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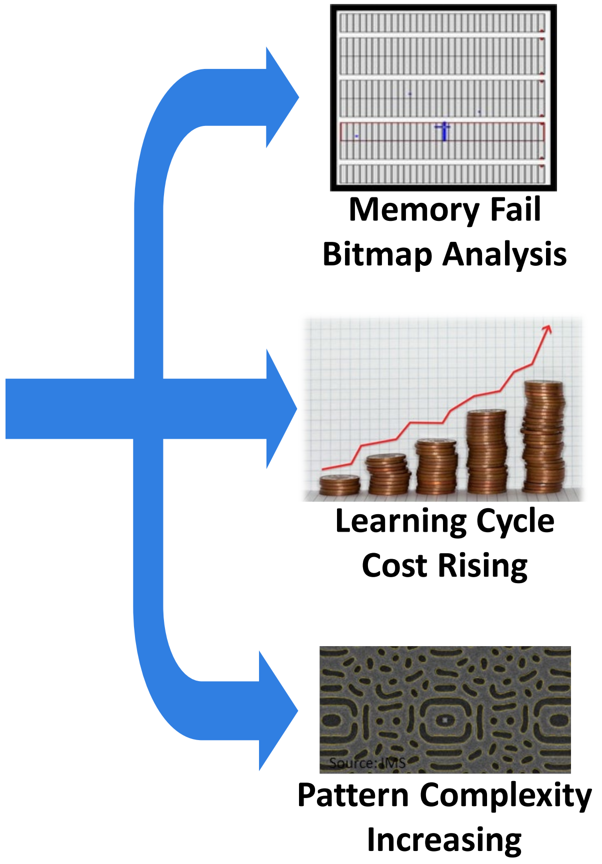
Accelerating Yield Learning

ITC 2023 / OCT 2023

PDF Solutions and Siemens EDA accelerating yield



Tessent SiliconInsight + Exensio Bitmap Integration

Accelerating setup and analysis
for complex embedded memory products

Tessent YieldInsight + Exensio Integration

Reduce time to yield by bringing together
scan diagnosis data with manufacturing analytics

Tessent YieldInsight + FIRE layout pattern systematics

Extend volume scan diagnosis
with layout pattern systematics

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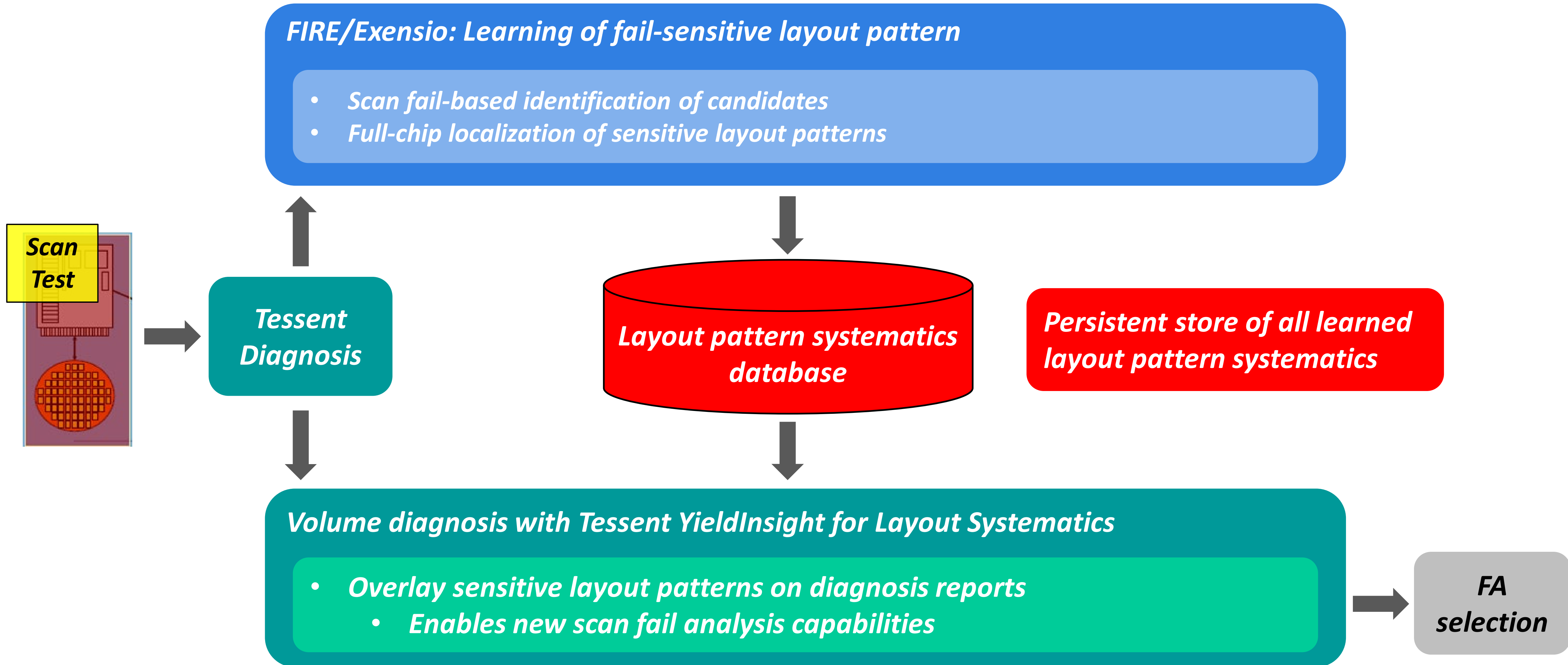
Tessent YieldInsight + FIRE/Exensio layout pattern systematics



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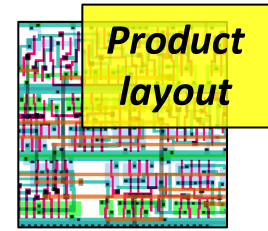
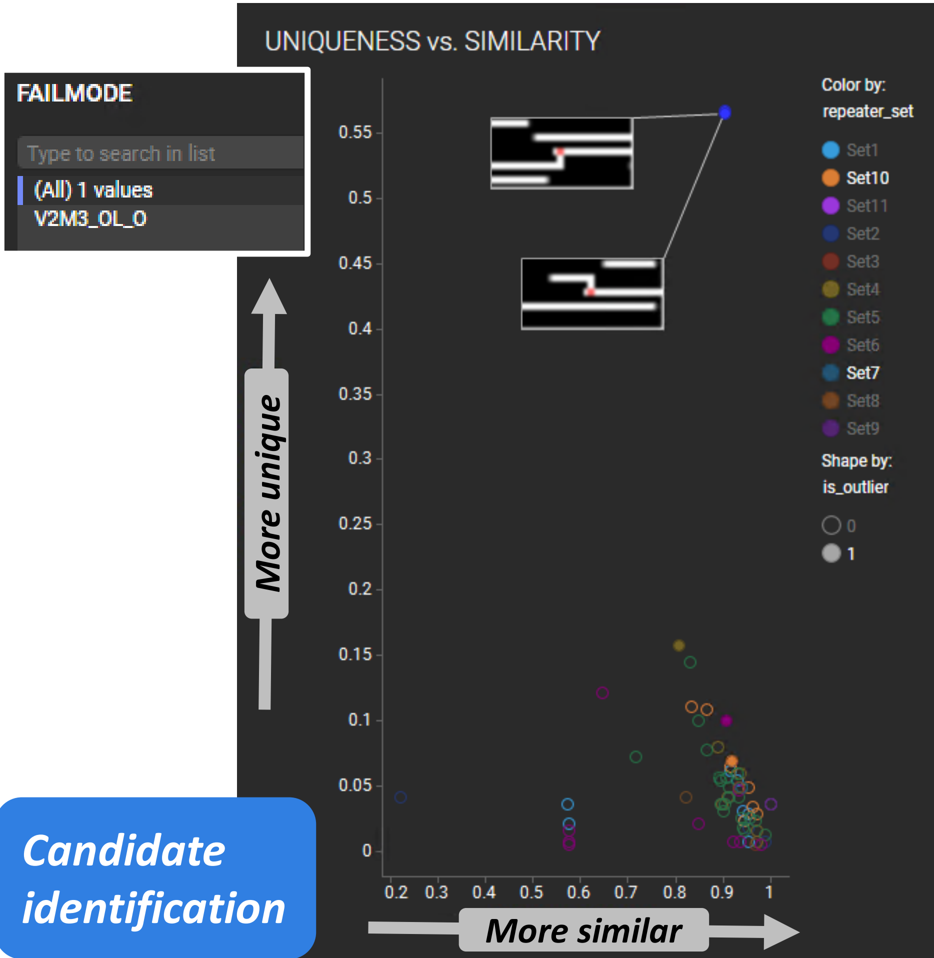
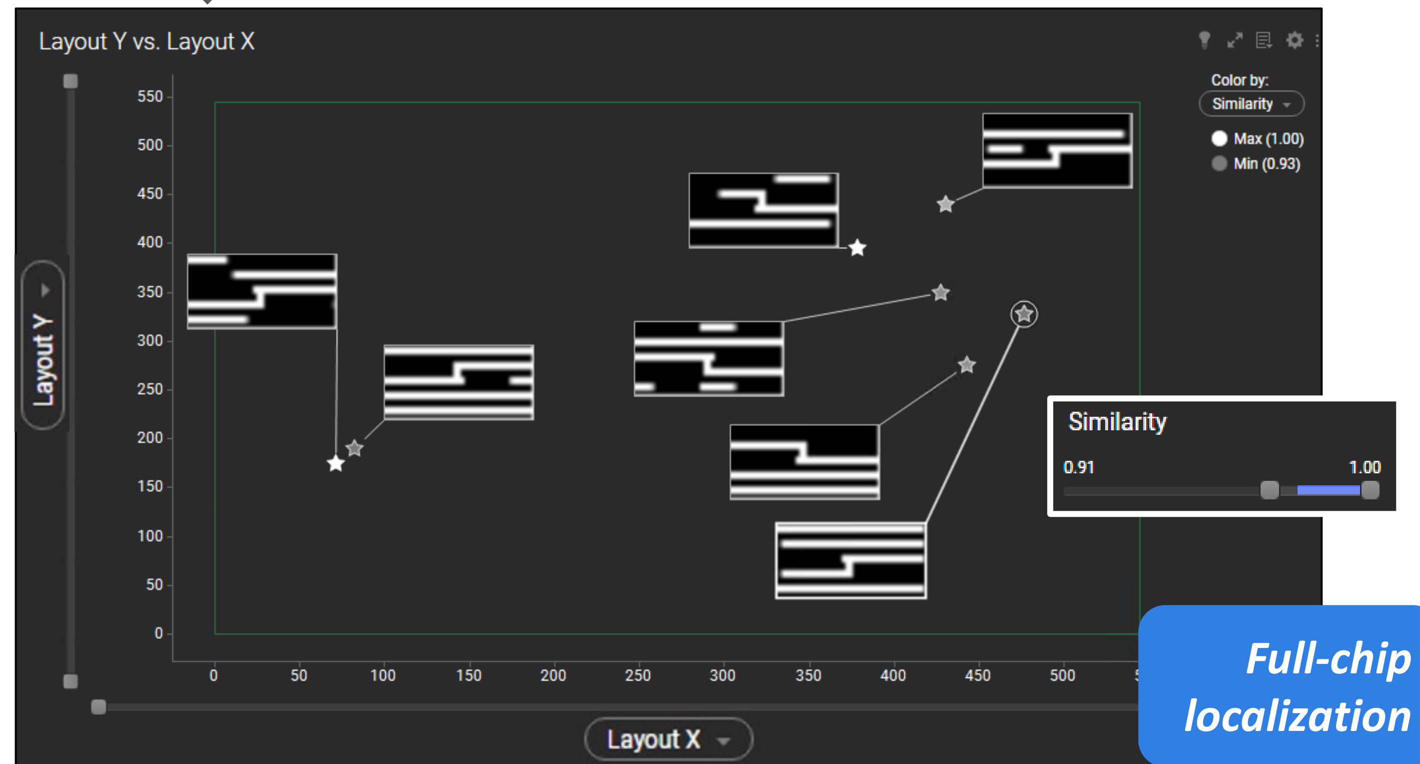
FIRE + Exensio: Layout pattern systematics learning



