Predictive Analytics for Semiconductor Process Equipment

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Agenda

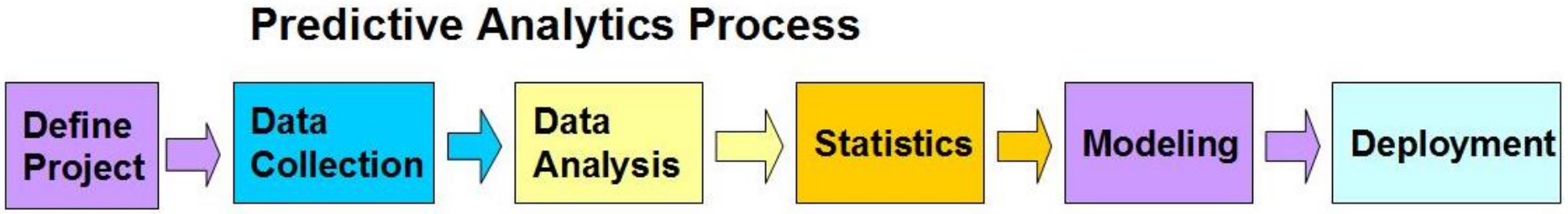
- What is Predictive Analytics?
- Ion Beam Etch Process Metrics
  - Vacuum
  - Consumables
  - Fixture
  - PBN + Source
  - Transfer Module
  - Endpoint system
- IBE Production Use Cases
- Interactive Dashboard
- Conclusion

What is Predictive Analytics?

Predictive analytics is the branch of the advanced **analytics** which is used to make predictions about unknown future events.

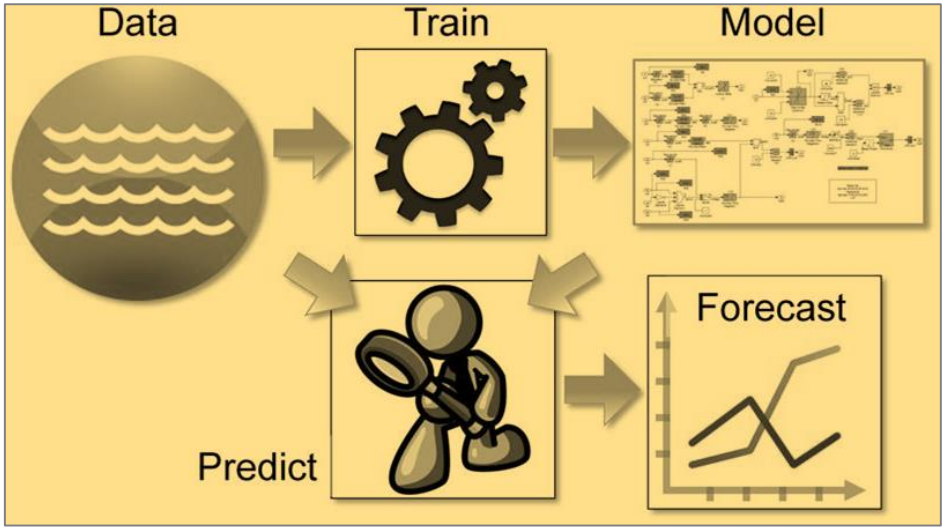
By knowledge sharing, we combined the knowledge of process engineers, equipment engineers, field service engineers, OEM design engineers

Predictive analytics uses many techniques from data mining, statistics, modeling, machine learning, and artificial intelligence to analyze current data to make predictions.



Tool Monitoring Background

- Increased amount of tool data available
- Huge volume of *potentially* useful data
- Building/analyzing charts takes resources
- Solution: Collect only most-critical data



- Monitoring has shifted from collecting ALL data – to intelligently selecting, processing, and visualization
- With concentrated charts, engineers entered Predictive Analytics era!
- Predicting failures/the need for PM requires process AND tool knowledge
  - The strength of the Predictive analytics systems depends on the amount of knowledge sharing.

