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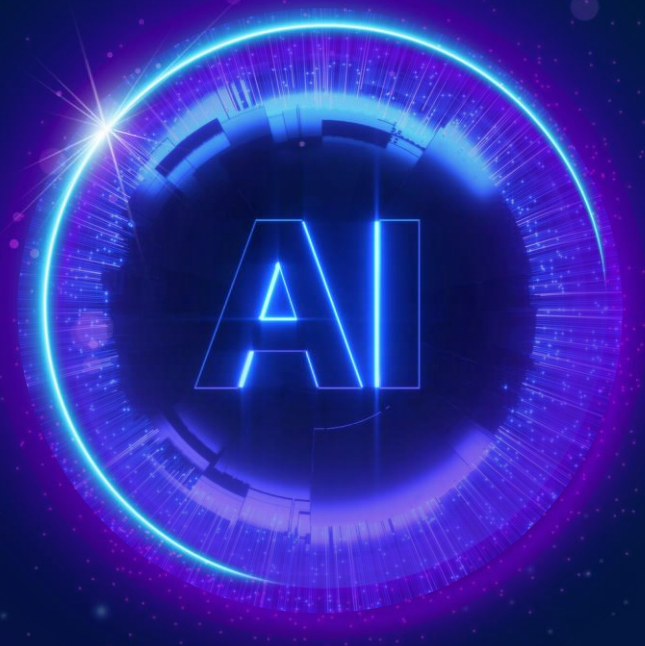
Artificial Intelligence

Executive Conference

explore the power of AI to transform semiconductor design & manufacturing



Presentation

AI to Use Semiconductor Design Information to Drive Inspection and Diagnostics

Michael Yu / Thomas Zanon
PDF Solutions
Marc Hutner
Siemens

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Background

One of the challenges for AI/ML application for semiconductor is the need of large data volume, while we could benefit from utilize the model at initial stage (where there is few data)

In last year (2023) PDF User Conference, we revealed our concept of how to use design information to better drive test and yield diagnostics.

Today, we will present two uses cases

01 Use Design info to drive better inspection of “undetectable defects”

02 Progress of Siemens EDA’s Tessent + PDF’s Exensio integration

01. Introduction of Foundation Capability

01 eProbe

02 FIRE

03 Exensio Guided Analytics

04 Siemens EDA Tessent

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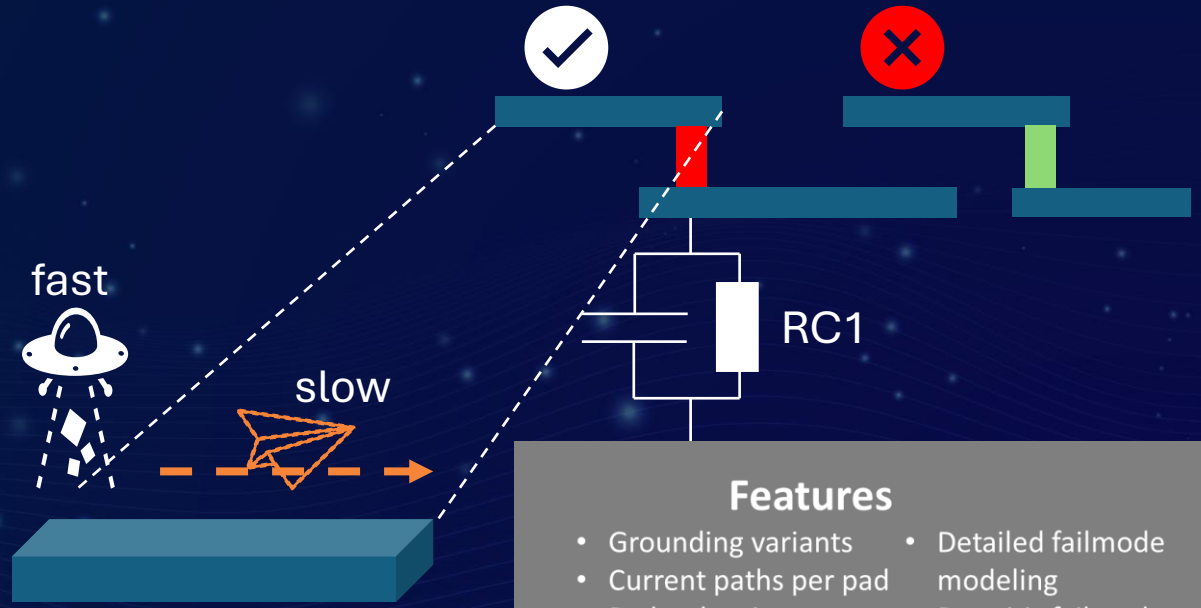
SIEMENS

As reported in 2023
PDF User Conference

FIRE to Drive More Efficient eBeam Inspection

FIRE AI algorithm

summarize design geometrical, electrical, and expected e-beam characteristics, to enable selection of scan points, to take advantage of eProbe hardware point scan capability.