Layout pattern systematics database





Candidate identification

Full-chip localization

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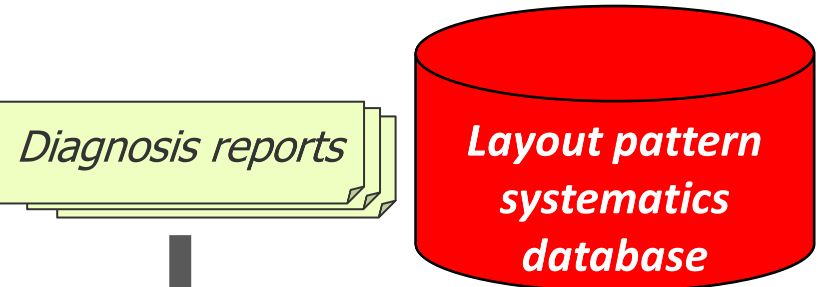
Tessent YieldInsight: Volume scan diagnosis with layout pattern systematics

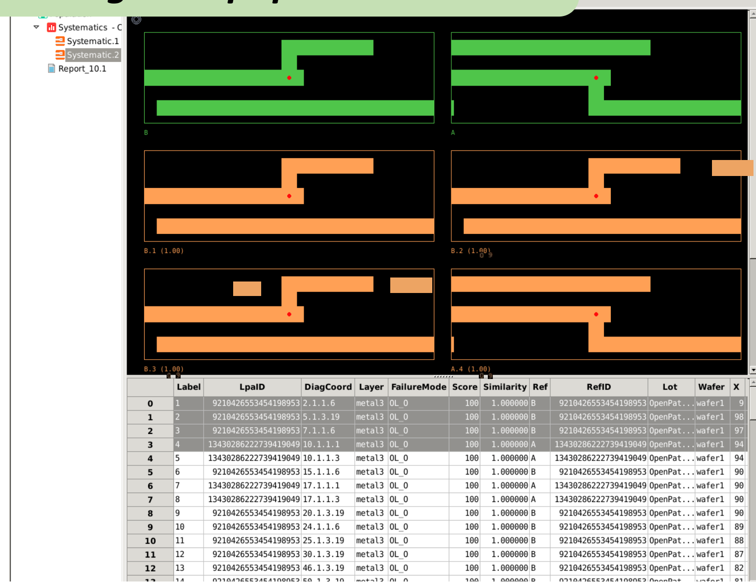


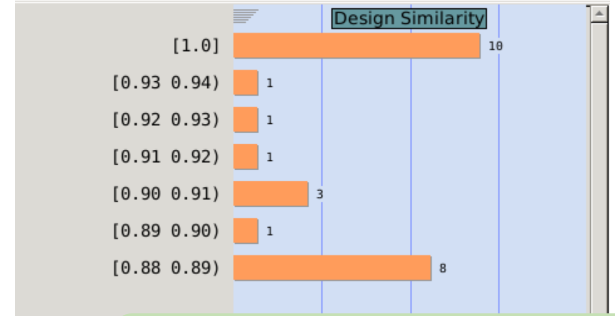
Annotate diagnosis population with layout pattern systematics

Identify fails with known sensitive layout patterns

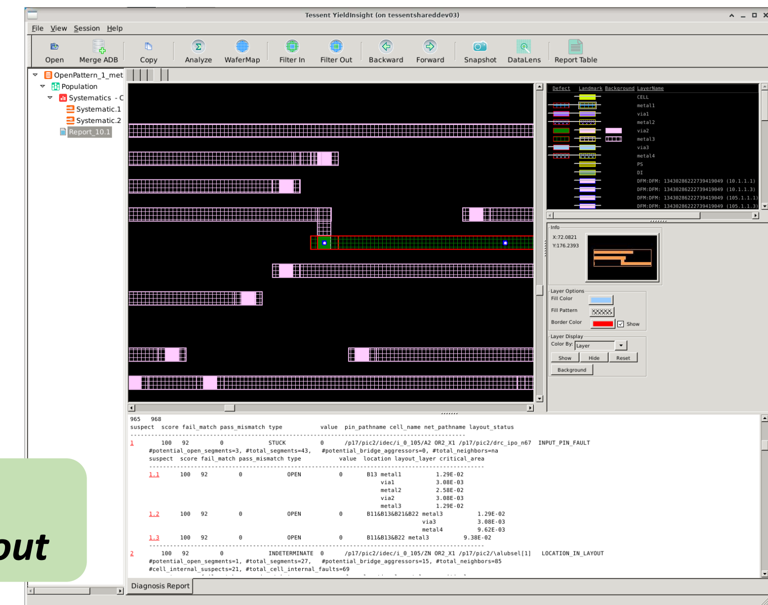
FA selection

Analyze layout pattern similarity over diagnosis population





Pattern similarity histogram over diagnosis population



Review in context of diagnosis report and layout

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Benefits of solution: FA efficiency

- **Confirming suspected systematics defect locations is**
  - expensive
    - Multiple PFA samples needed
    - Fault isolation (FI) + PFA costs range $50-100k
  - time consuming
    - 3-6 weeks for fault isolation / part + PFA time / sample

- **Solution provides**
  - isolation of PFA search area to high confidence locations ➔Shorter FI + PFA time
  - tagging of fails with previously confirmed systematics ➔ Reduced number of PFAs
  - learning of layout pattern systematics across multiple products

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Silicon demonstration results

- **Successful demonstration on silicon dataset comprising multiple lots/wafers of scan diagnosis data with foundry confirmed layout systematics**
- **Via opens in two lower metal layers identified as root cause for repeater fails**
- **88% of repeater sets attributed to the same two root causes**
  - Multiple identified locations confirmed by PFA results
- **<10 layout patterns per repeater set identified for visual inspection**
  - Demonstrated solution provides significant reduction in number of layout patterns to inspect
- **Ongoing live silicon engagements on advanced process nodes**

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Summary

- Enables identification of layout pattern systematic candidates
- Silicon-validated methodology
- Improves productivity by making efficient use of FA resources
- Faster closing of the entitlement yield gap

Siemens and PDF Solutions are ready to engage with you to demonstrate the benefits of the integrated solution

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Thank You

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Benefits of integrated Tessent – Exensio/FIRE solutions