Predictive Analytics Benefits

- Improve Equipment Field Service troubleshooting capabilities
  - Develop models to prevent/monitor common failure modes
  - Provide data to (1) reduce the amount of time required to investigate field service issues and (2) analyze new yield loss mechanisms
- Improve new tool qualification and hardware/component testing
- Provide customers with a simple, intuitive dashboard to improve tool uptime and yield by **detecting faulty hardware in advance**

Ion Beam Etch Metrics

Vacuum Metrics

IBE operates in sub atmospheric environment, thus monitoring system pressure and pump behavior is critical – models include:

- Start of Run Pressure – measures ion gauge pressure for 25 seconds after wafer clamps to identify if there are FlowCool leaks
- Idle Pressure - measures ion gauge pressure after 30 min, 60 min, 2 hr, and 4 hr of tool idle time
- Recovery Pressure – measures the pressure to which the system pumps down to 1 minute after processing a wafer

Consumables Metrics

A major sauce of downtime is related to replacing consumables, thus tracking these help PM scheduling and reducing tool downtime:

- Grids Counter – electrical shorts in the grids is the leading cause of tool downtime at most customers, thus monitoring this counter is essential
- Shields Counter – knowing when shields are close to replacement helps technicians group PMs together to reduce downtime
- Clamp Claws Counter – clamp claws hold wafer in place and need to be replaced prior to causing leaks in the system

Fixture Metrics

The fixture has 3 axis or motion, thus tracking its motion behavior is important – it is a possible source of leaks because of its motion:

- FlowCool pressure – this flow is helps maintain wafer temperature and therefore process uniformity and repeatability
- FlowCool Max/Min Ratio – monitoring to ensure process stability
- Rotation Speed Delta – monitors the difference between programmed value and actual rotation speed

PBN and Source Metrics

The beam neutralization (PBN) is an important aspect of reducing the charge build-up on wafers during processing – models include:

- Etch Filament Current monitoring detects when the filament must be replaced
- Etch PBN Body Current – this critical signal controls how the ion beam is neutralized
- Probe Voltage is also related to the neutralization of the ion beam, this it is tracked for trends over time
- Suppressor Current versus Beam Current – this ratio indicates impending shorts

Transfer Module Metrics

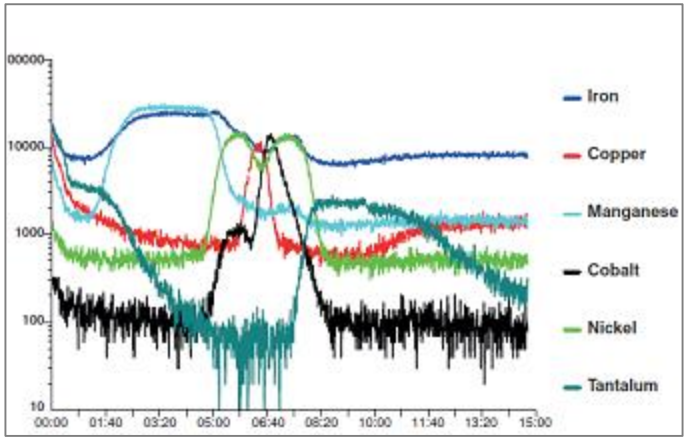
The Transfer Module monitoring examines the alignment values to verify the aligner is optimally adjusted – models include:

- Aligner eccentricity Angle – this metric will drift over time - excessive drift will trigger a PM

- Pre-process-Post Process alignment tracking
  - If wafer accidentally, physically contacts something (in PM or TM) during transfer, the model will alert the user based on the change in alignment from pre-process versus post-process values

- Alignment Time tracking reports the total amount of time that is required to align each wafer
  - Excessive time = decreased throughput, and need for aligner PM

End Point Detection Metrics



Endpoint monitoring examines the endpoint signal intensity and critical process settings:

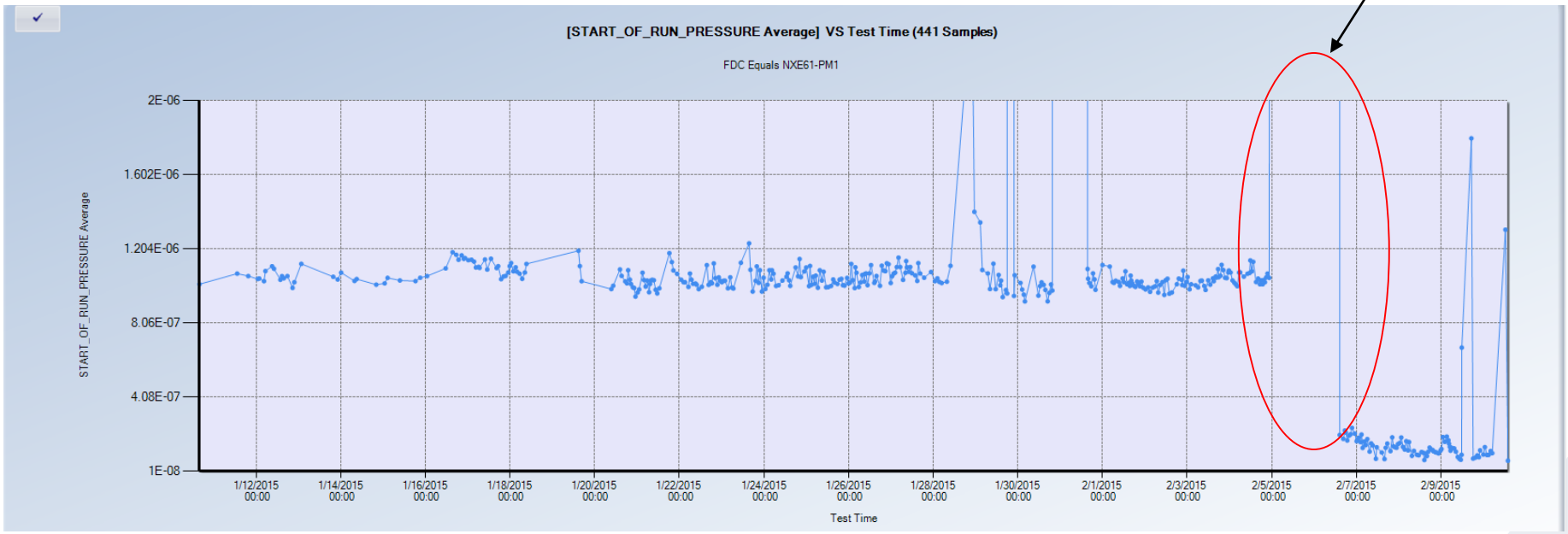
- Endpoint systems are critical feature in the etch and deposition process control
- Deterioration of the optics reduces the accuracy and function of the EP system
- Metrics have been developed for both Hiden and Verity systems
- Metrics include signal intensity and process settings such as PMT voltage

Production Use Cases

Use Case 1: Leaking Bellows on PM1

Process Module 1 on tool had been starting the process at a slightly higher vacuum pressure for several months – this introduced etch process variations

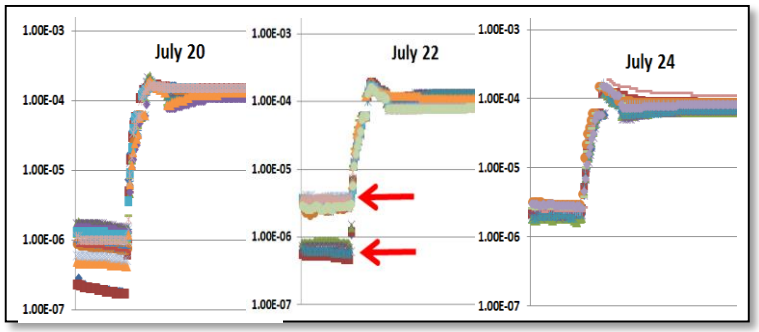
- Observing differences between “start of pressure” on PM1 versus PM2, Veeco Field Service discovered the problem and replaced a leaking bellows – note the drop in “Start of Run Pressure” after maintenance



