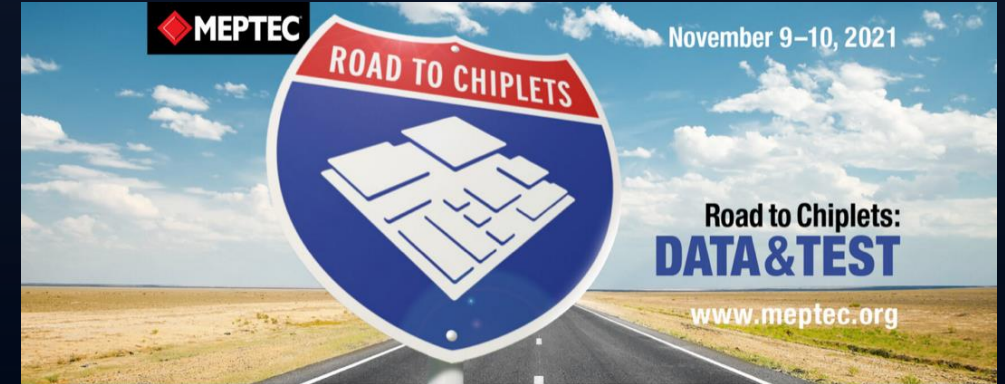




Road to Chiplets: Data & Test

November 9 - 11, 2021

PDF/SOLUTIONS™



Leveraging semiconductor lifecycle data to drive closed-loop and cost-efficient chiplet quality testing

Kimon Michaels, Exec. VP

November 11, 2021

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PDF Solutions: Predictive Power for Semiconductor Manufacturing & Test and Electronic Systems

Founded

1991

30th

Anniversary

PDFS

Listed on
Nasdaq

> 400
Employees



>100 Ph.D.



>200 Advanced
Technical Degree

HQ

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USA

Our
Customers:

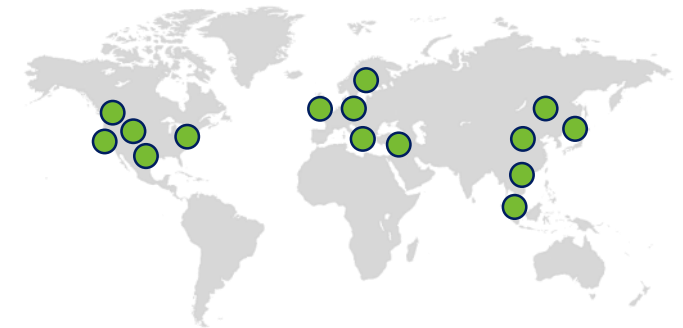
18 of Top 20

Semiconductor Companies

and

The Top 6

Foundries

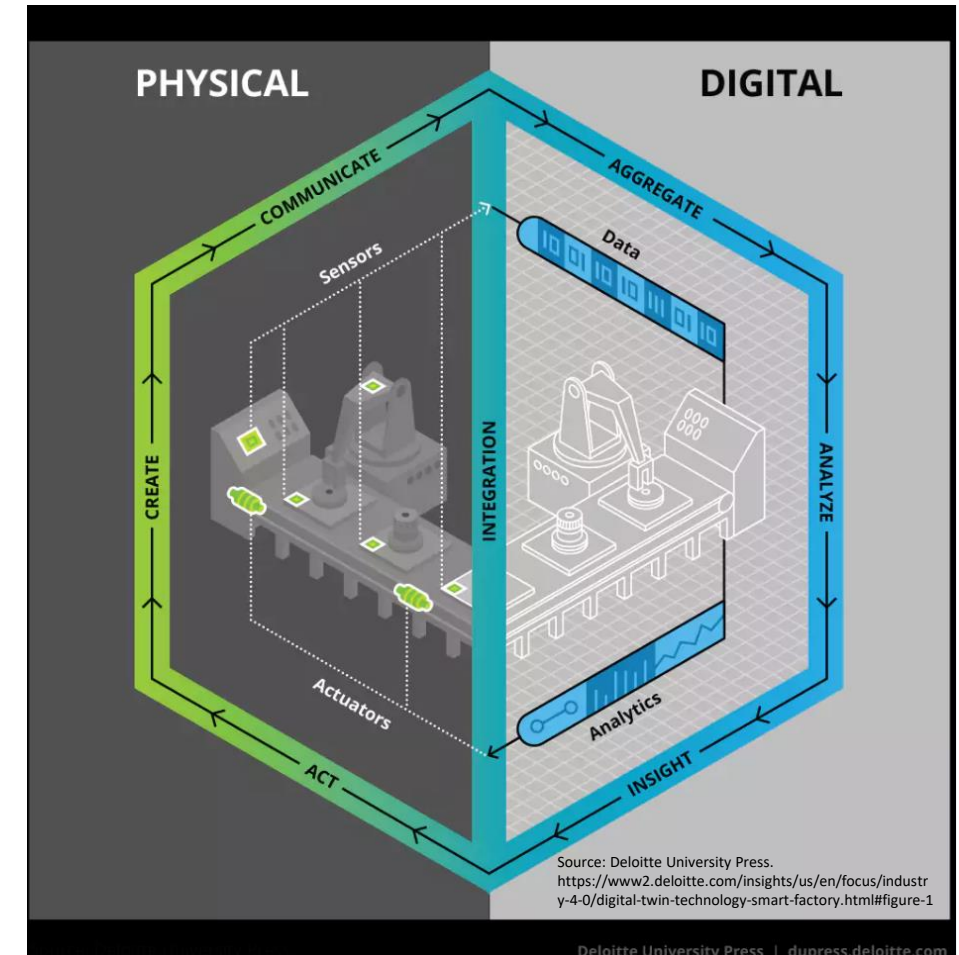


Offices and Support
Centers Worldwide

Semi and Electronics Adopting Smart Manufacturing

■ Digitization drives the realization of Industry 4.0

- **Sensors** – e.g. FDC or cell controllers
- **Integration** – common platform to access data
- **Advanced AI/ML** – analytics at the edge for yield prediction, advanced outlier detection/screening etc.
- **Semantic data models** – to enable digital twins
- **Online Control** – for closed-loop smart mfg. solutions
- **Site-to-site connectivity** – integrating data across the entire supply chain