Exclude
Include some in wor

Integration	Before integrated solution	Benefit of integration solution
Tessent SiliconInsight (TSI) / MemoryBIST ***+*** ***Exensio Bitmap / Manufacturing Analytics (E-MA)***	Configuration of embedded memories for bitmap analysis is time consuming	Efficient automated setup and comprehensive memory fail analysis using all yield and manufacturing data
Tessent YieldInsight (TYI) ***+*** ***Exensio Manufacturing Analytics (E-MA)***	Use scan diagnosis data only to identify potential failure suspect for PFA	Use Exensio yield analysis to narrow down suspected wafer and die populations for TYI analysis ➔ Improve accuracy and efficiency
Tessent YieldInsight (TYI) ***+*** ***FIRE layout pattern systematics***	Use random defectivity fail mechanisms to narrow down potential scan fail suspects	Add layout sensitive fail mechanisms into scan diagnostics ➔ Increased diagnosis resolution and accuracy

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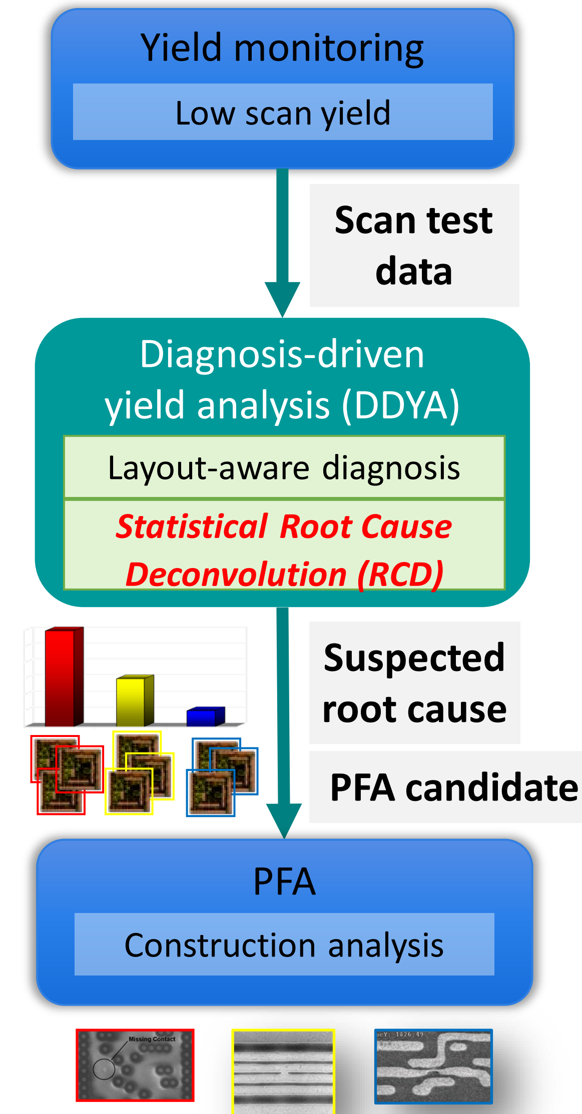
Tessent YieldInsight – Exensio integration

Combining volume scan diagnosis data with yield and manufacturing data

Comprehensive diagnosis-driven yield analysis

- Siemens' diagnosis-driven yield analysis (DDYA)
  - Provides root cause defect Paretos
  - Enables PFA candidate selection
- Effectiveness depends on good selection of failing dies
- DDYA methodology does not use all available product data

Needs efficient solution to identify best die population based on comprehensive product fail analysis
➔ Integration with Exensio Manufacturing Analytics



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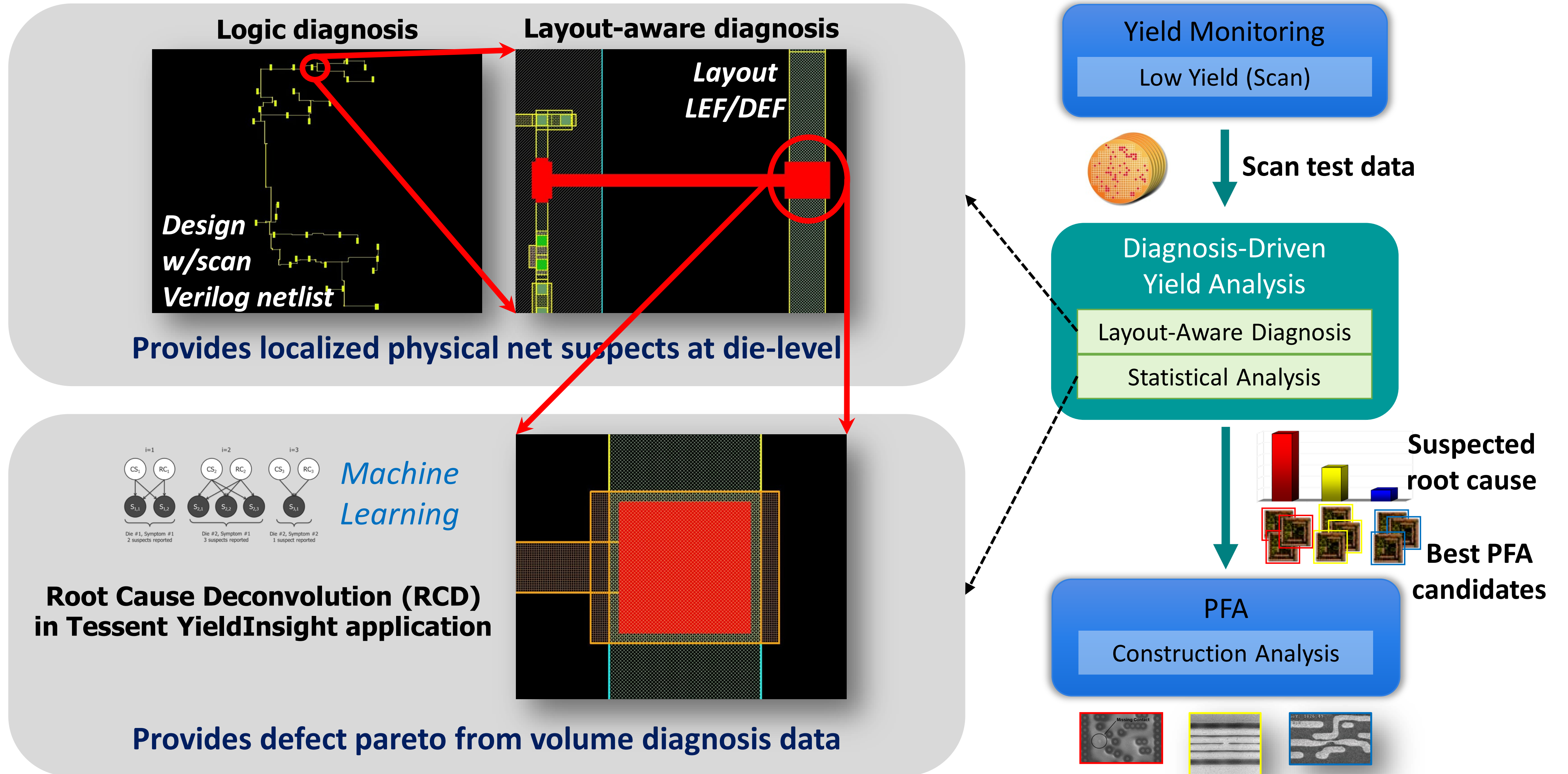
Tessent Diagnosis-driven yield analysis (DDYA)



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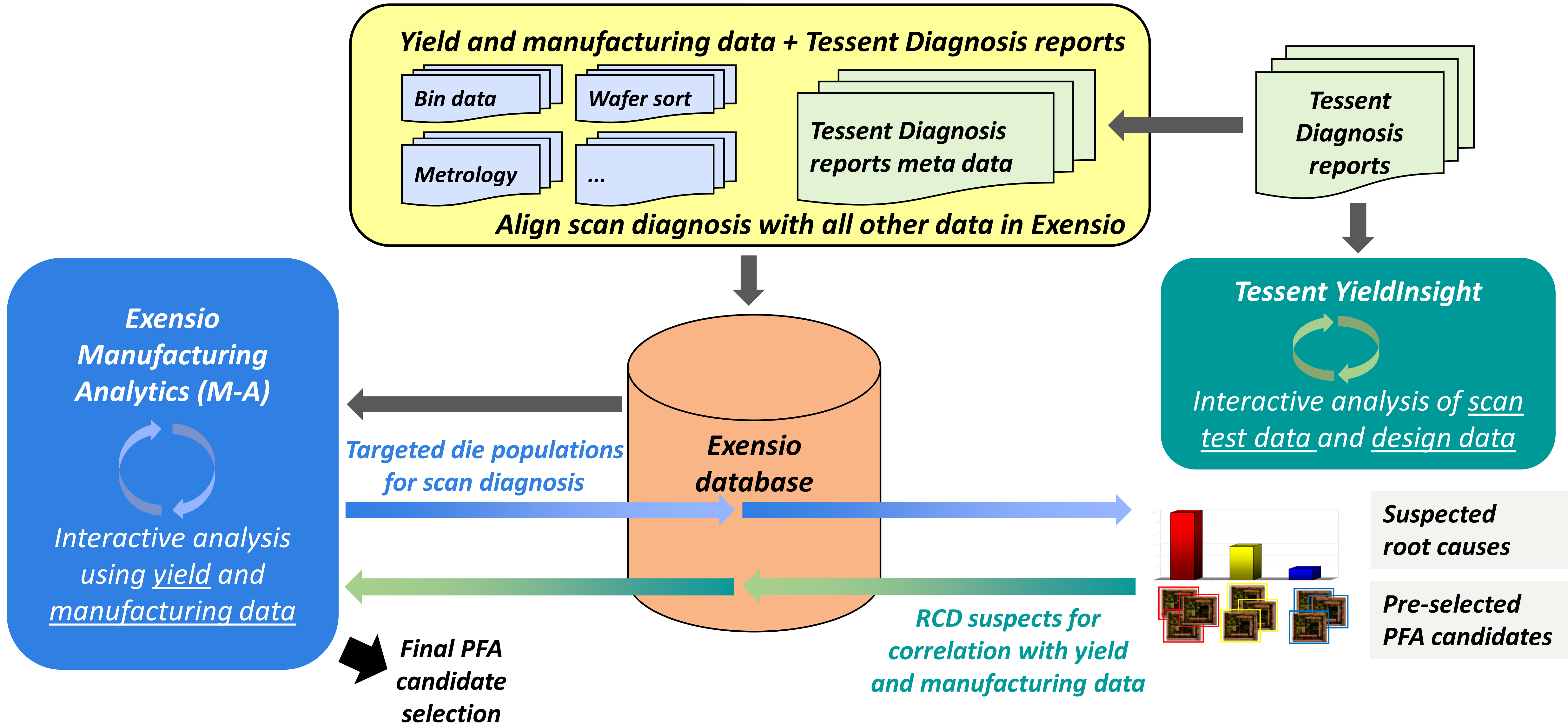
Tessent YieldInsight + Exensio integration overview