Use Case 2: Start of Run Pressure Trending Up

Case Study: Predicting Unscheduled Downtime

Field Case Study – Start of Run Pressure

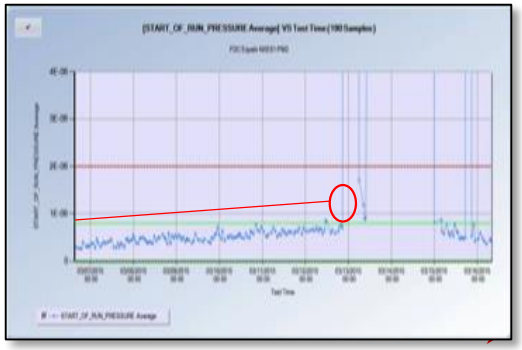


Old Diagnostic Process

- Manually Pull logs – FSE Travel Costs
- Manipulate, Align and Filter data – Man Days
- Offline analysis at HQ – Man Days
- Unscheduled Equipment downtime
- Scrap Potential

5 days to root cause identification

15% Reduction in OEM Maintenance Costs



Predictive Analytics Monitoring

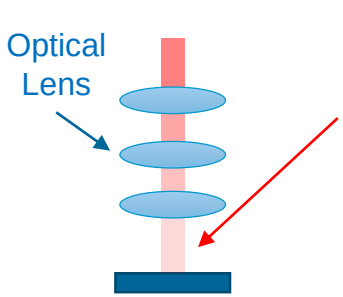
Run Pressure is being constantly monitored
Critical timing after wafer clamp, before Gas flow starts
Model detects upward slope and alarms

- Automated Notification
- Dashboards displays error state

Equipment team know exactly what the issue is to resolve
Standard procedures now at customers site

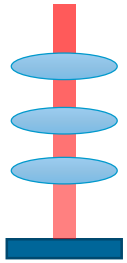
Prevented unscheduled downtime & drastically lower MTTR

Use Case 3: Endpoint Optics Preventative Maintenance



Poor intensity results In poor Endpoint Metrology

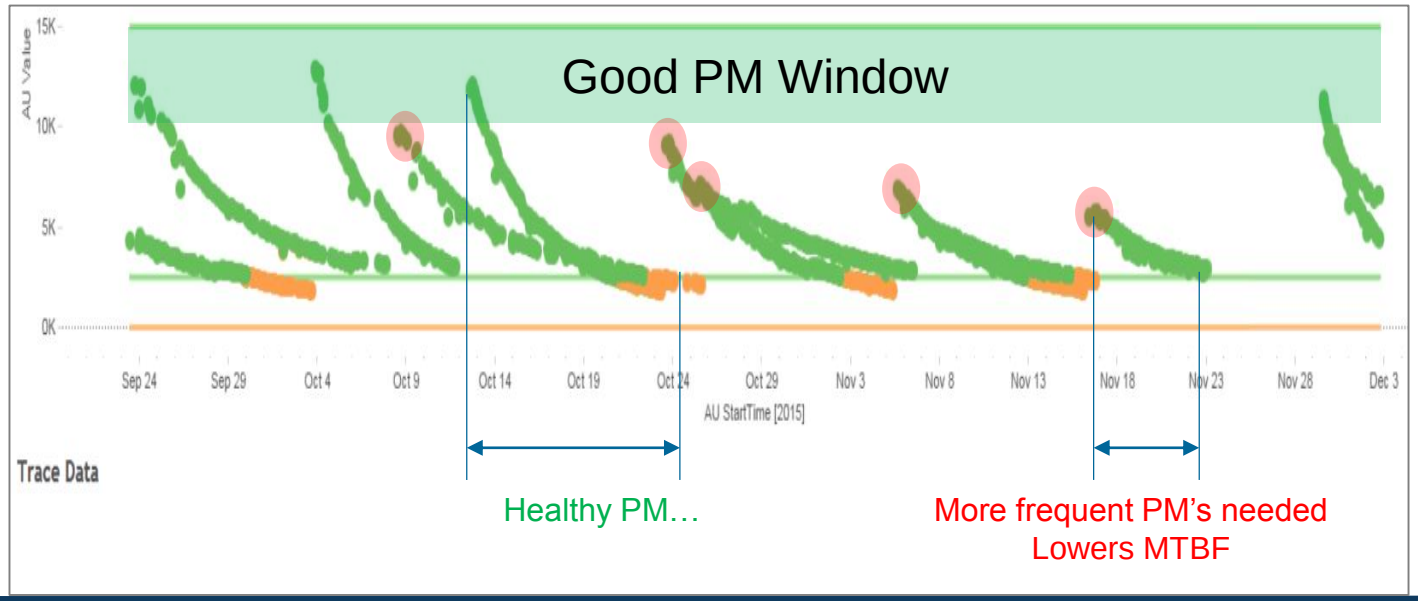
Pre – PM
Low intensity
Un- Stable Metrology