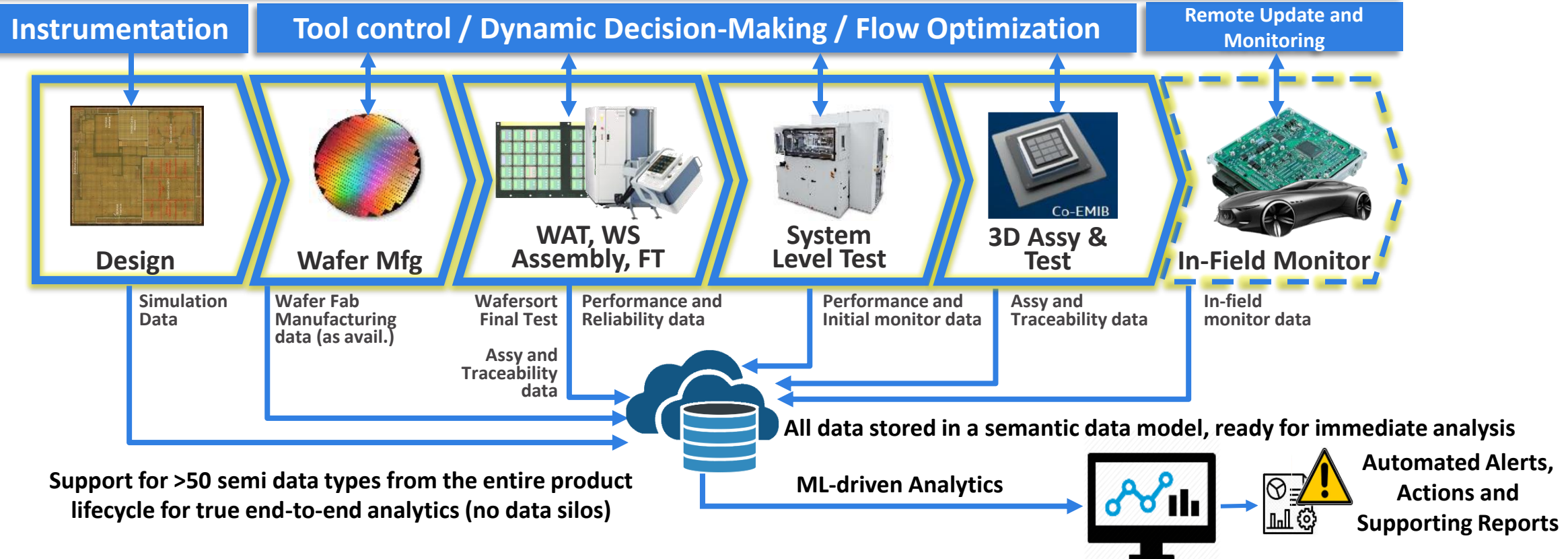


Industry 4.0 is driving digital transformation spanning the Silicon Life Cycle

Leveraging Data Across the Silicon Product Lifecycle

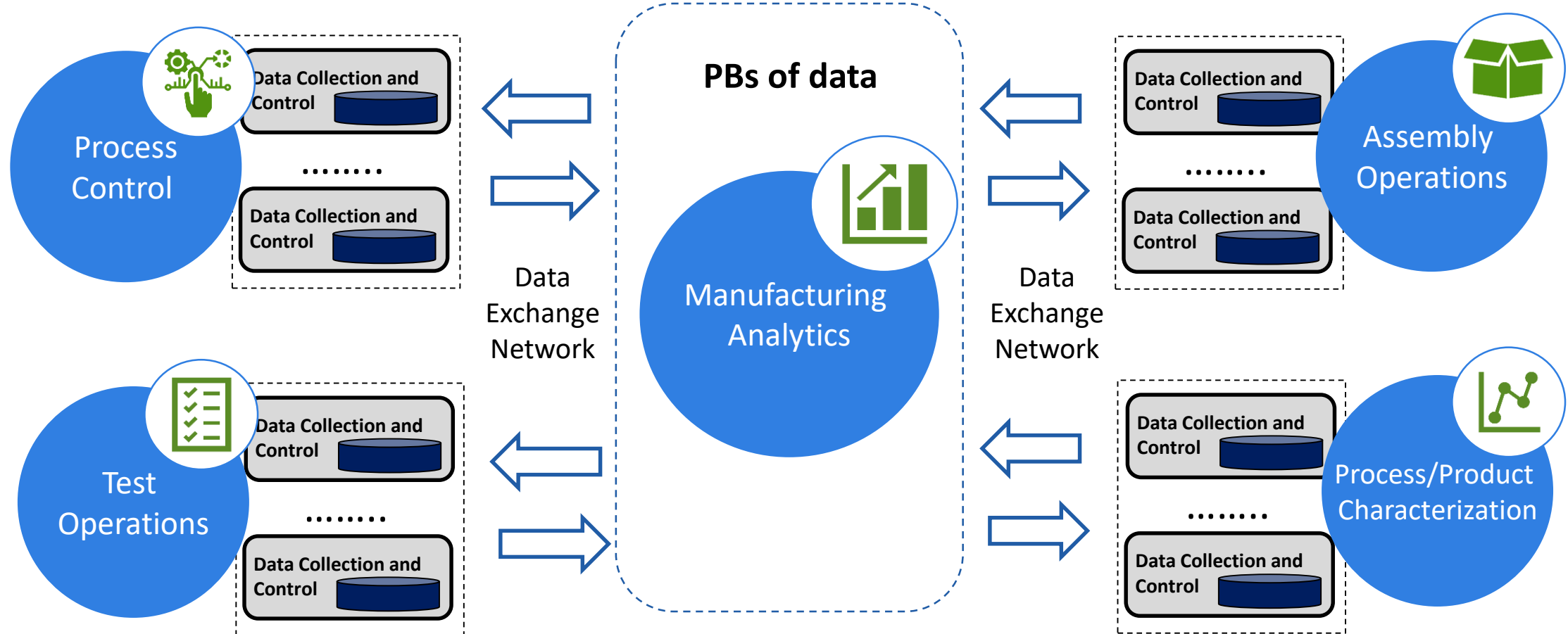
Data Feed Backward: Performance & Variability Optimization | Quality & Reliability Improvement