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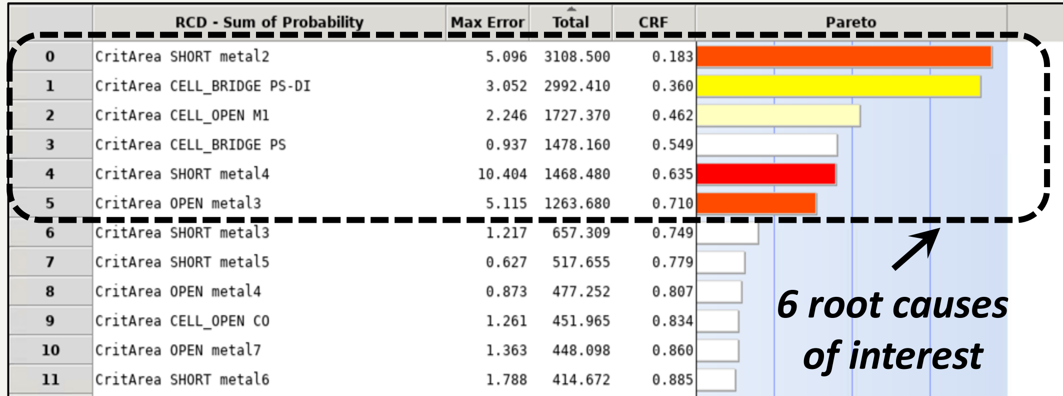
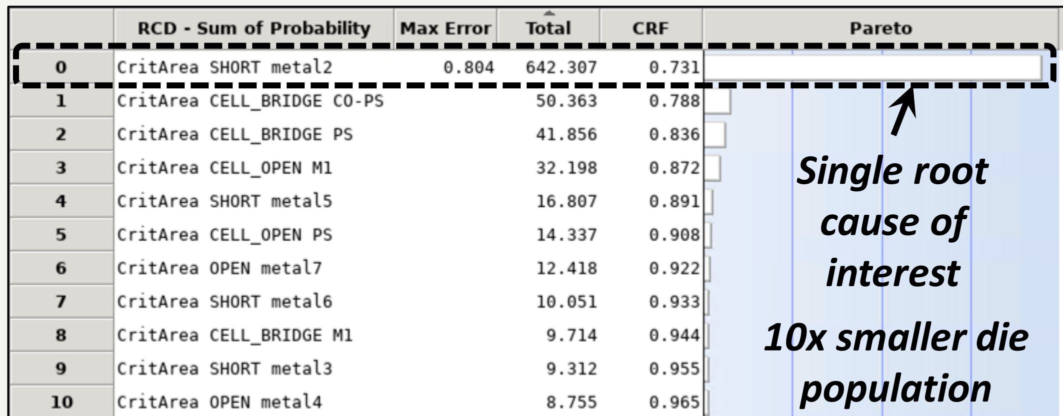
Generating targeted populations for Tessent YieldInsight

RCD Pareto with dies from all 200 wafers



	RCD - Sum of Probability	Max Error	Total	CRF	Pareto
0	CritArea SHORT metal2	5.096	3108.500	0.183	
1	CritArea CELL_BRIDGE PS-DI	3.052	2992.410	0.360	
2	CritArea CELL_OPEN M1	2.246	1727.370	0.462	
3	CritArea CELL_BRIDGE PS	0.937	1478.160	0.549	
4	CritArea SHORT metal4	10.404	1468.480	0.635	
5	CritArea OPEN metal3	5.115	1263.680	0.710	
6	CritArea SHORT metal3	1.217	657.309	0.749	
7	CritArea SHORT metal5	0.627	517.655	0.779	
8	CritArea OPEN metal4	0.873	477.252	0.807	
9	CritArea CELL_OPEN CO	1.261	451.965	0.834	
10	CritArea OPEN metal7	1.363	448.098	0.860	
11	CritArea SHORT metal6	1.788	414.672	0.885	

Tessent YieldInsight



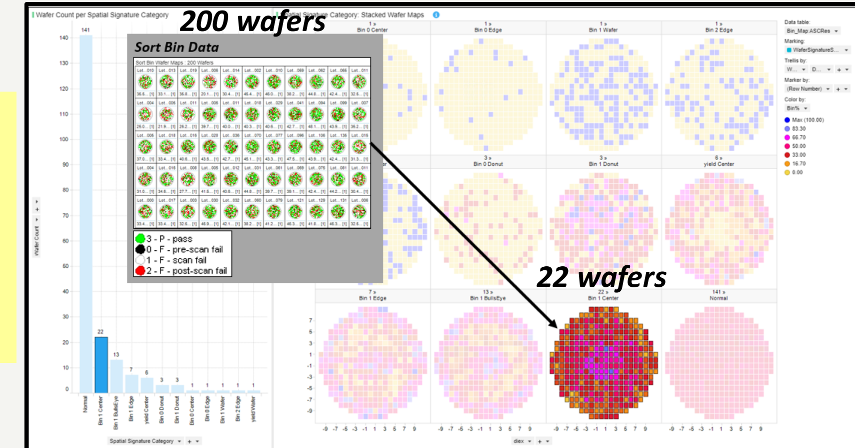
	RCD - Sum of Probability	Max Error	Total	CRF	Pareto
0	CritArea SHORT metal2	0.804	642.307	0.731	
1	CritArea CELL_BRIDGE CO-PS		50.363	0.788	
2	CritArea CELL_BRIDGE PS		41.856	0.836	
3	CritArea CELL_OPEN M1		32.198	0.872	
4	CritArea SHORT metal5		16.807	0.891	
5	CritArea CELL_OPEN PS		14.337	0.908	
6	CritArea OPEN metal7		12.418	0.922	
7	CritArea SHORT metal6		10.051	0.933	
8	CritArea CELL_BRIDGE M1		9.714	0.944	
9	CritArea SHORT metal3		9.312	0.955	
10	CritArea OPEN metal4		8.755	0.965	

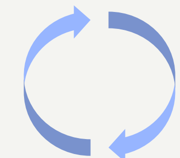
RCD Pareto with targeted die population

Die Population Transfer

Exensio M-A

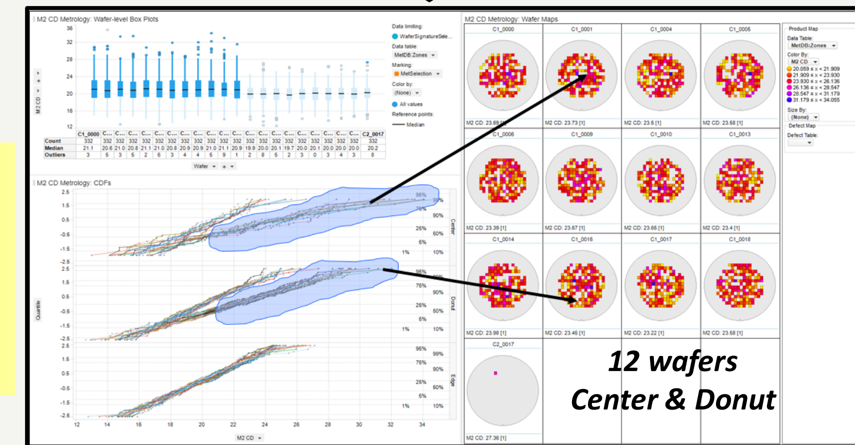
Targeted Wafer Population
E.g., Sort Bin Data
Wafer-level SSA





Refinement

Targeted Die Population
E.g., Metal CD Metrology / WAT Distribution Analysis



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Correlation of RCD suspects with yield & manufacturing data