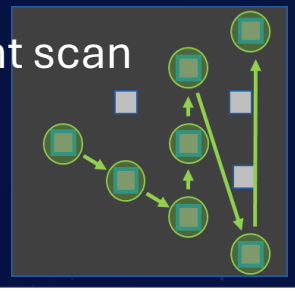
Features

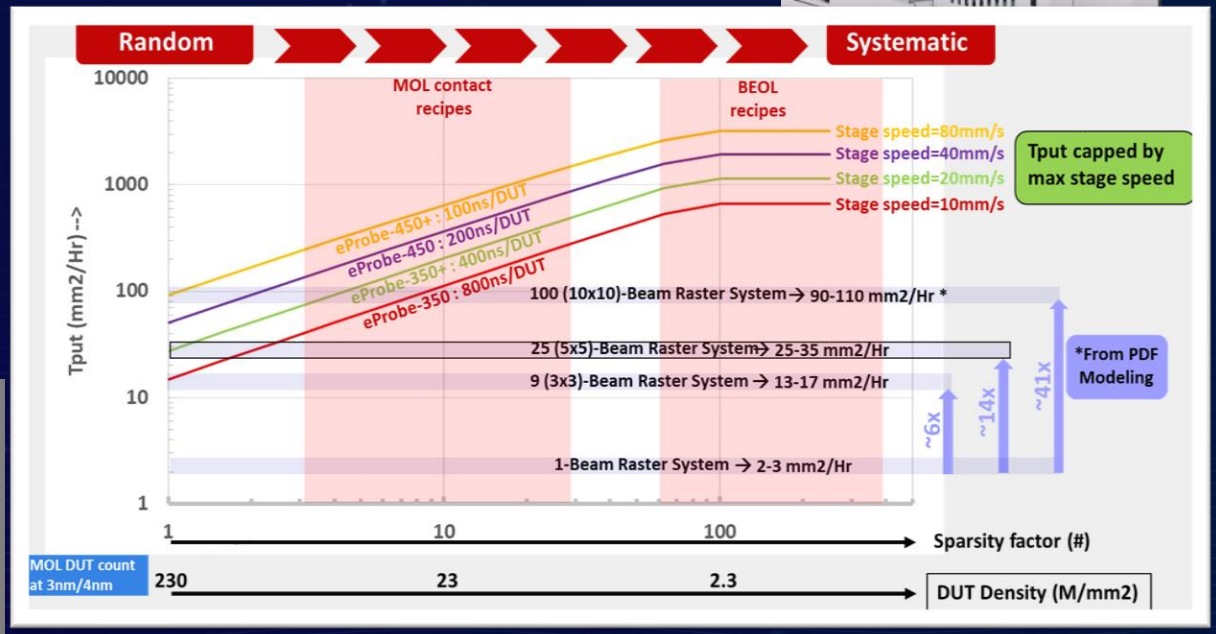
- Grounding variants
- Current paths per pad
- Redundancies
- Leakage modeling
- Detailed failmode modeling
- Parasitic failmodes
- E-beam brightness simulation

PDF eProbe ebeam Inspection Tool

use Point Scan capability to achieve high inspection speed

Point scan





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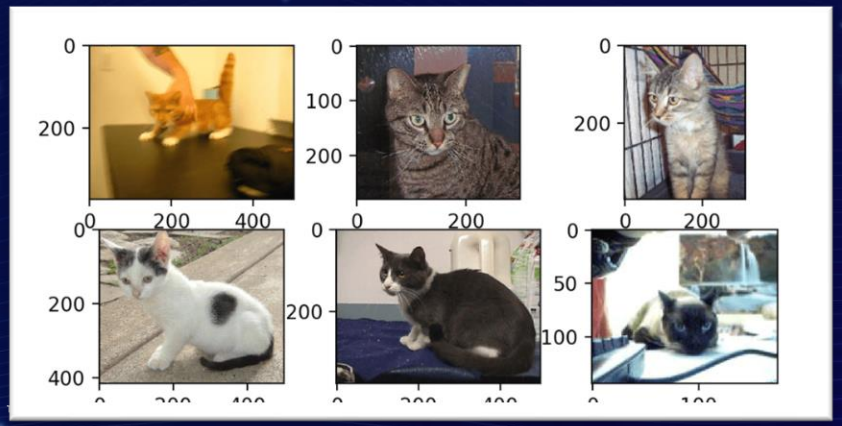
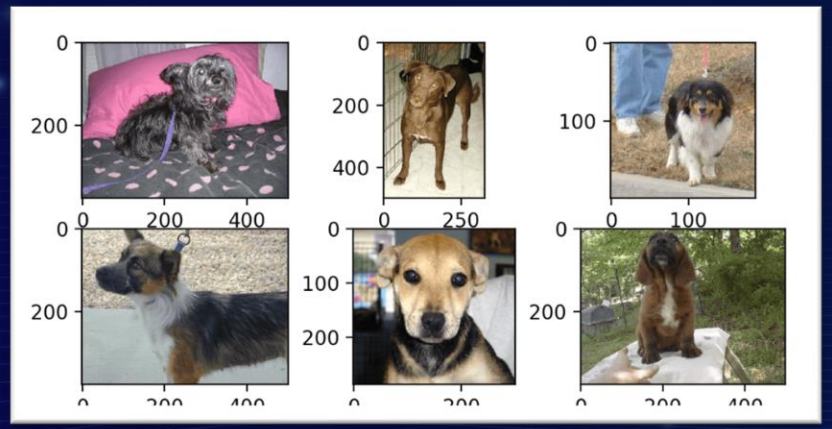
Exensio FIRE Software: Fuzzy Pattern AI

A given systematic fail mode usually comes from, not one, but a “family” of layout configurations. Traditional rule-based approach is insufficient for the evolving complexity of product design at advanced nodes

Using fuzzy pattern classification algorithm, PDF’s Exensio FIRE software automatically groups all similar patterns of same fail mode into a “pattern family”.





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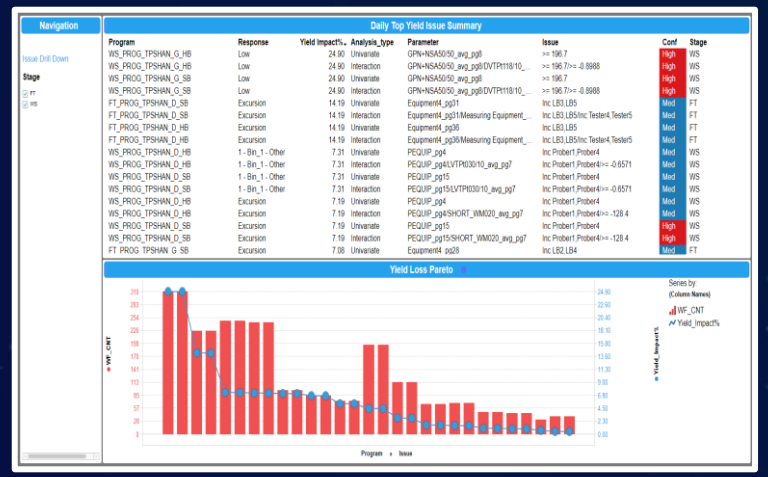
Guided Analytics AI/ML - Auto Diagnostics based on AI/ML