Data Feed Forward: Drift & Excursion Monitoring | Drilldown & Diagnostics



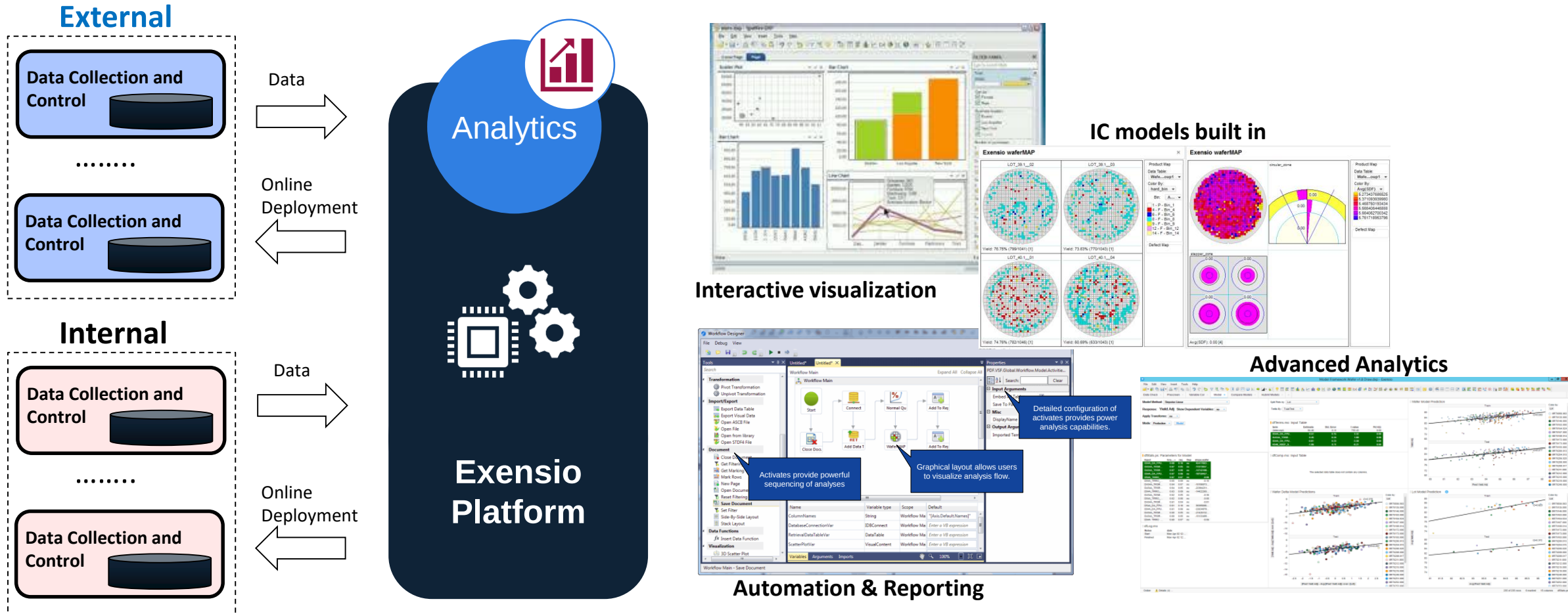
A semantic data model is essential to support heterogeneous packaging & test