Tessent YieldInsight

RCD Pareto : Dies from target population only

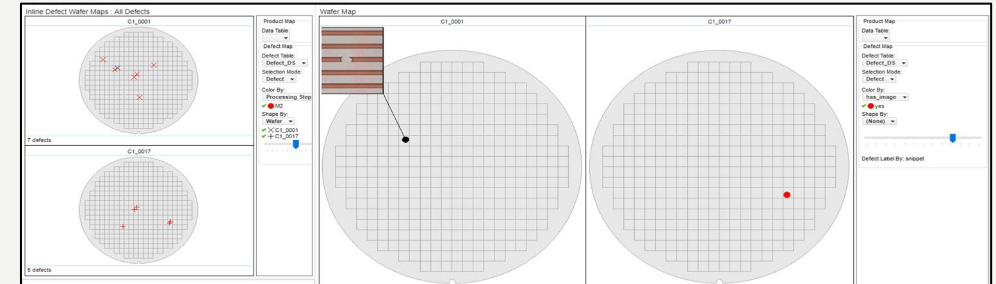
	RCD - Sum of Probability	Max Error	Total	CRF	Pareto
0	CritArea SHORT metal2	0.804	642.307	0.731	
1	CritArea CELL_BRIDGE CO-PS		50.363	0.788	
2	CritArea CELL_BRIDGE PS		41.856	0.836	
3	CritArea CELL_OPEN M1		32.198	0.872	
4	CritArea SHORT metal5		16.807	0.891	
5	CritArea CELL_OPEN PS		14.337	0.908	
6	CritArea OPEN metal7		12.418	0.922	
7	CritArea SHORT metal6		10.051	0.933	

	Wafer	X	Y	SymID	SusID	Score	SymCNT	SusCNT	SymSusCNT	TotalProb	CritArea SHORT metal2	CritArea CELL_BRIDGE CO-PS
0	Lot_0009:C1_0017	7	-3	1	1.1	100	1	1	1	1.000	1.000	0.000
1	Lot_0009:C1_0017	-3	4	1	1.1	100	1	1	1	1.000	1.000	0.000
2	Lot_0019:C1_0001	3	1	1	1.1	100	1	1	1	1.000	1.000	0.000
10	Lot_0019:C1_0001	5	0	1	1.1	100	1	4	4	1.000	1.000	0.000
11	Lot_0019:C1_0001	3	-5	1	1.1	100	1	4	4	1.000	1.000	0.000
15	Lot_0019:C1_0001	2	-7	1	1.1	100	1	17	17	1.000	1.000	0.000
18	Lot_0009:C1_0017	-3	2	1	1.1	100	1	7	7	1.000	1.000	0.000
38	Lot_0019:C1_0001	-2	6	1	1.1	100	1	1	1	1.000	1.000	0.000
44	Lot_0019:C1_0001	-3	-7	1	1.1	100	1	14	14	1.000	1.000	0.000
47	Lot_0009:C1_0017	0	-2	1	1.1	100	1	1	1	1.000	1.000	0.000
50	Lot_0019:C1_0001	3	3	1	1.1	100	1	1	1	1.000	1.000	0.000
56	Lot_0019:C1_0001	-1	-5	1	1.1	100	1	3	3	1.000	1.000	0.000

RCD suspects with high M2 short root cause

Exensio M-A

Correlation of RCD suspects with Yield & Mfg Data



Correlation of RCD suspects with yield & manufacturing data to increase the PFA success rate

Gallery review of RCD suspect layout snippets

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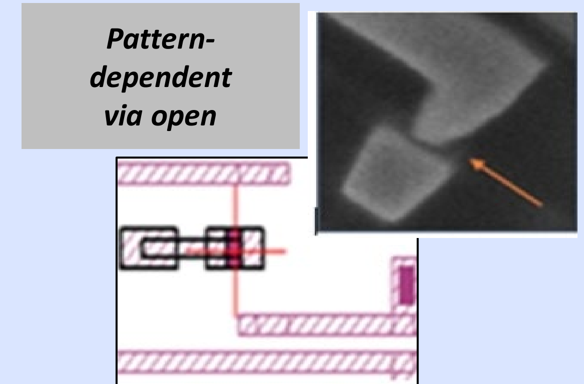
Tessent Diagnosis/YieldInsight + FIRE integration

Extending Tessent YieldInsight with FIRE layout pattern systematics

Volume scan diagnosis with layout pattern systematics

- Volume scan diagnosis with analysis in Tessent YieldInsight proven for learning of random defect sources
- In advanced technologies layout pattern systematics contribute significant yield loss well into volume production

Layout pattern systematic defects



Prevent entitlement yield for high volume production

Scan diagnosis-based yield learning needs to factor in layout patterns systematics
➔ Combine Tessent Diagnosis / YieldInsight with layout pattern systematics using FIRE

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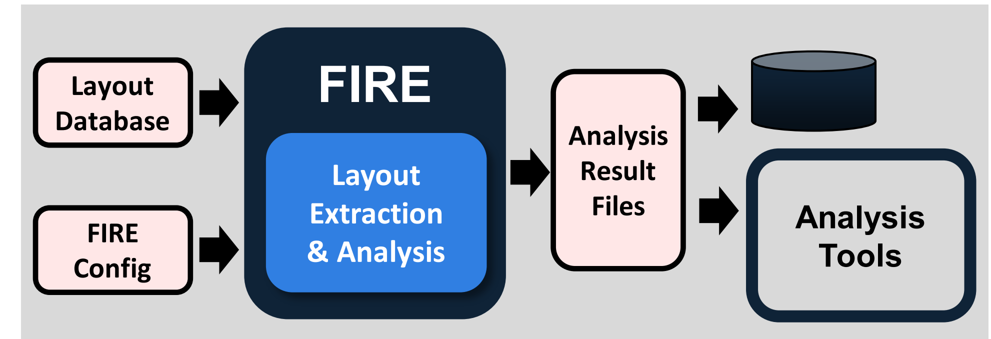
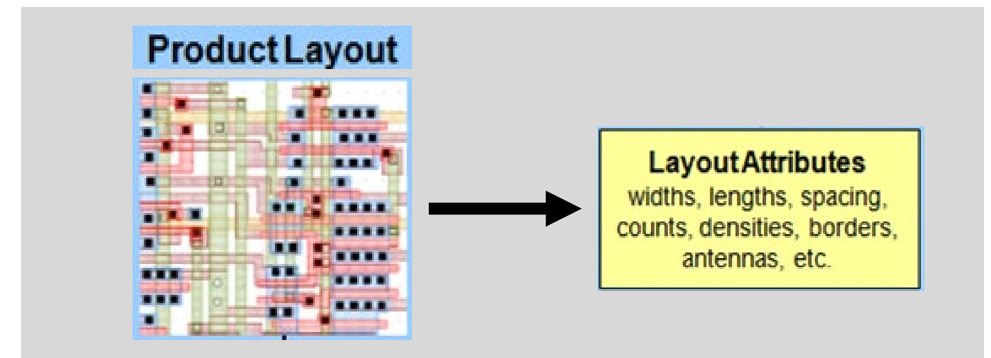
FIRE advanced layout analysis technology

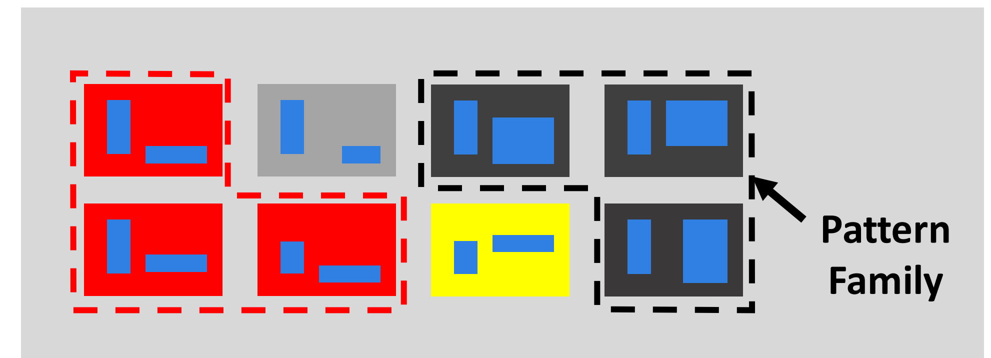
High-performance
Full-chip
Electrical connectivity-aware



Extraction of layout attributes
Fully-customizable



Automated pattern classification
Grouping of similar patterns into pattern families