Achieve up to 5x faster insights compared to conventional yield analysis methods

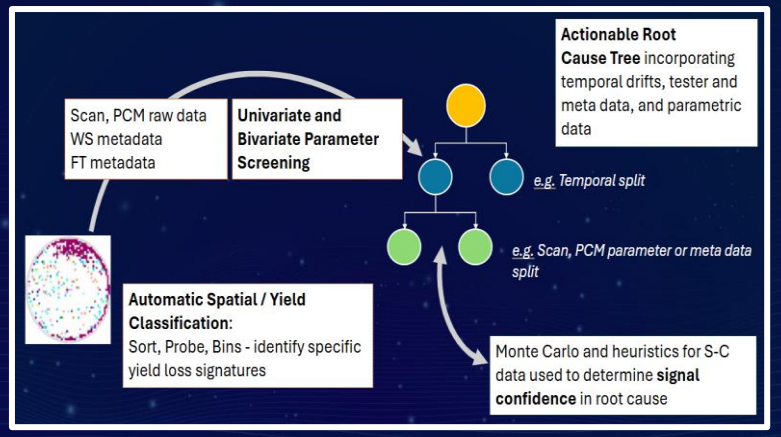
Simplifies engineering with an intuitive dashboard highlighting key signals, root causes, and detailed plots across all products in just a few clicks.



01 Automatic yield loss and root cause identification

02 **Automatic spatial / yield classification: Sort, Scan, Probe**

03 Automatic yield dashboard (by past 90 days)



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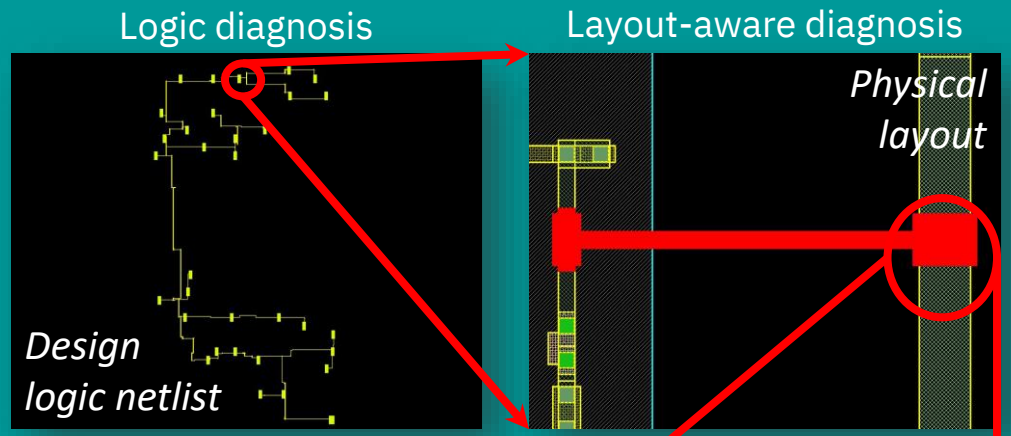
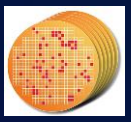
Tessent Scan Diagnosis and Root Cause Deconvolution

1 Layout-aware diagnosis

Provides localized physical net suspects at die-level



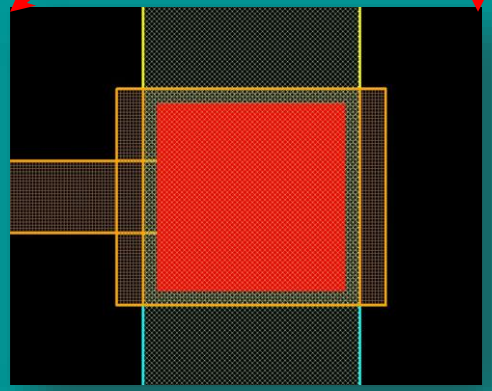


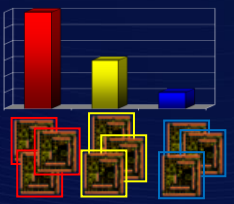
Scan test data

2 Root Cause Deconvolution

Provides defect pareto from volume diagnosis data

Machine Learning





Suspected root cause

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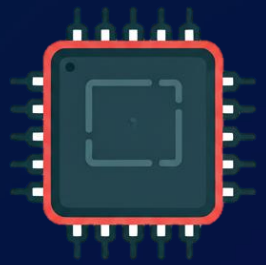
Summary of 4 Foundation Capability



Design Info

Analysis

Inspection

FIRE

Siemens EDA Tessent

Exensio Guided Analytics

eProbe directScan

Driven by AI

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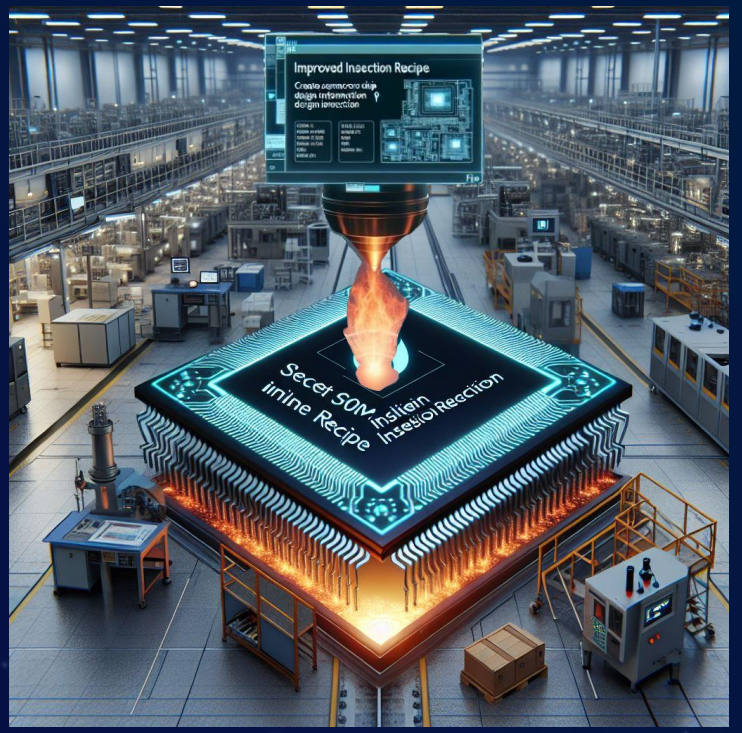
02.

