Lifecycle



Unleashing AI



Learn

- **Getting data**
Data is collected and harmonized all the time, making it available at the click of a button
- **Feature extraction**
Advanced features are extracted via out-of-the-box capabilities (e.g. geographic and parametric outliers)
- **Freedom of choice**
Full support for data science platforms

Act

- **Complex “plumbing”**
Plumbing is handled under the hood by the Optimal+ infrastructure
- **Actionability**
Integration with equipment and systems is part of the Optimal+ deployment
- **Distributed mfg.**
Optimal+ is deployed across the entire mfg. ecosystem – internal and outsourced

Validate

- **Ongoing validation**
Standard rules monitor ML models for excursions
- **Ongoing data collection**
Data collection and harmonization is already fully automatic
- **Technical debt**
24x7 monitoring frees data scientists for their next project

Adapt

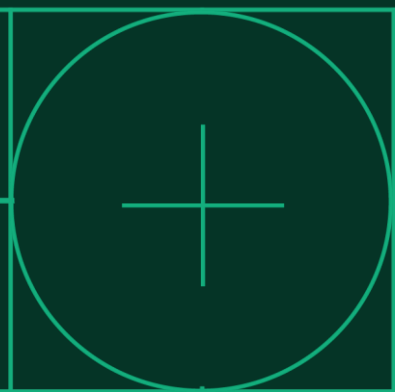
- **Stale models**
Automated rules detect when models are going stale and can even disable them if needed
- **Human-in-the-loop**
Users can browse results and provide feedback directly
- **Relearning**
Model relearning can be partially or fully automated

Connect it all Together with O+

- Model any type of manufacturing data
- Connect all levels of assembly
- Group or analyze data from any level
- Correlate parametric data across any operation at scale
- View and analyze cross operation heat maps
- Reconstruct wafer maps based on any level results

 connect

2024 AUSTIN



Other “Connectivity, Data, and Insight” Activities