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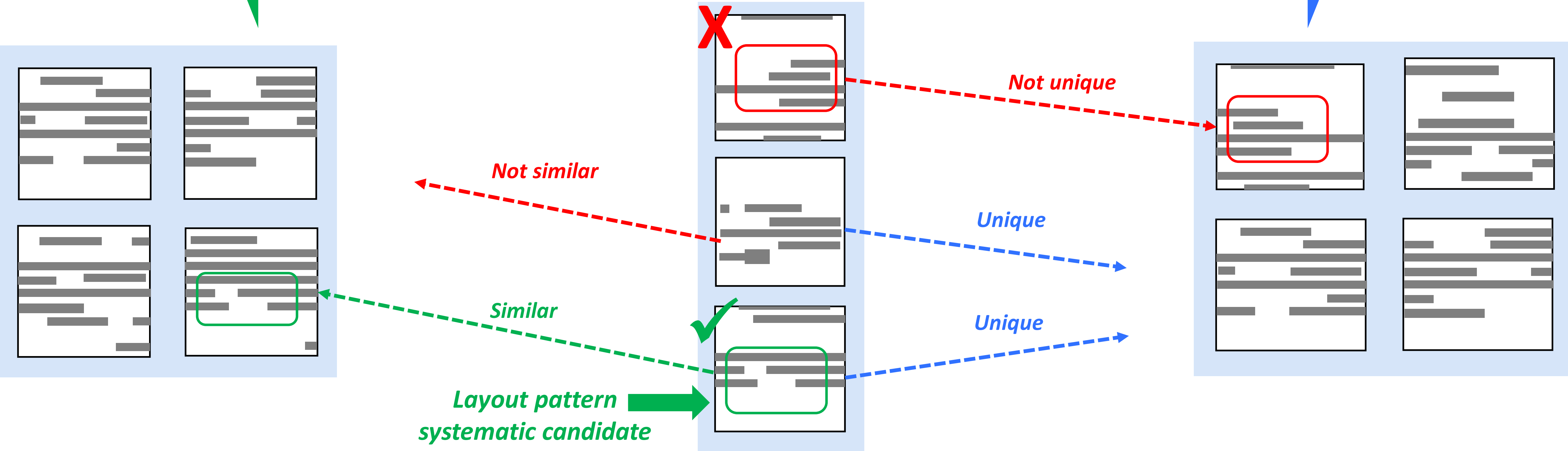
Net repeater-based layout pattern systematics learning



Net repeater fails - same net fails on multiple dies - are high-confidence indicators of an underlying systematic fail root cause

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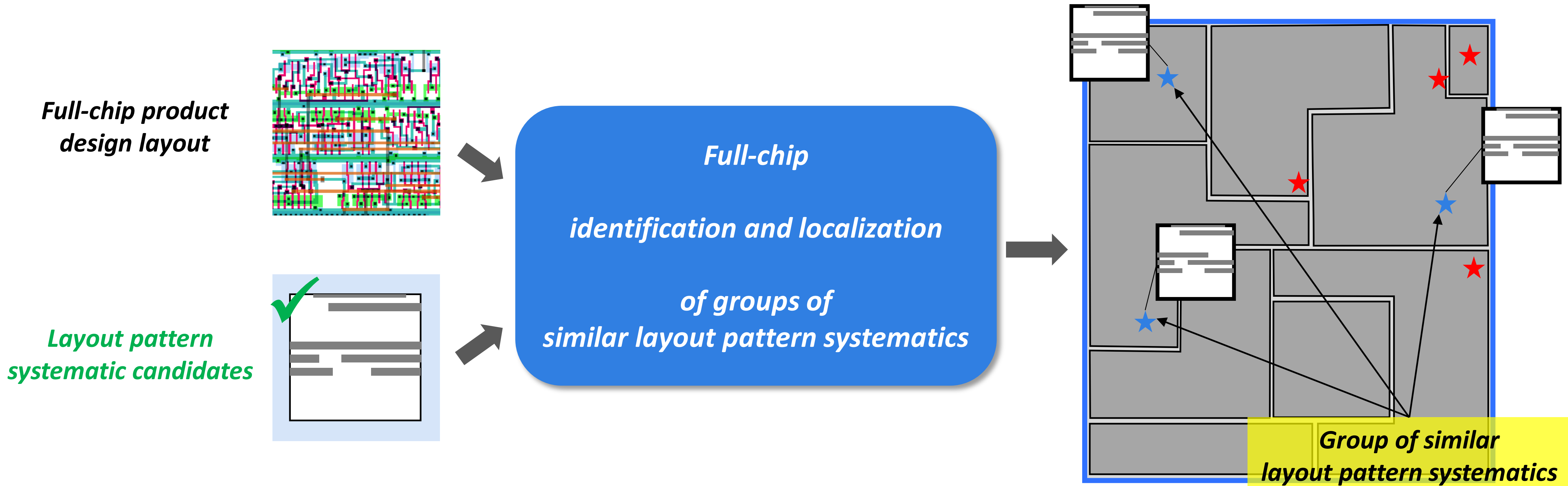
Full-chip extraction of layout pattern systematics



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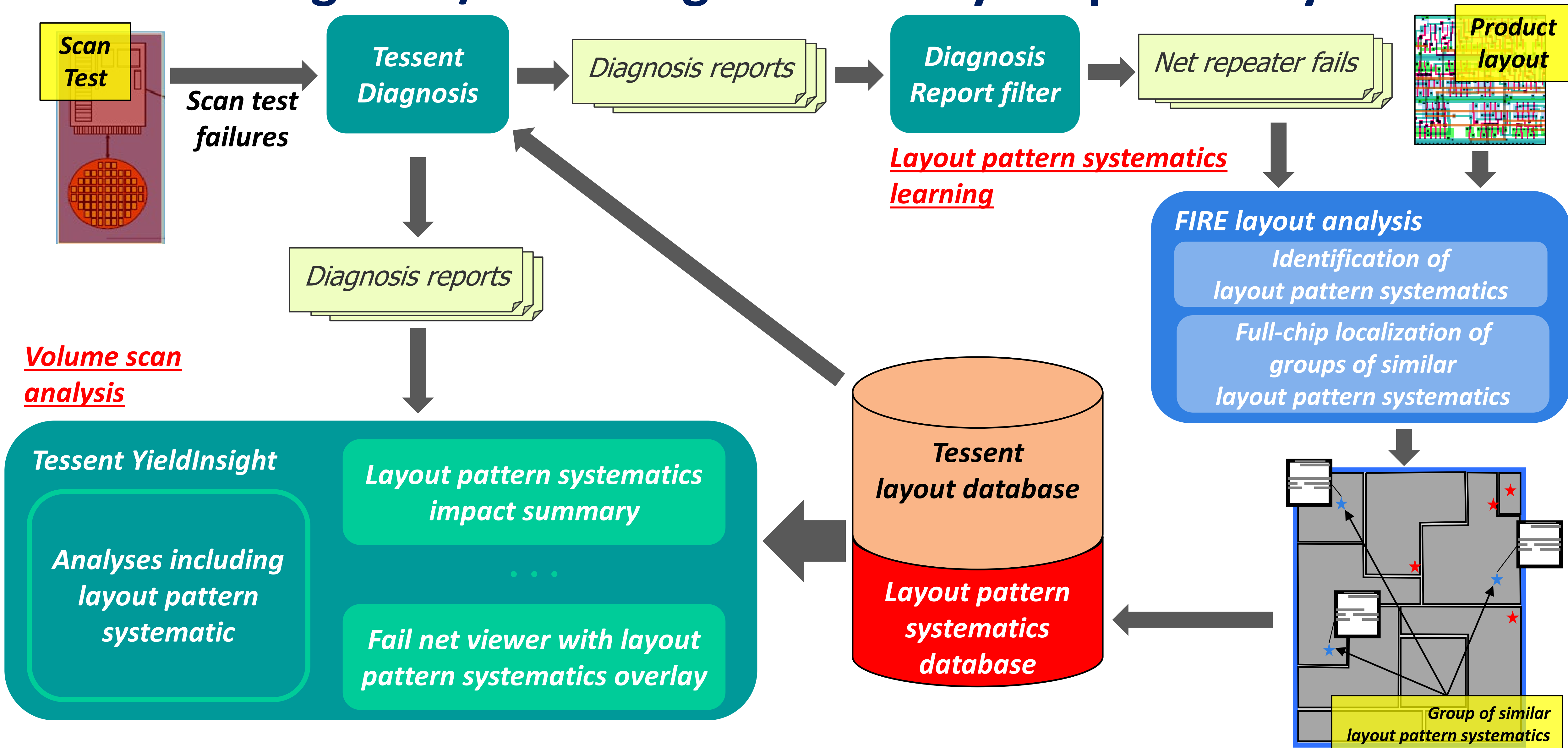
Tessent Diagnosis/YieldInsight + FIRE layout pattern systematics



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Tessent SiliconInsight - Exensio integration

Addressing the analysis needs of complex embedded memory products

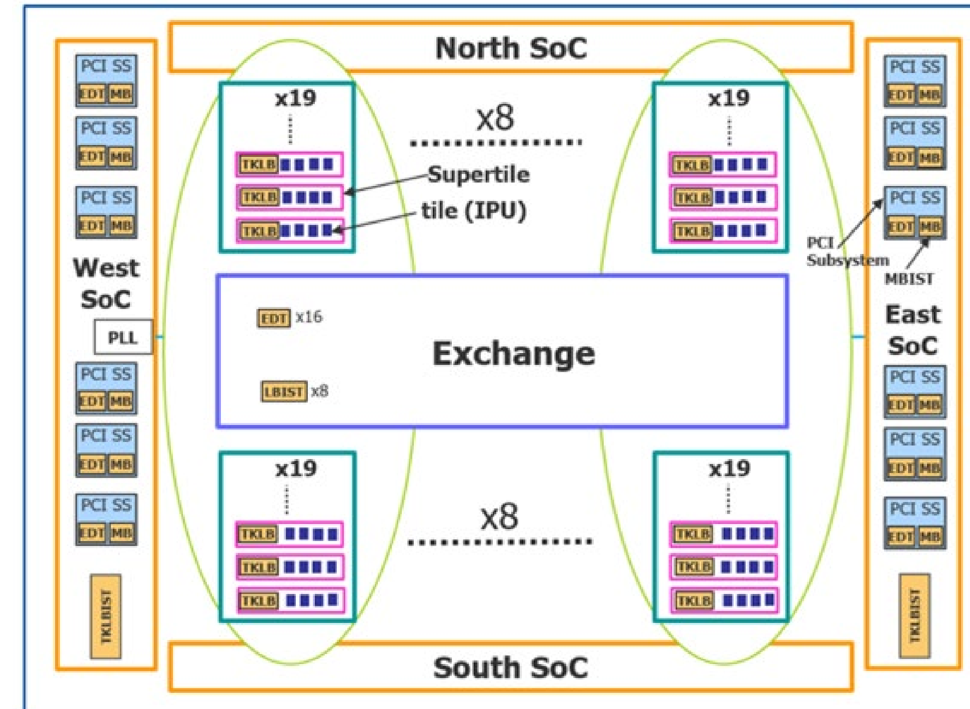
Memory trends and yield learning challenges