AI to Generate Smart Inspection Recipe



** Image created by Microsoft co-pilot*

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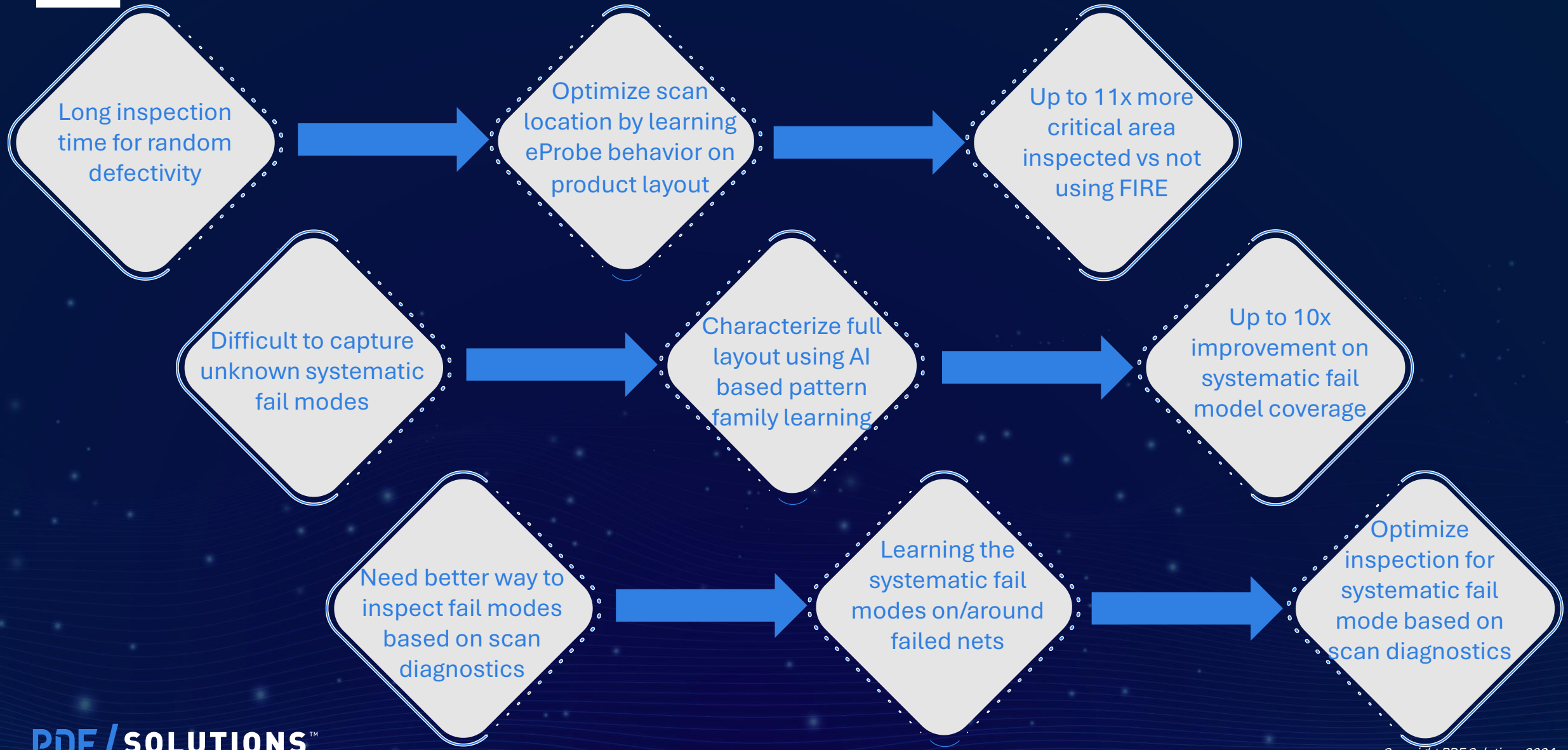
eBeam inspection by eProbe: Use Cases



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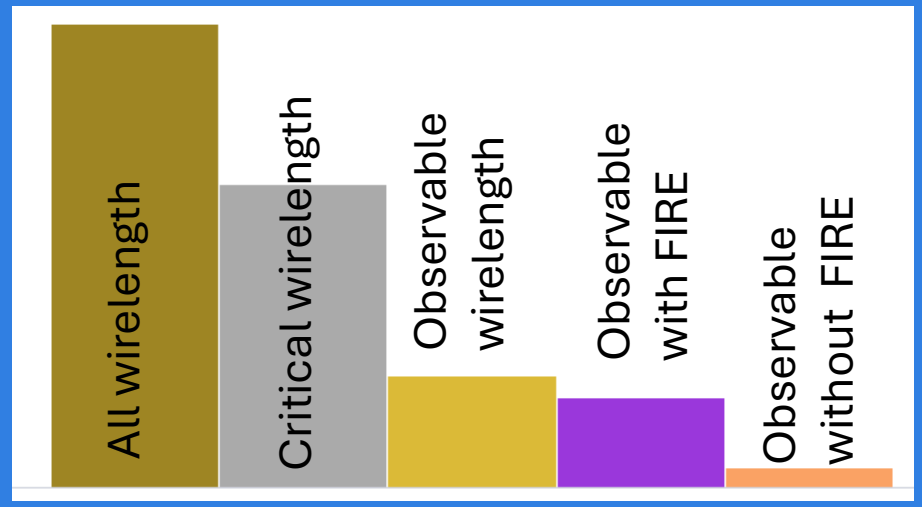
AI Application for Random Defectivity