Post – PM
High intensity
Stable Metrology

Key Benefits

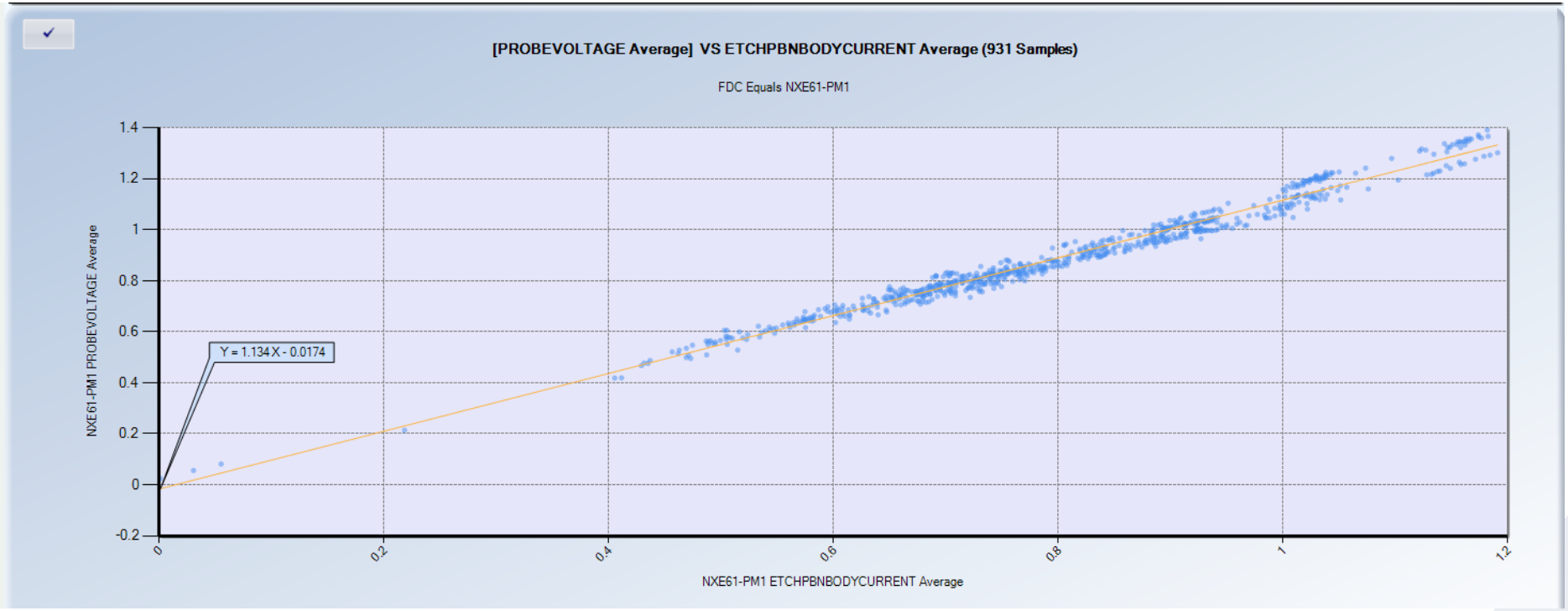
- Higher Equipment uptime
- PM Quality Verification
- Ability to predict PM need
- MTBF improvements