Data Exchange Network to Share Data Across the Silicon Lifecycle



Enabling Data Access for Heterogeneous Test and Packaging

Exensio Platform: Integrating FE & BE Data for Mfg & Test



- Powerful signature analysis and diagnostics

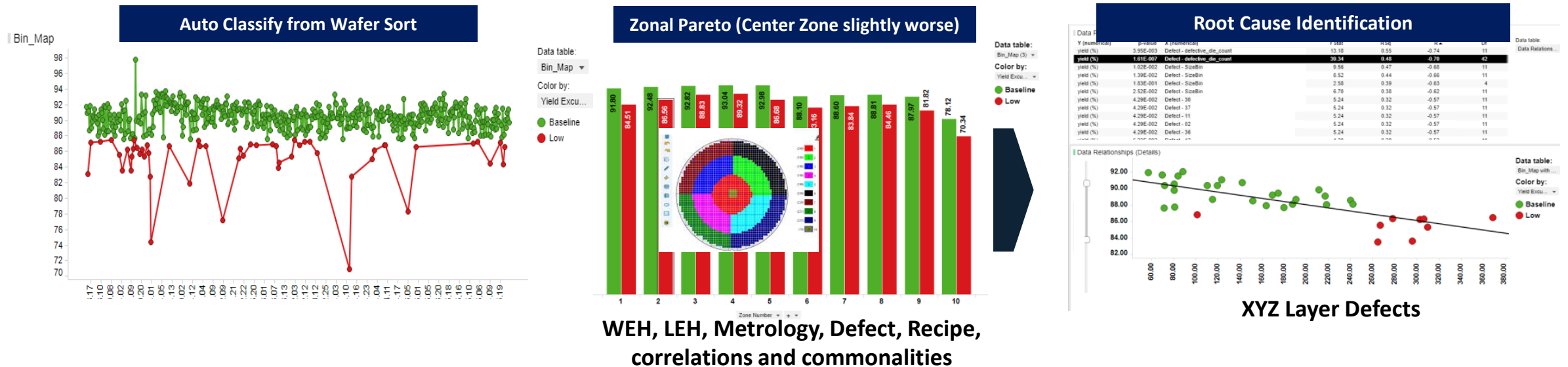
Predictive power for the analysis of advanced ICs and electronic systems

The Need for a “Single Source of Truth” for all Product Data

- **Allows companies to integrate their offline AND online systems**
 - Use the same data for analytics and actions for test and overall quality assurance
- **Enables broader and faster implementation of online actions**
 - No waiting for “clean and aligned” data to arrive
- **Facilitates “Womb-to-Tomb” product traceability**
 - Single die traceability from the fab to test operations to in-field
- **Drives creation of closed loop product lifecycle optimization**
 - Automated root cause analysis + proactive/predictive OCAP

Start Analysis Early to Catch Problems Sooner

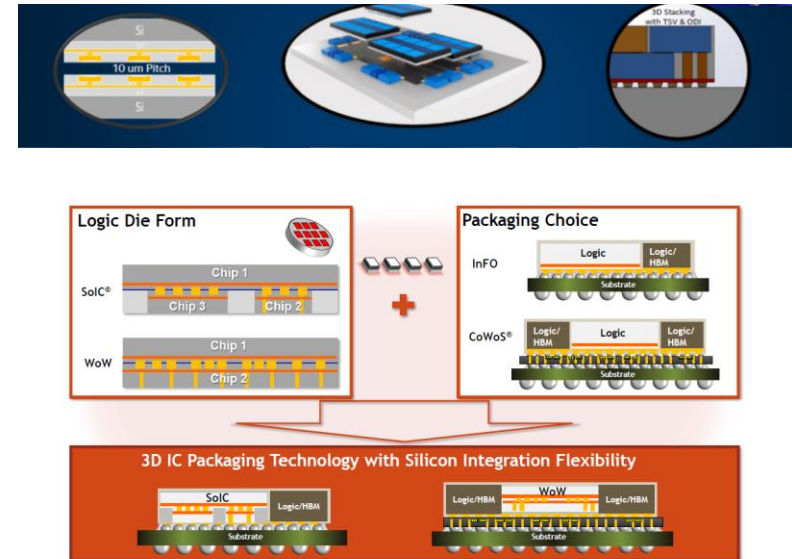
- Identify root cause of excursions faster with auto-analysis and drill down on fab manufacturing data



Automated analysis reduces yield variability and removes human factor

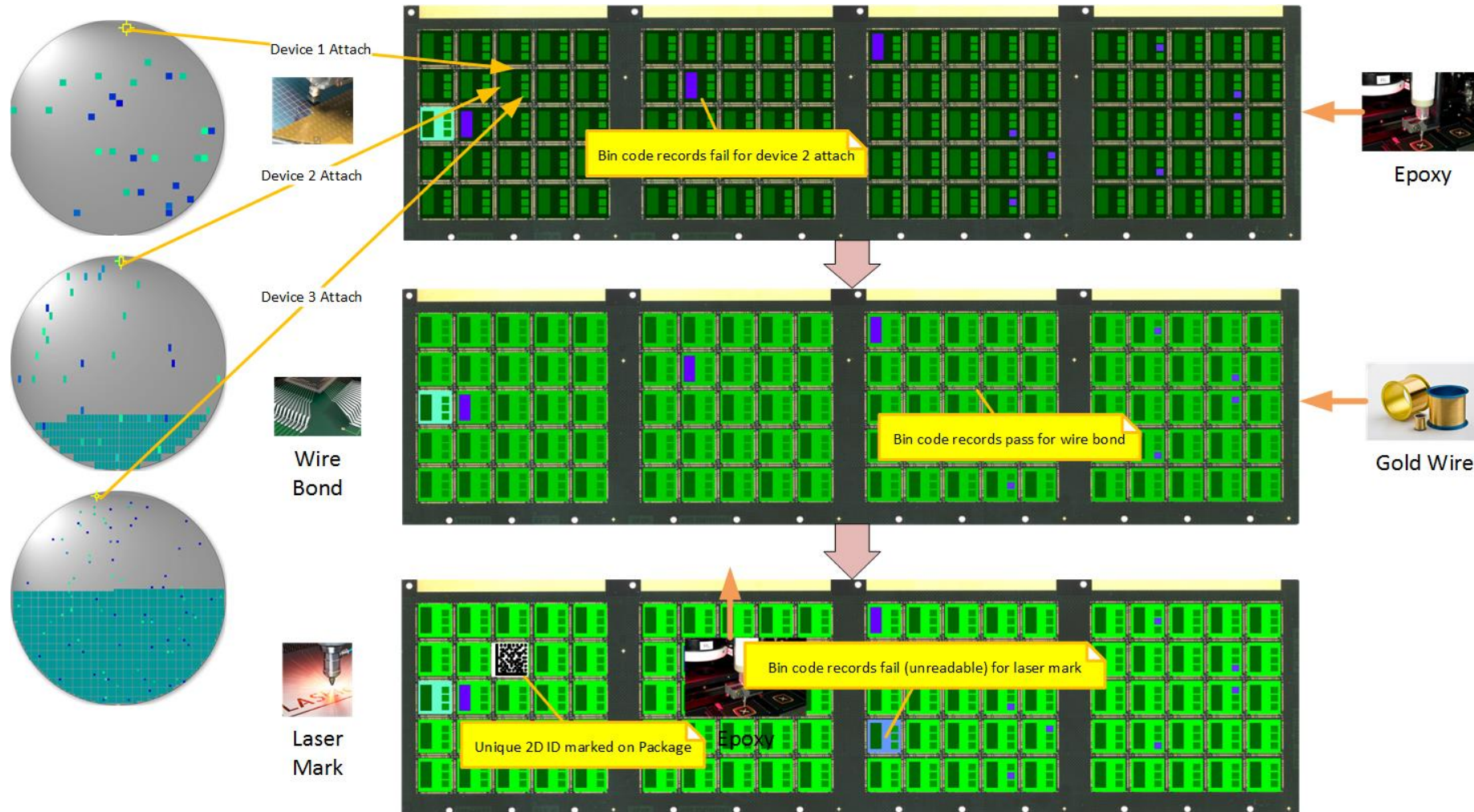
Heterogeneous Integration is a Traceability Challenge