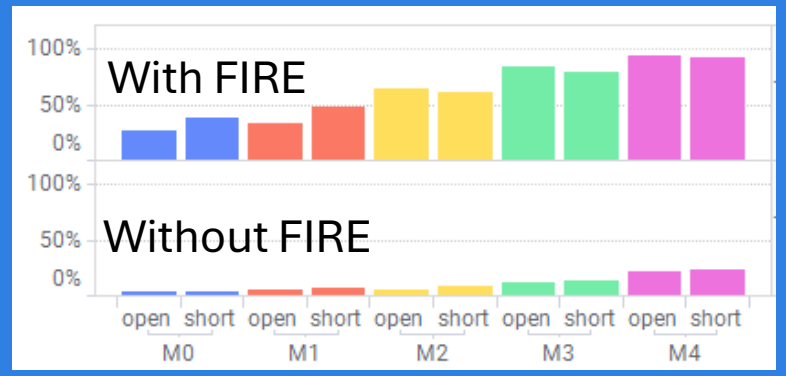
Randoms

By learning eProbe characteristics, FIRE can optimize scan locations



Randoms

FIRE enables scanning up to 94 % of all observable wirelength – up to 11x more than without FIRE.



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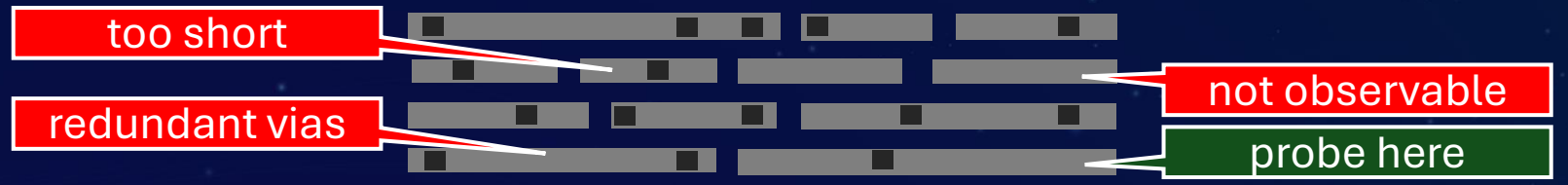
Examples

1) AI learns e-beam response
2) This guides on-net selection

probe optimization for **opens**
- learned observability
- electrical + geometrical analysis



probe optimization for **shorts**
- learned observability
- electrical + geometrical analysis

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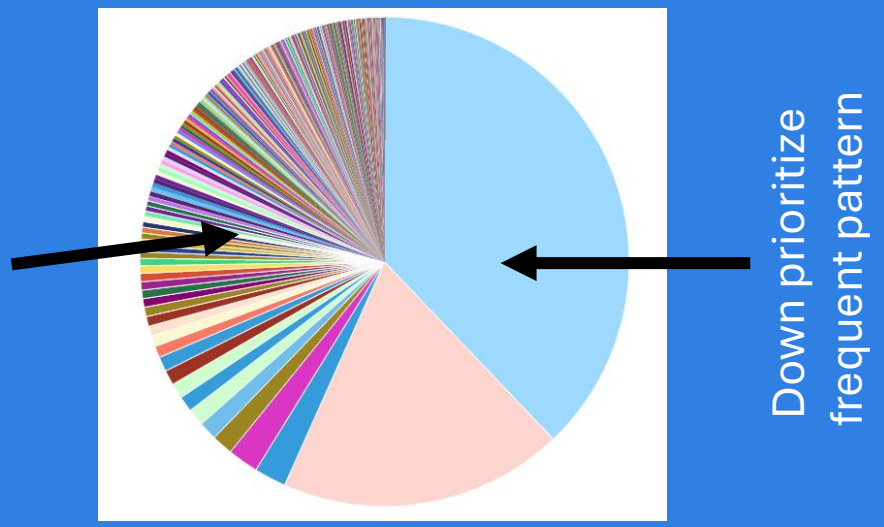
AI Application for Unknown Systematic Fail Mode Coverage

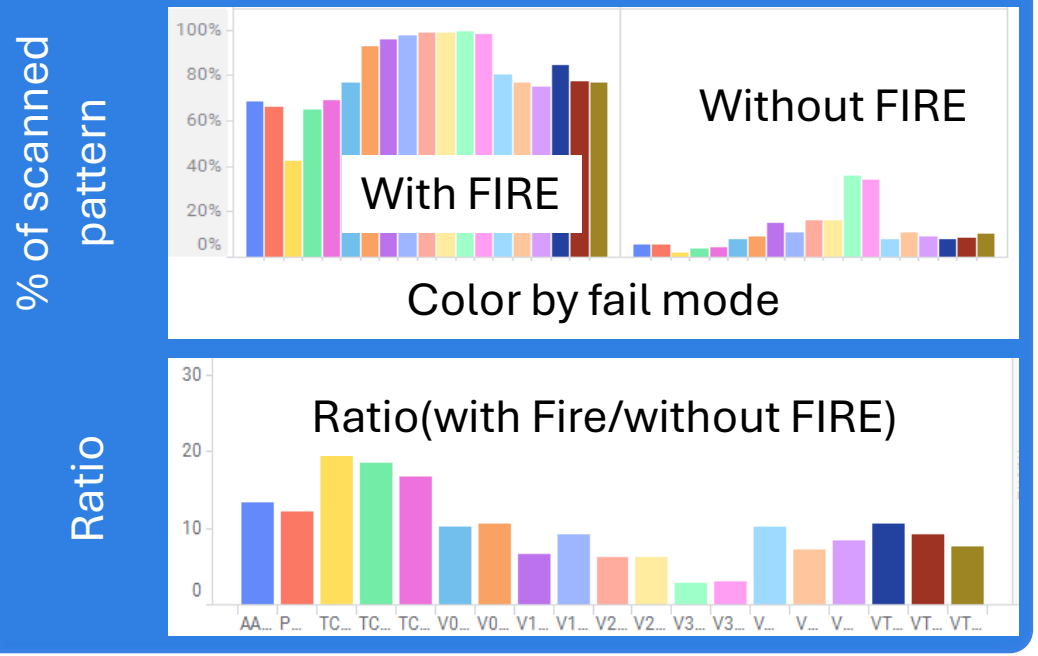
Systematics

Using AI based pattern families, FIRE can characterize the full layout.