- Complexity of embedded memory products increases
  - >10K memories
  - 100s of MBIST controllers

- Failure root cause analysis and setup of such complex embedded memory chips is a time-consuming task

Needs an efficient automated setup and analysis solution

Example of complex AI chip: Graphcore



- 1216 IPUs (Intelligence Processing Units) + local memory = 'Tiles'
- Total 10.000 memories = 300MB

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Integrating Tessent SiliconInsight and Exensio M-A

Tessent SiliconInsight

MemoryBIST technology

- Proven technology to collect fail information from complex embedded memory products
- Analysis of raw memory test data does not allow for volume data analysis

Exensio Manufacturing Analytics

Exensio Bitmap

- Efficient processing of raw MemoryBIST data
- Extensive tool set for comprehensive memory fail analysis

Tessent SiliconInsight / MemoryBIST + Exensio Manufacturing Analytics = Single memory analysis platform

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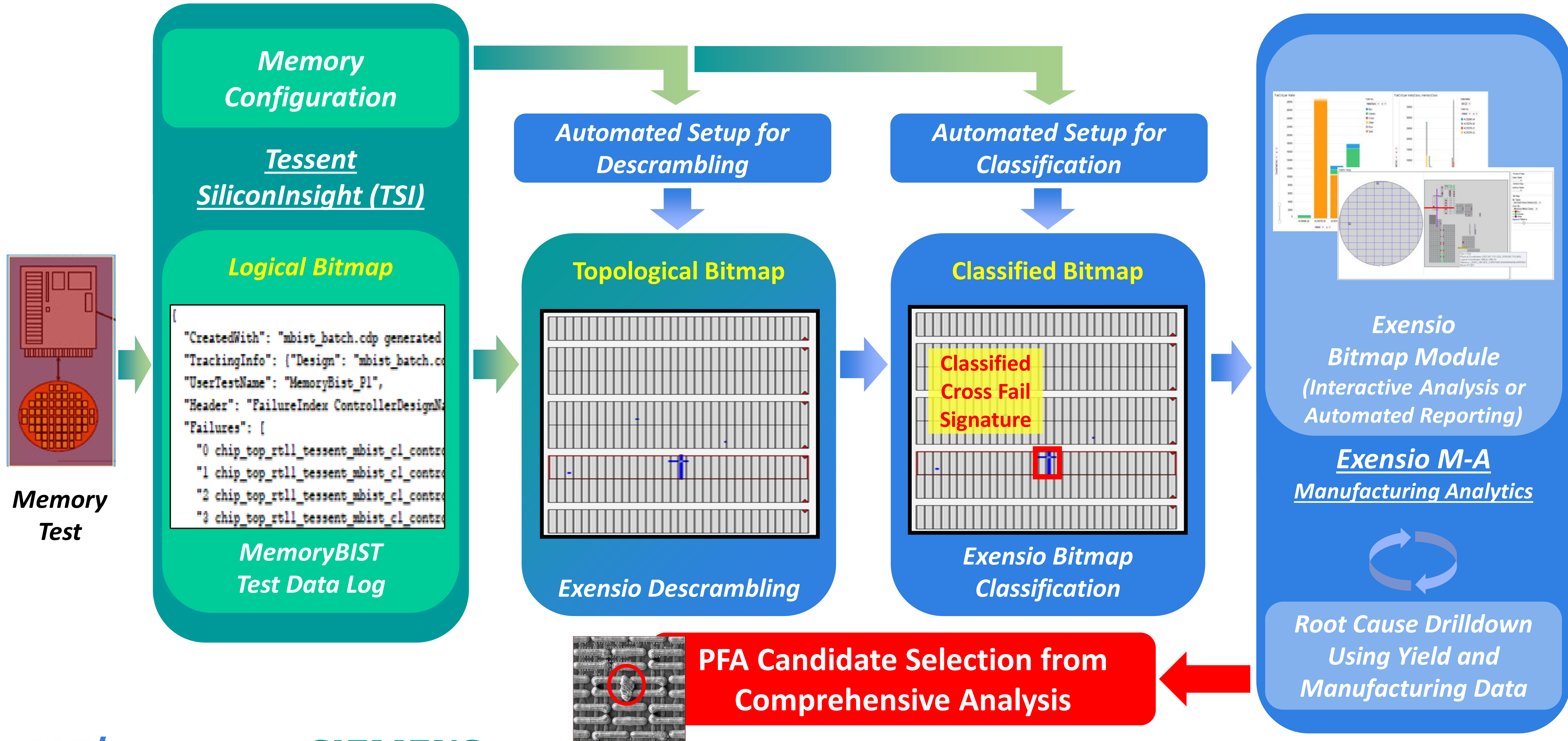
Tessent SiliconInsight + Exensio memory analysis platform



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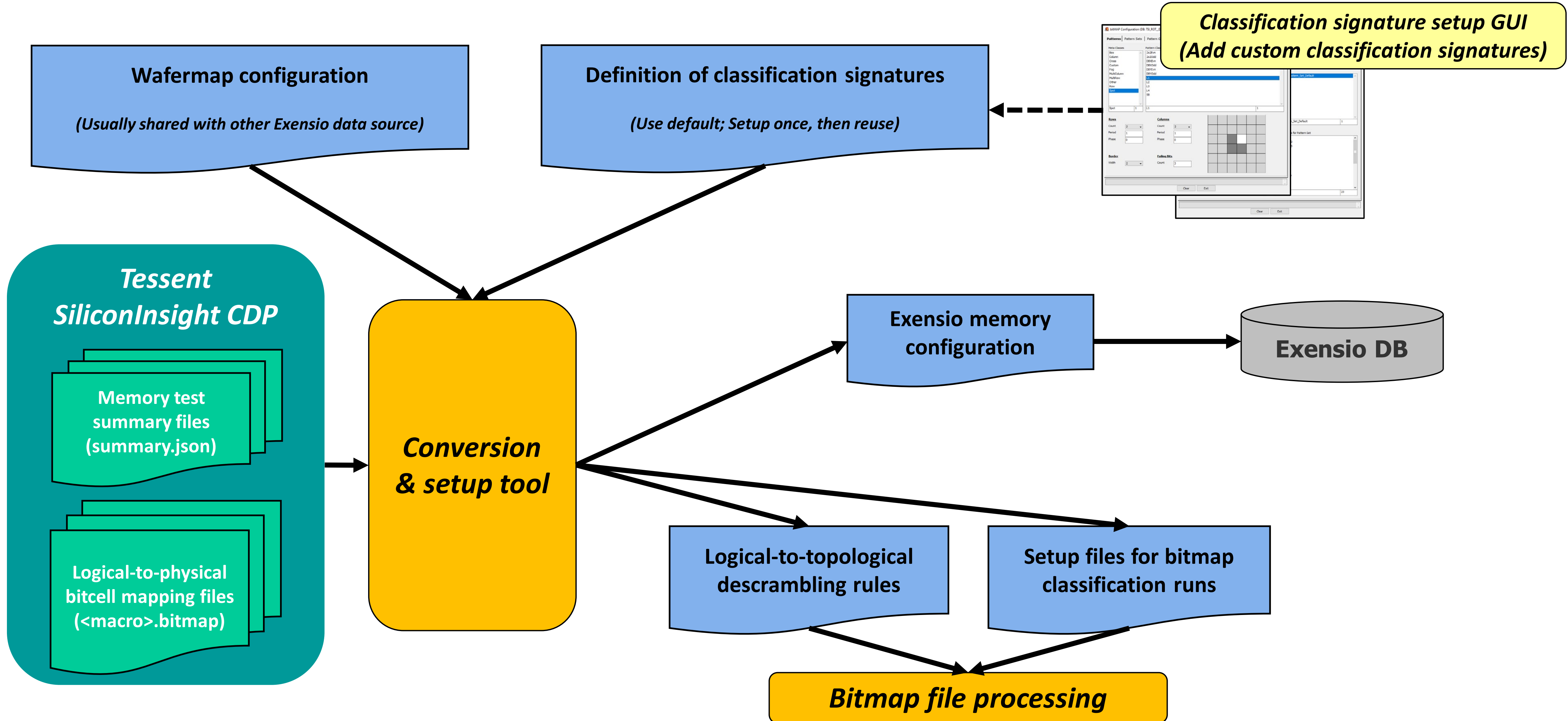
Setup of memory product