- According to an example from AMD*, when comparing a 32-core monolithic IC to 4x8-core chiplet, the chiplet area penalty is ~10%, but the cost savings are ~40%
- But what happens if you put 4 good chiplets into a heterogeneous, integrated package, and it doesn't work?
- How do you find the root cause?



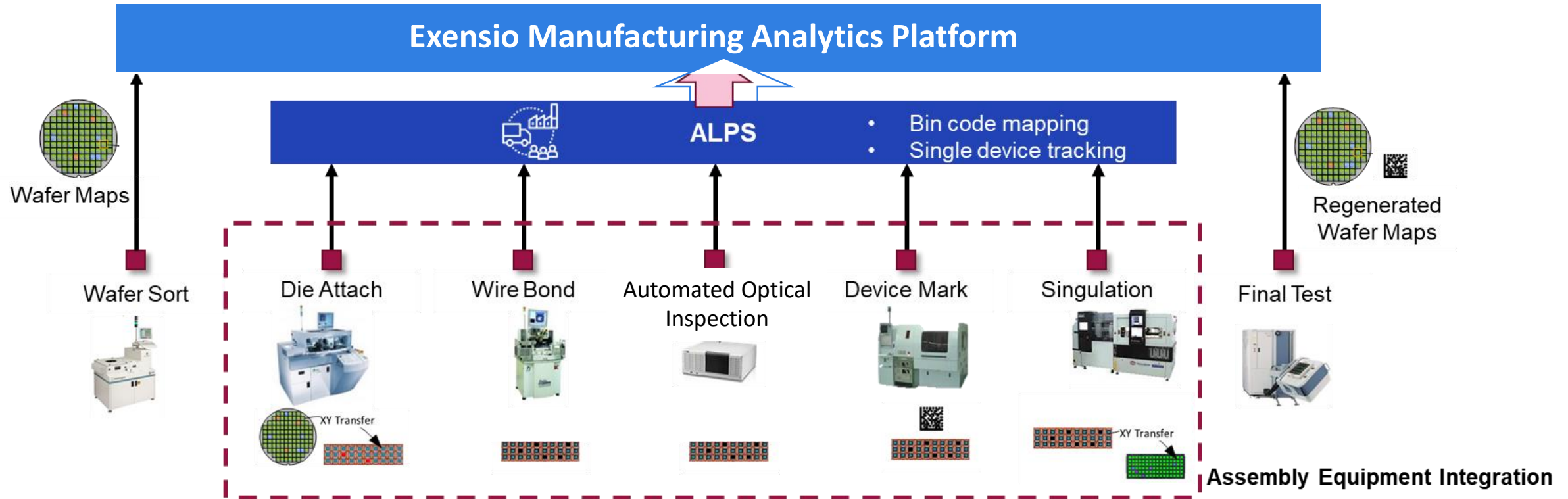
* <https://www.nextplatform.com/2021/06/09/amd-on-why-chiplets-and-why-now/>

SEMI E142 Standard* for Single Die Traceability & Consumables



<https://store-us.semi.org/products/e14200-semi-e142-specification-for-substrate-mapping>

Linking All Product Data Through Assembly Without ECIDs



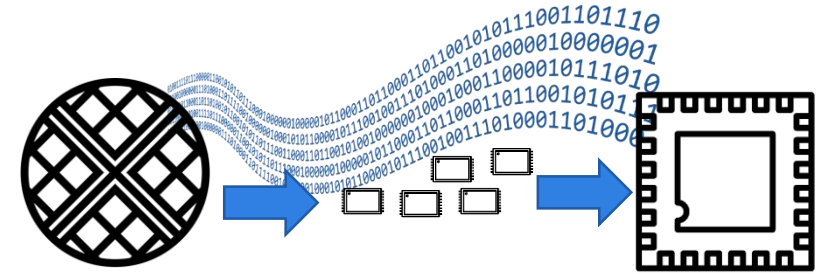
- Perform root cause analysis of reliability and performance issues related to assembly
- Essential for regulated market segments and high value consumer segments