Systematics

With FIRE, the location count of pattern is up to 99%. An average improvement of 10x more than without FIRE.



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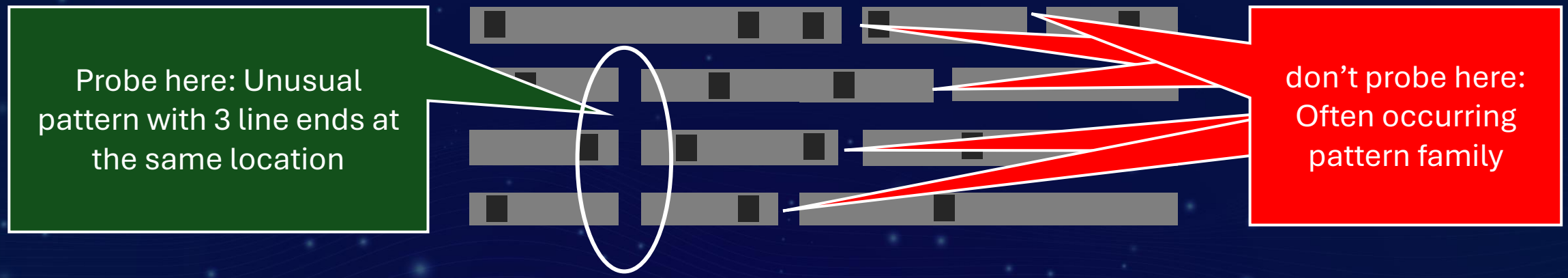
Example

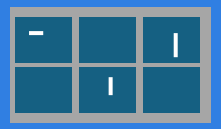
First, AI learns pattern families I.e., similar pattern are grouped into a family.
Then, seldom families can be use as probe candidates to check “unknown” pattern.



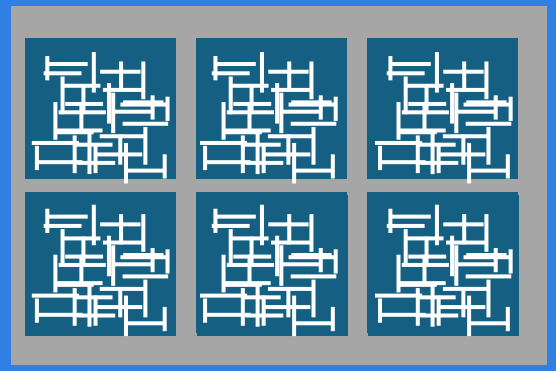
AI Application from Scan Diagnostic to Inspection

Siemens EDA: Tessent Diagnosis

Diagnosis information



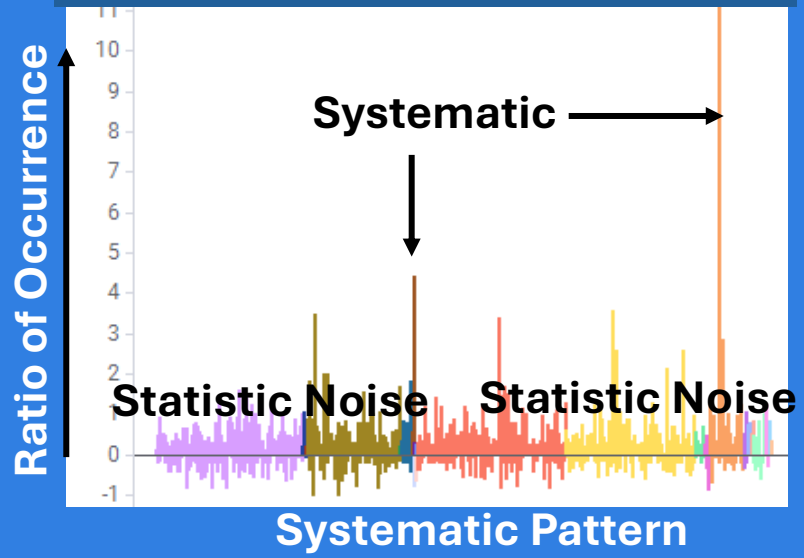
Scan all nets with selected patterns



Test Case

Even when randoms are 100x stronger than systematic

Results: Correct systematic identified

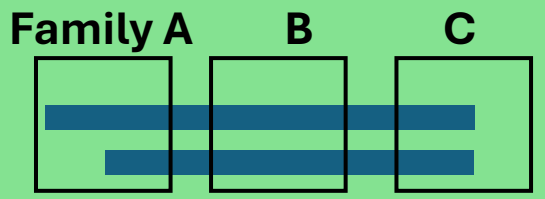


Example

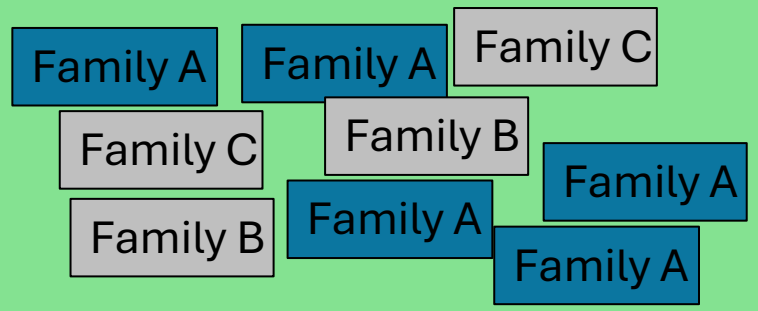
00101001001
01101001000

Digital test yields test response

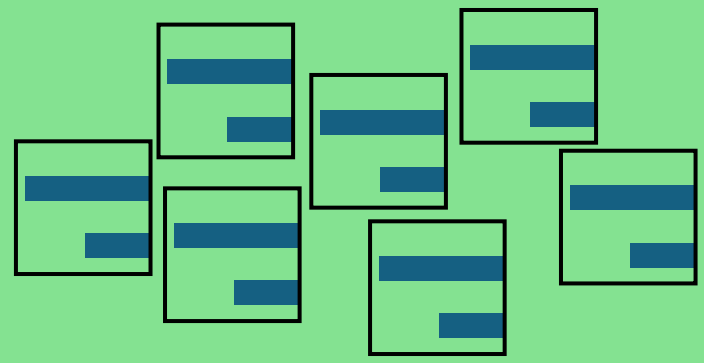
Diagnosis identifies polygons responsible for test response



FIRE associates potential fail locations with the AI learned pattern families



Outlier analysis identifies unexpected high occurrence of certain families



eProbe scans all locations of this pattern family

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eBeam inspection by eProbe: Use Cases Summary

Random defectivity

Unknown systematic

Using scan diagnostics

03.