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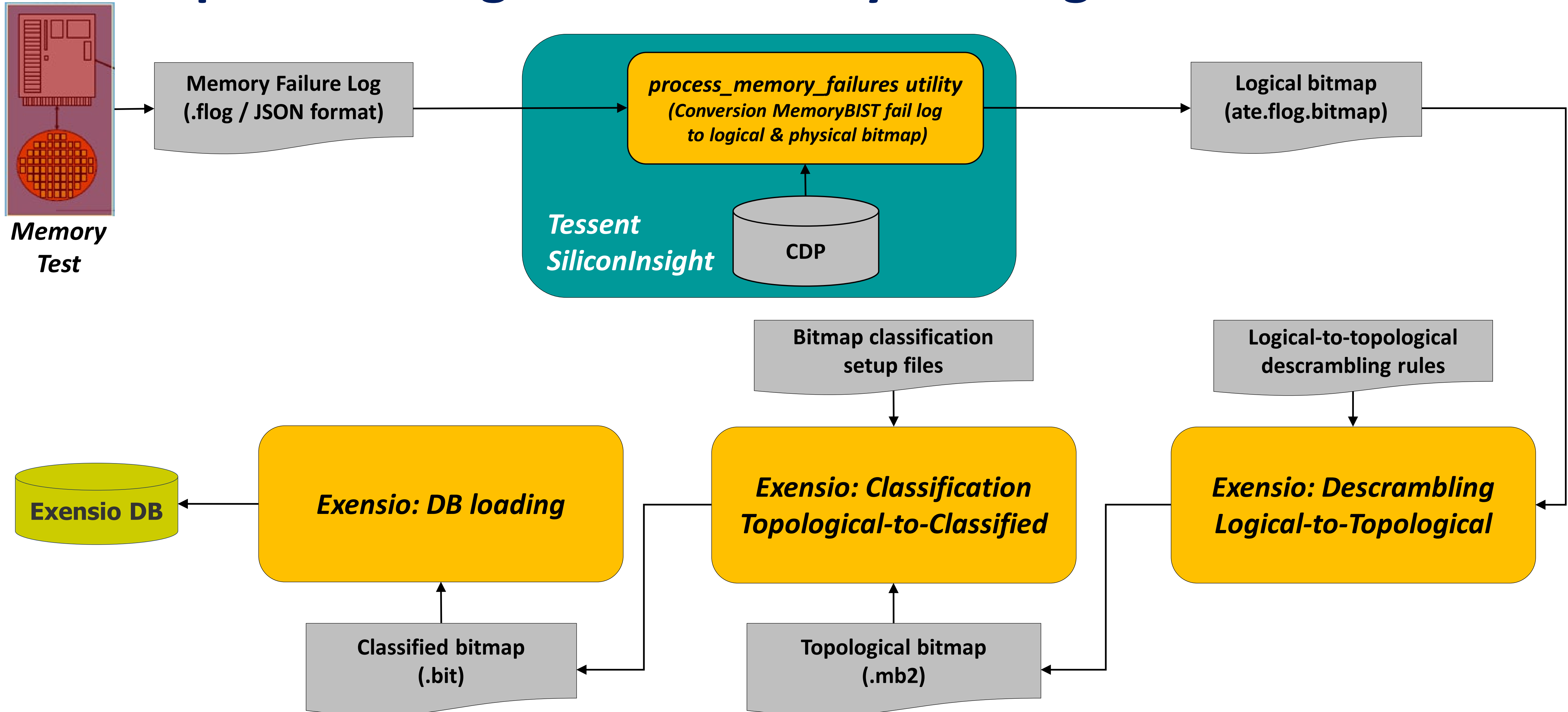
Bitmap Processing Flow: Memory Fail Log ➔ Exensio DB



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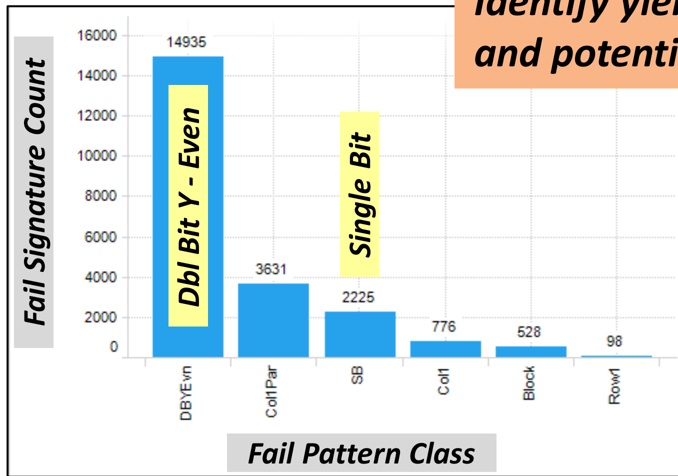
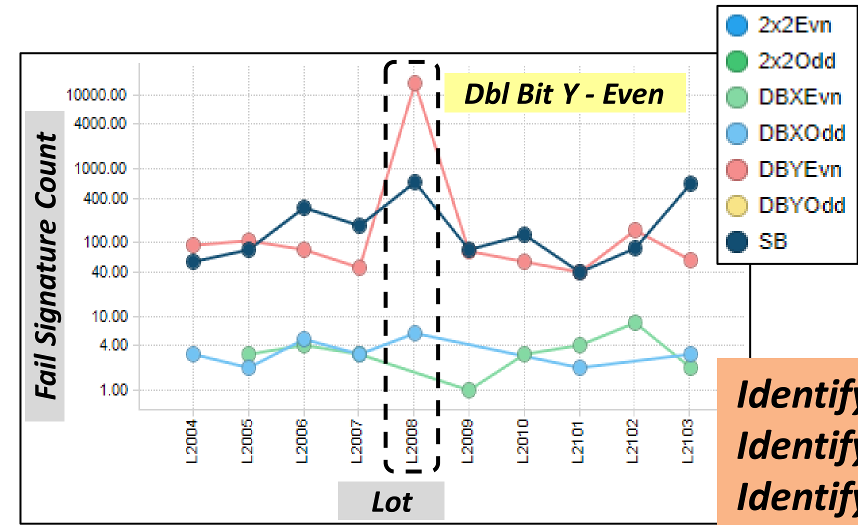
Exensio bitmap analysis capabilities

Fail Signature Paretos

Identify yield-relevant fail signatures and potential failure root causes

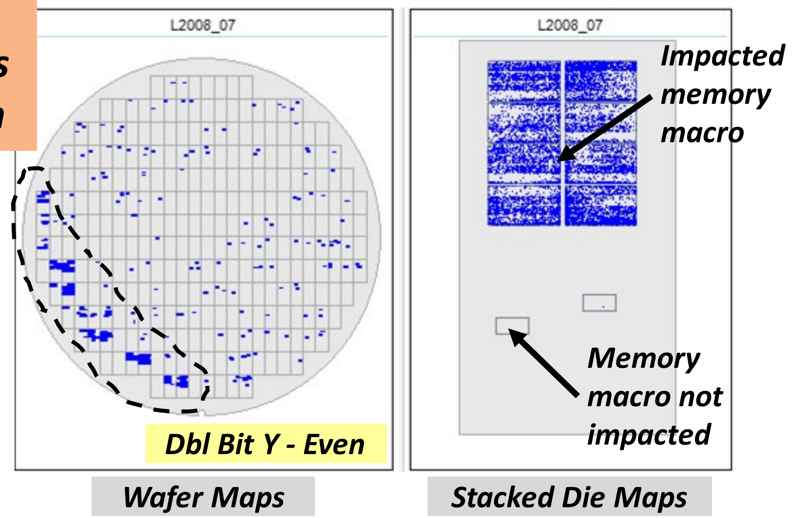


Trending



Identify variabilities
Identify excursions
Identify subtle trends

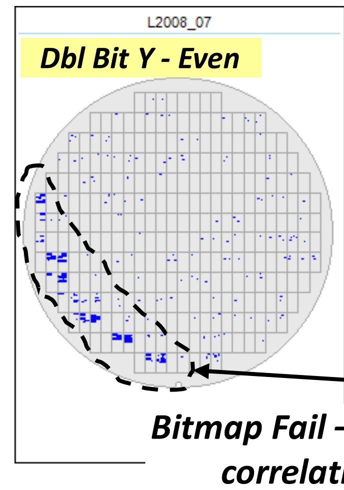
Identify process and memory macro issues with spatial variation

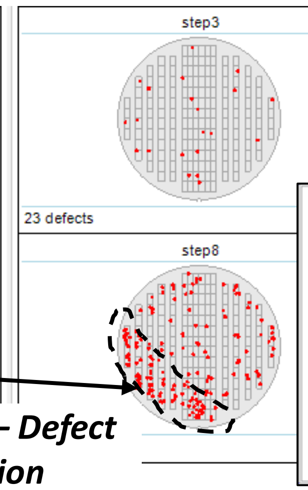


Stacked Maps

Bitmap Fails | *Inline Defects*

Correlate with other yield & mfg data to narrow down root causes diagnosis





Bitmap Fail – Defect correlation

Bitmap – Defect overlay hits for PFA submission

Multi-Data Correlations

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