Traceability of all components AND materials of a heterogeneous package

Additional Visibility is Needed for Chiplet-Based Systems

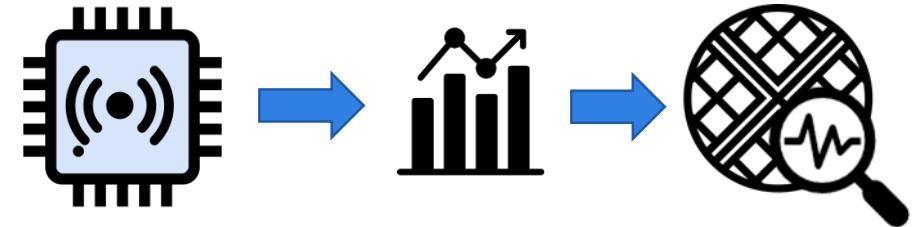
■ Leveraging front-end characterization

- Full core characterization for KGD determination
- Chiplet performance matching (slow/fast die challenge)



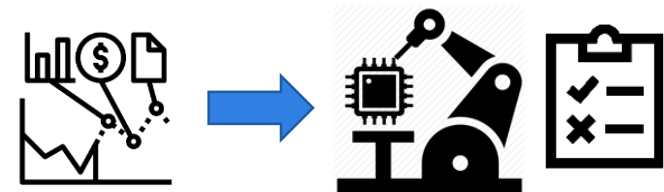
■ Lifetime diagnosis (via on-die sensors and monitors)

- Wafer sort chiplet screening for marginality and latent defects (reliability risks)



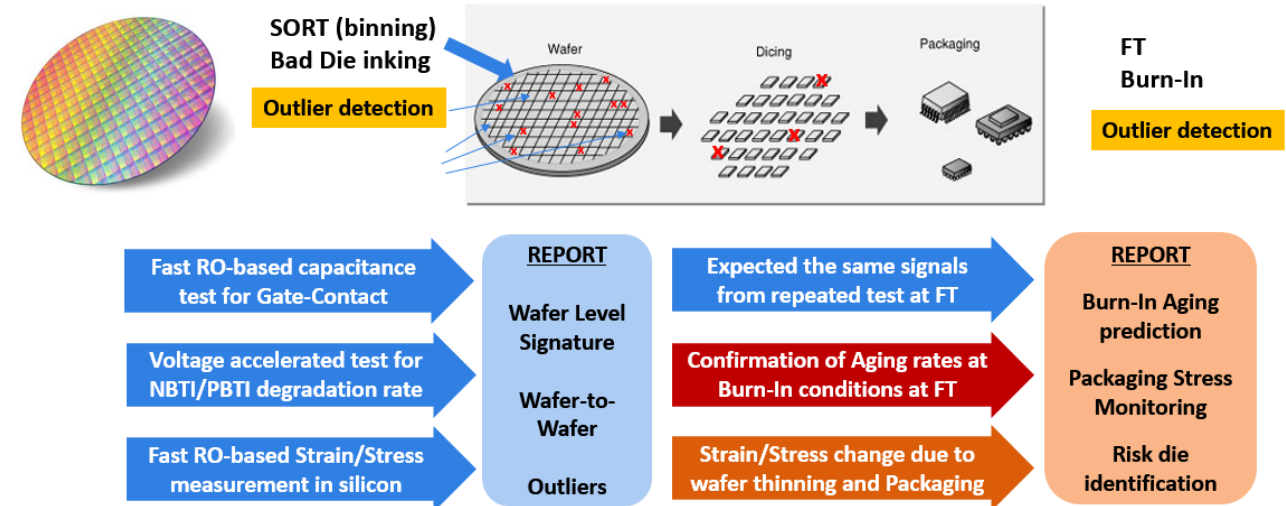
■ Optimizing cost and quality (predictive analytics)

- Test escapes elimination based on scan data diagnostics
- Burn-in optimization
- Full assembly process traceability