Tessent + Exensio, Driven by AI

** Image created by Microsoft co-pilot*

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Why integrate Tessent scan diagnostics into Exensio ?

01 Comprehensive yield analysis leveraging all data sources

02 Efficient yield analysis through a single analysis user interface

03 AI-driven automated yield analysis powered by Exensio

Enhanced yield analysis
with *seamless integration*
and *advanced AI capabilities*

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Making scan test data available in Exensio : Tessent Diagnosis

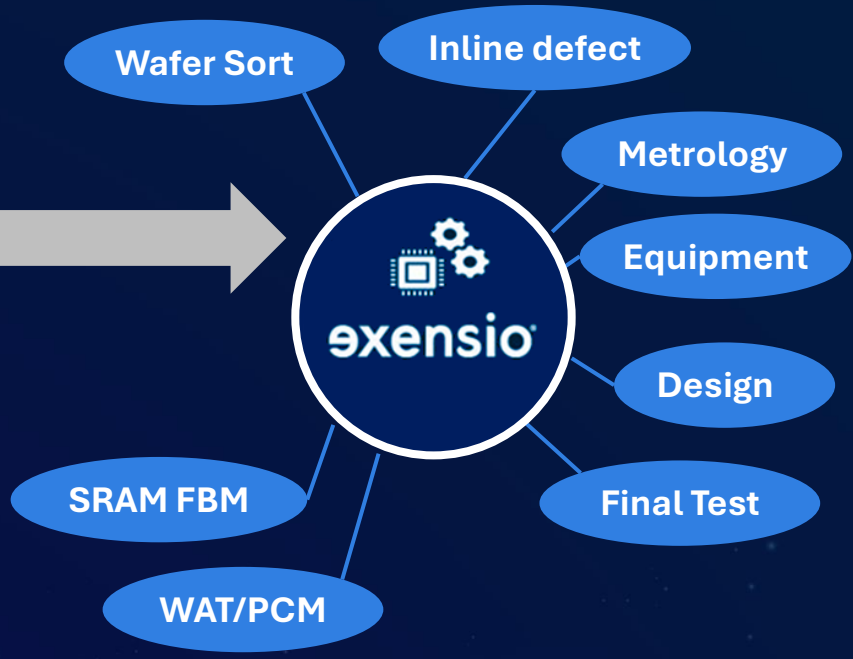
Scan test data

Default rule

Tessent Diagnosis

Layout-aware diagnosis

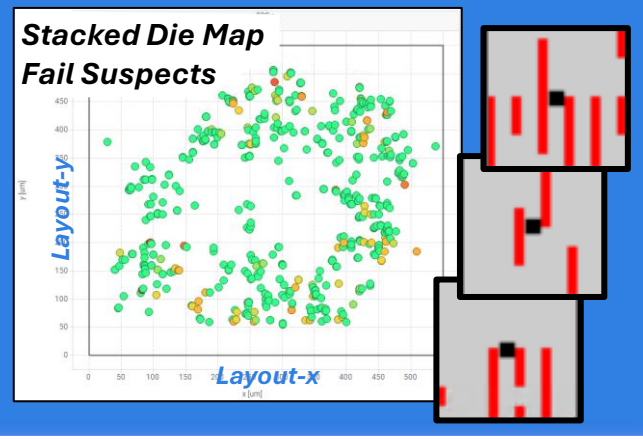
Raw scan diagnosis reports



SIEMENS

- Identifies failing nets and cells using scan test data
- Identifies localized physical net suspects at die-level

lot_id	wafer_id	die_x	die_y	symptom	suspect	score	type	pin_pathname	cell_name	net_pathname	layout_layer	category	x_coord1	y_coord1	x_coord2	y_coord2
Lot1	Wafer17	4	2	1	4.37	100	DOM	/p17/pic1/\inst_reg[2] /Q	SDFF_X1	/p17/pic1/drc_ipo_n75	metal2	C2C	103.11	163.24	103.23	163.38
Lot1	Wafer17	4	2	1	4.38	100	DOM	/p17/pic1/\inst_reg[0] /Q	SDFF_X1	/p17/n_12	metal1	C2C	102.79	163.28	102.84	163.38
Lot1	Wafer17	4	2	1	4.39	100	DOM	/p17/pic1/\inst_reg[5] /Q	SDFF_X1	/p17/n_17	metal1	S2S	102.85	163.28	102.98	163.38



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Making scan test data available in Exensio : Tessent RCD

Scan test data

Tessent Diagnosis

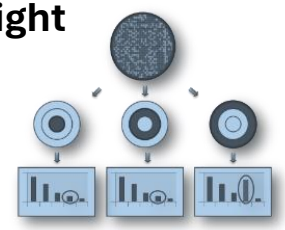
Layout-aware diagnosis

Default rule

Die population

Default rule

Tessent YieldInsight



ML-based RCD
(Root Cause Deconvolution)