Use Case 4: Understanding Process Correlations

According to Veeco, prior to our data analysis, understanding critical process correlations would take hundreds of log files to be exported and plotted manually

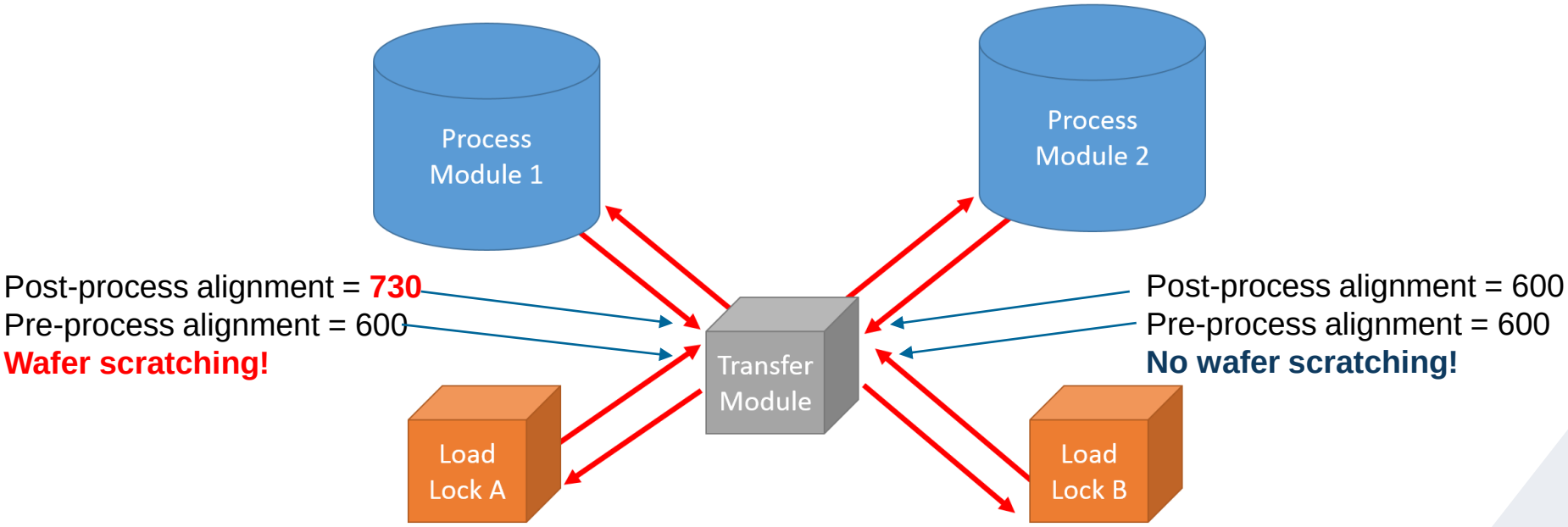
- This correlation chart saved hours of time for Service engineers