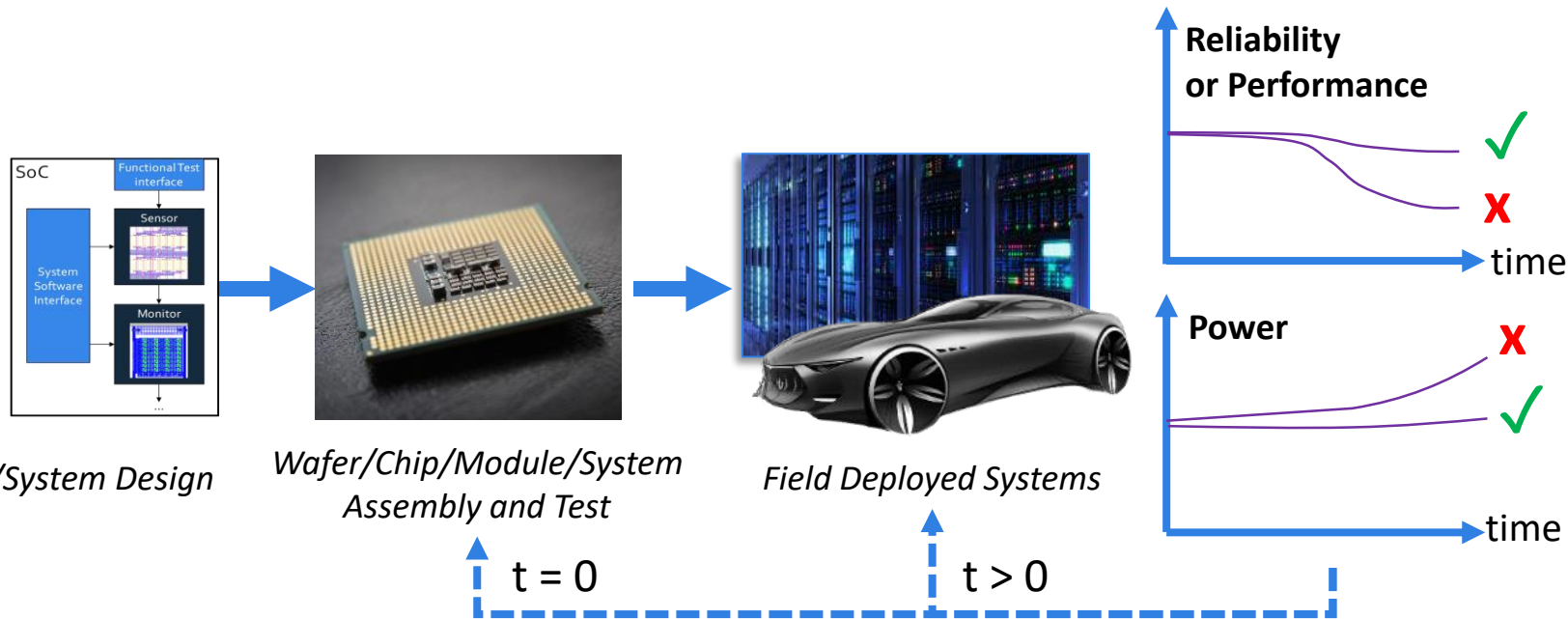


Utilize Front-End Data to Solve Back-End Problems

- ML models built on integrated FE and BE data quantify the relationship between upstream data and final yield
- Scribeline characterization can drive increased visibility and cost reduction
 - Optimize test operations for quality and efficiency
 - Identify scrap material sooner to eliminate wasted BE test



Leverage In-die Sensing for Actionable Insights into Heterogeneous Devices



Test Optimization

- Optimized test flows
- Higher quality
- Faster bring up

Mission-mode optimization

- Increased reliability
- Better Power/Perf. vs. Reliability
- Mission mode failure prediction (e.g., due to delamination, corrosion or cracking)