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Raw scan diagnosis reports

Fail mode / Root cause

exensio

Wafer Sort

Inline defect

Metrology

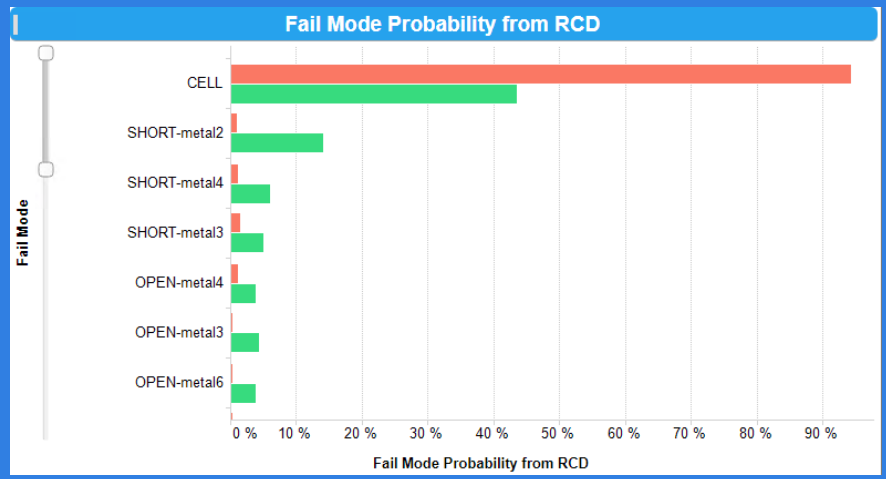
Equipment

Design

Final Test

WAT/PCM

SRAM FBM



Generates fail mode paretos from volume diagnosis data

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Making scan test data available in Exensio : AI-driven enhancements

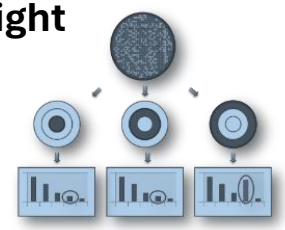
Scan test data

Tessent Diagnosis

Layout-aware diagnosis

Raw scan diagnosis reports

Tessent YieldInsight



ML-based RCD
(Root Cause Deconvolution)

Fail mode / Root cause

Die population

SIEMENS

Default rule

Smart rule

Default rule

Smart rule

exensio

Wafer Sort

Inline defect

Metrology

Equipment

Design

Final Test

WAT/PCM

SRAM FBM

Exensio ModelOps

Determine smart rules based on yield signal to
- select relevant wafers for scan diagnosis
- cluster optimized die populations for Tessent RCD

Signature

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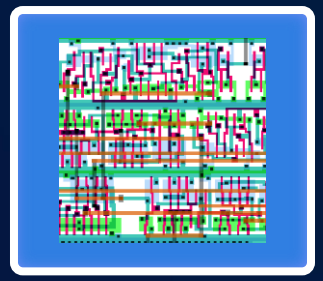
Yield Issue Dashboard with Efficient Root Cause Drilldown



exensio

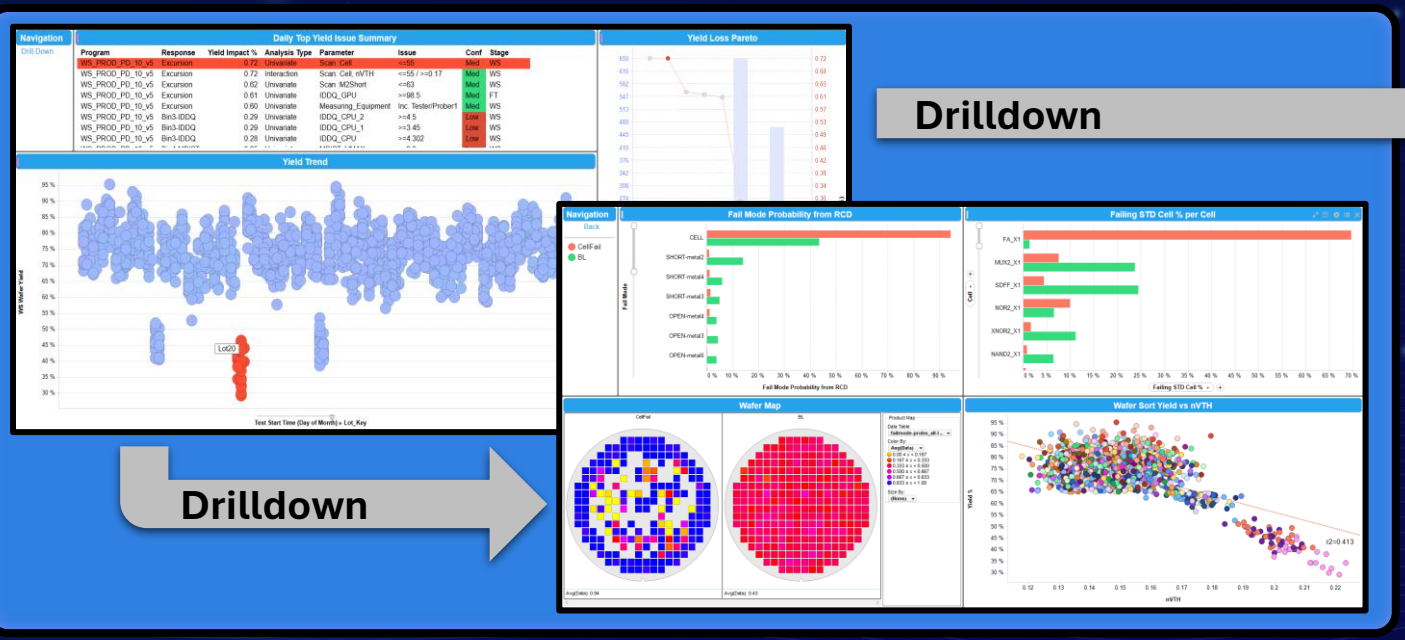
Guided Analytics AI/ML (GA-ML)

Automatically identify yield signals and root causes

Enhanced with scan diagnosis

Exensio FIRE: Fuzzy Pattern AI

Identify sensitive
layout pattern configurations



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Key Takeaways

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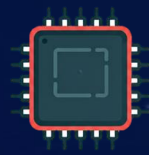
Driven by AI

AI enables us to use design information with other rich data in Exensio to significantly improve inspection and diagnostic capabilities.



Design Info

Analysis

Inspection

Efficient eProbe inspection using FIRE AI-driven relevant inspection points only

Efficient yield analysis using AI and design-driven root cause identification

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