Use Case 5: Transfer Module Monitoring

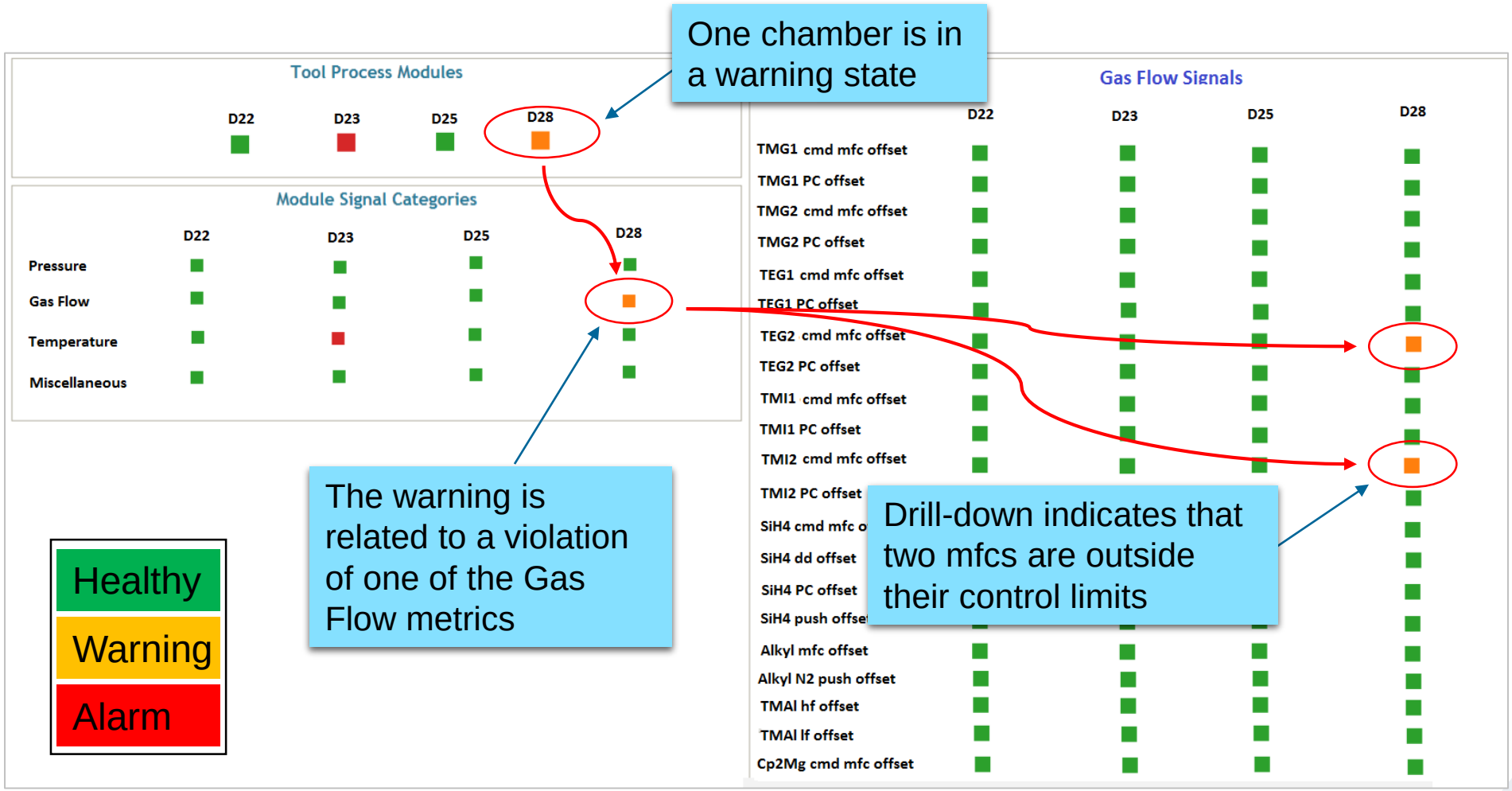
Wafers can become scratched due to wafer transfer process

- Typically process engineers and FDC solutions monitor only process chamber conditions (and ignore the potential for the transfer process to impact yield)
- The wafer contact can be detected by new metric which compares the pre and post-processing alignment values
- A change in alignment values indicates wafer contact and potential scratching