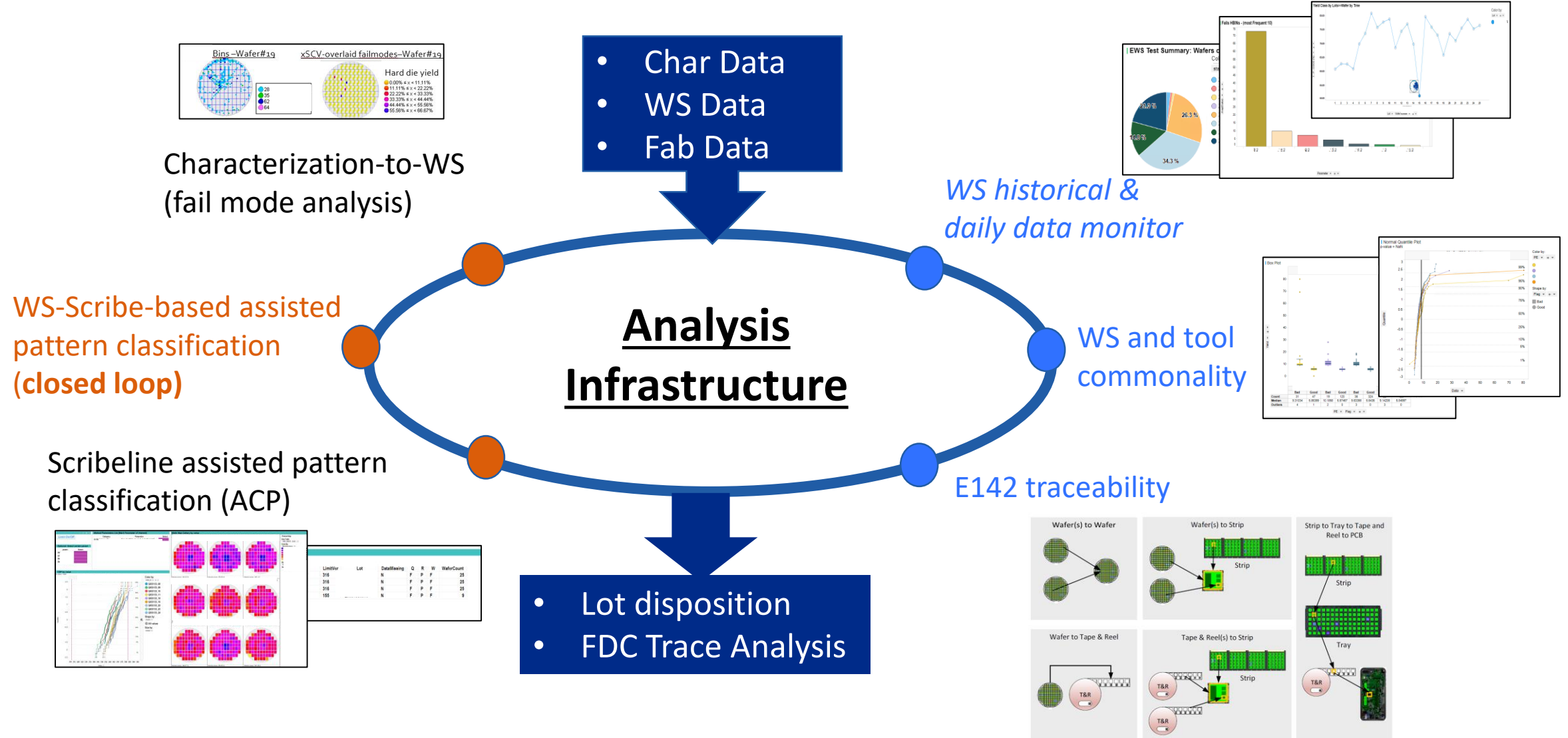
In Field Monitoring

- **Fast issue diagnosis and solution**
 - Burn-in fails
 - RMA containment
 - End-to-end Analytics for root cause understanding and failure prediction
- **Improved Quality and Reliability**
 - Better screening at $t=0$
 - Meet aggressive SLA commitments
- **Performance Optimization**
 - Process centering
 - Power (MWh)
 - Variability (bin)

Holistic Product Data Can Provide “Predictive Power”

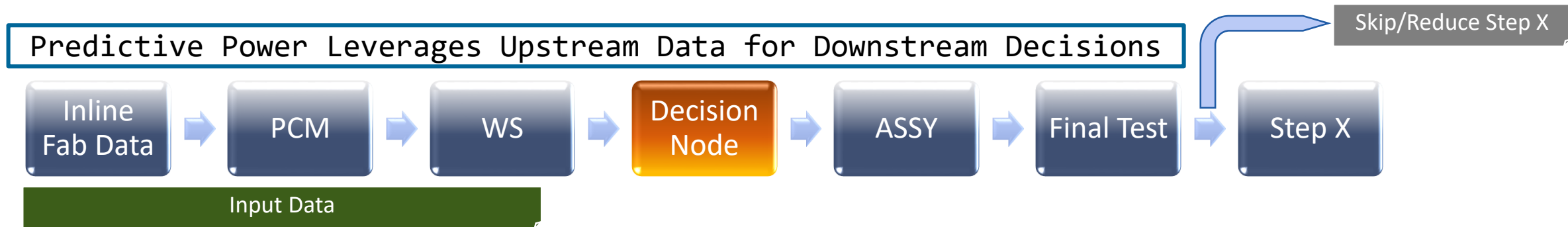
- **Product data is collected to answer product engineering questions**
 - Do I have enough product yield to meet my contractual obligations?
- **Are you leveraging your product data to achieve Predictive Power?**
 - Machine learning enables you to model alternative product test flows very early in the NPI phase when the entire product team is still intact
 - Achieve maximum optimization of yield/quality/reliability based on the target end market for every product

Data + Infrastructure + ML Analytics = Predictive Power



Applying Predictive Power To Improve Quality & Cost

- Using upstream data, ML analytics can be used to predict if certain downstream steps can be fully or partially skipped



Failure Bin A Prediction	Failure Bin B Prediction	Combined Prediction	Die Population Passed	ACTION
PASS	PASS	BOTH_PASS	30%-50%	Completely Skip
FAIL	PASS	FAIL_BIN_A_ONLY	10%-20%	Partial Testing
PASS	FAIL	FAIL_BIN_B_ONLY	10%-20%	Partial Testing
FAIL	FAIL	BOTH_FAIL	10%-50%	Complete Testing

Value Assessment:
\$1.2M - \$1.7M test savings annually on just one product with no quality impact

Summary

- **A comprehensive semantic data model and data infrastructure is needed to leverage product data for heterogeneously packaged devices**
- **Complete end-to-end data can enable Predictive Power to achieve:**
 - Reduced variability in manufacturing, more KGD
 - In-die characterization and sensing to improve “in field” prediction of reliability
 - Single die/chiplet traceability for rapid root cause analysis and automated correction
 - Creation of multiple test populations to reduce test costs with no impact on quality

Heterogeneous integration requires an inclusive data approach from manufacturing to test/assembly/packaging to in-field

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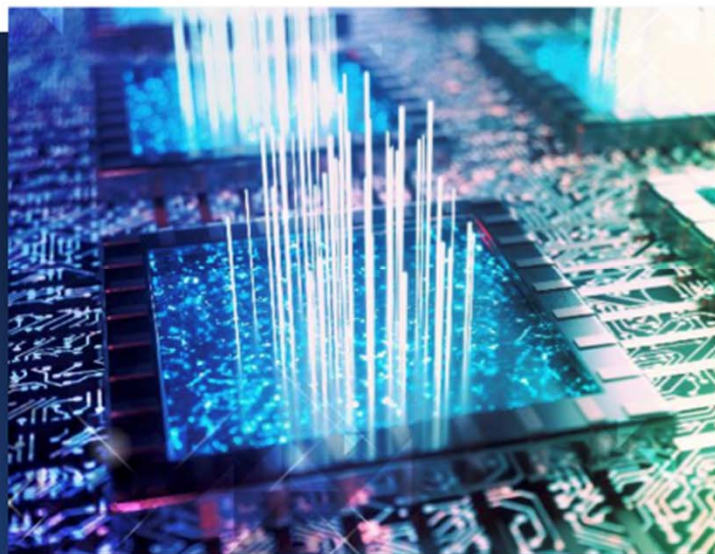
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