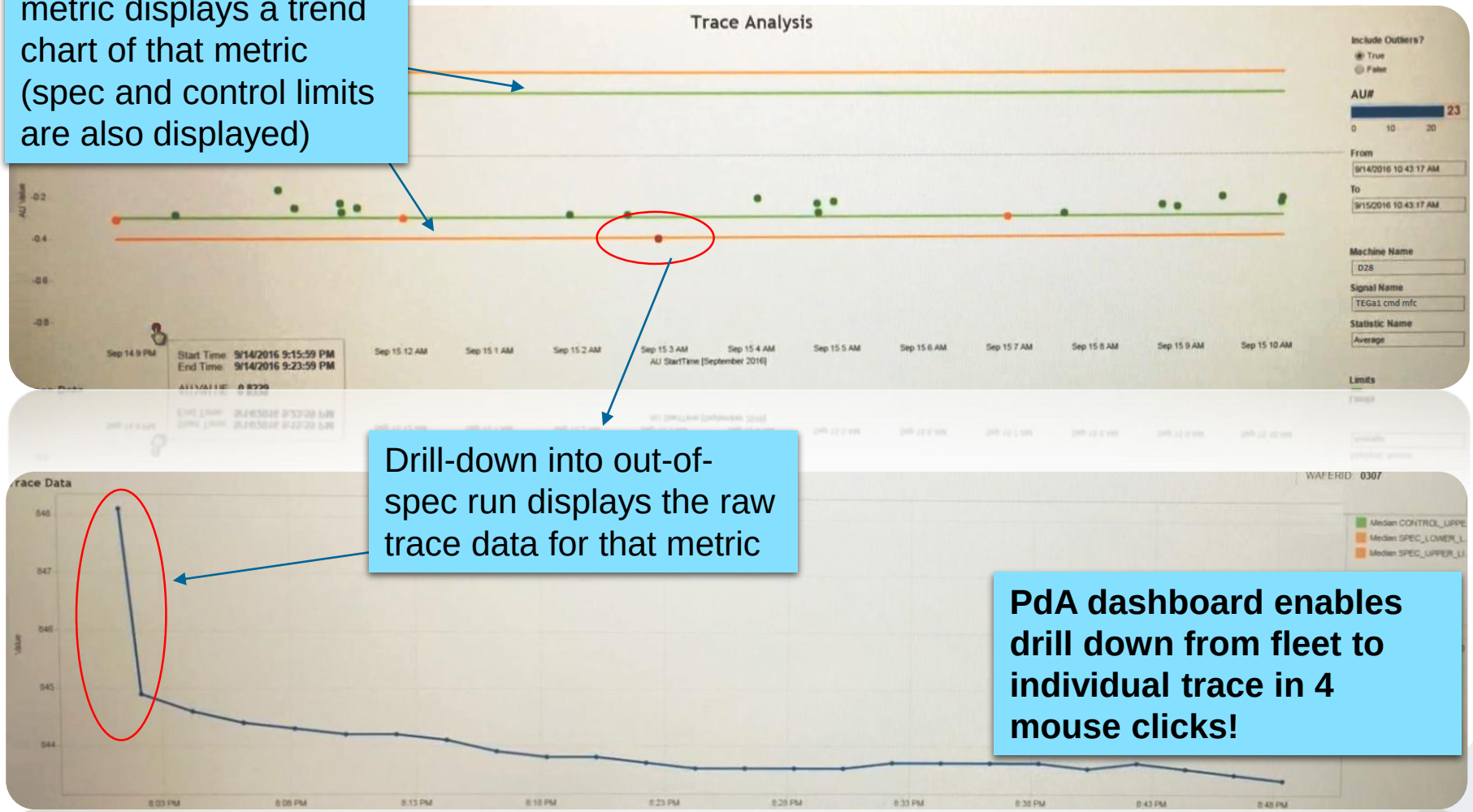
Interactive Dashboard

Interactive PdA Dashboard



Dashboard Drilldown

Drilling down into a metric displays a trend chart of that metric (spec and control limits are also displayed)



Drill-down into out-of-spec run displays the raw trace data for that metric

PdA dashboard enables drill down from fleet to individual trace in 4 mouse clicks!

Conclusion

- Intelligent data collection enables the creation of simple, yet intuitive tool health dashboards
- without creating process–in-specific metrics, the subtle yet critical process differences would be hidden in the noise
- Predictive Analytics is built upon an OEM’s deep understanding of field failures, and component vulnerabilities, and failure rates warning signs

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Thank you!

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