KGx – Known Good x

September 7, 2022

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Today's Presenters

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ProteanTecs

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Quality Screening

Concepts and Advances for using IC Manufacturing Defect Data to assess Known Good Die

Jay Rathert

September 2022

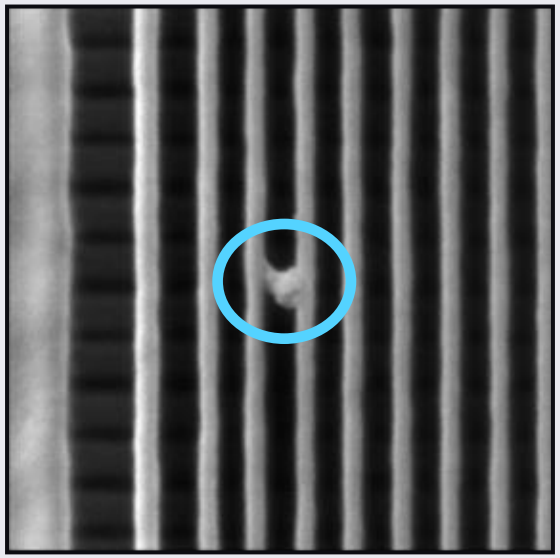
Who is KLA?

And why are they in a Known Good Die discussion?

KLA in the chip fab

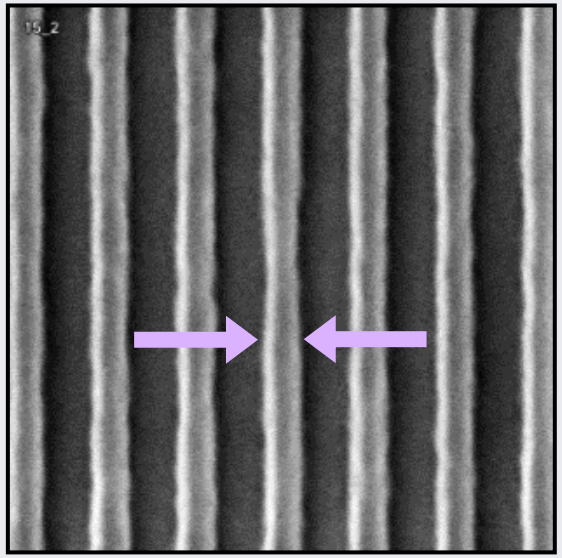
Two Areas to Control

Inspection



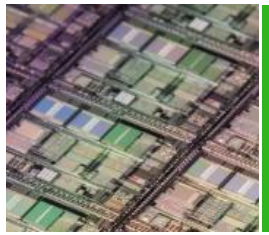
Find Defects

Metrology

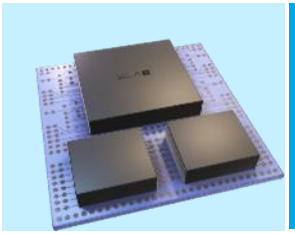


Measure Parameters

KLA at a Glance



Semiconductor Process Control



Electronic Packaging & Components (EPC)

KLA Services

1976

Founded

>60,000

installed base (tools)

>14,000

Employees

$8.2B

Revenue

$1.0B / y

R&D

Beyond yield

Our growing role in Quality

Boston Globe

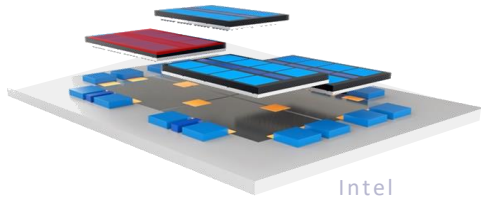
Is *this* die fit for purpose?

• Automotive • 5G • HPC • Industrial & IOT

Will it be reliable? Is this a known good die?

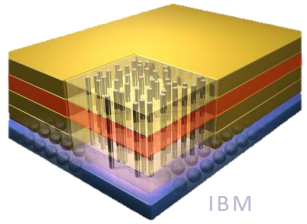
• Increasingly complex packages • Test uncertainty

2.5D



Intel

3D Stack

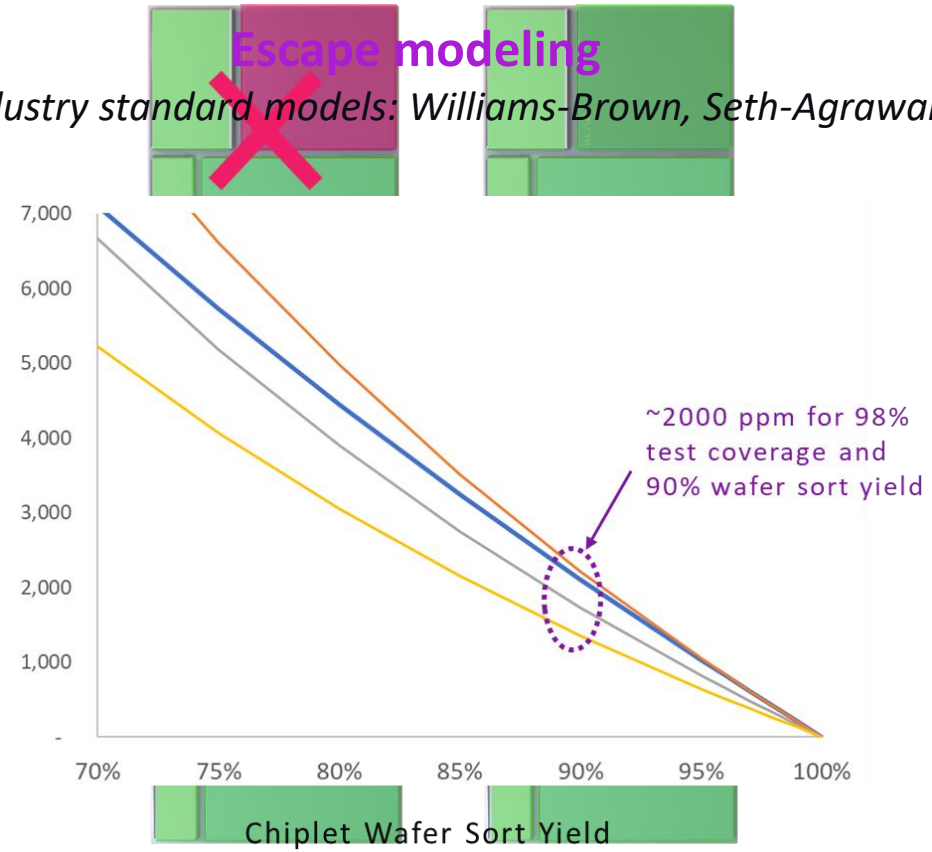


IBM

Known Good Die: Increasing importance

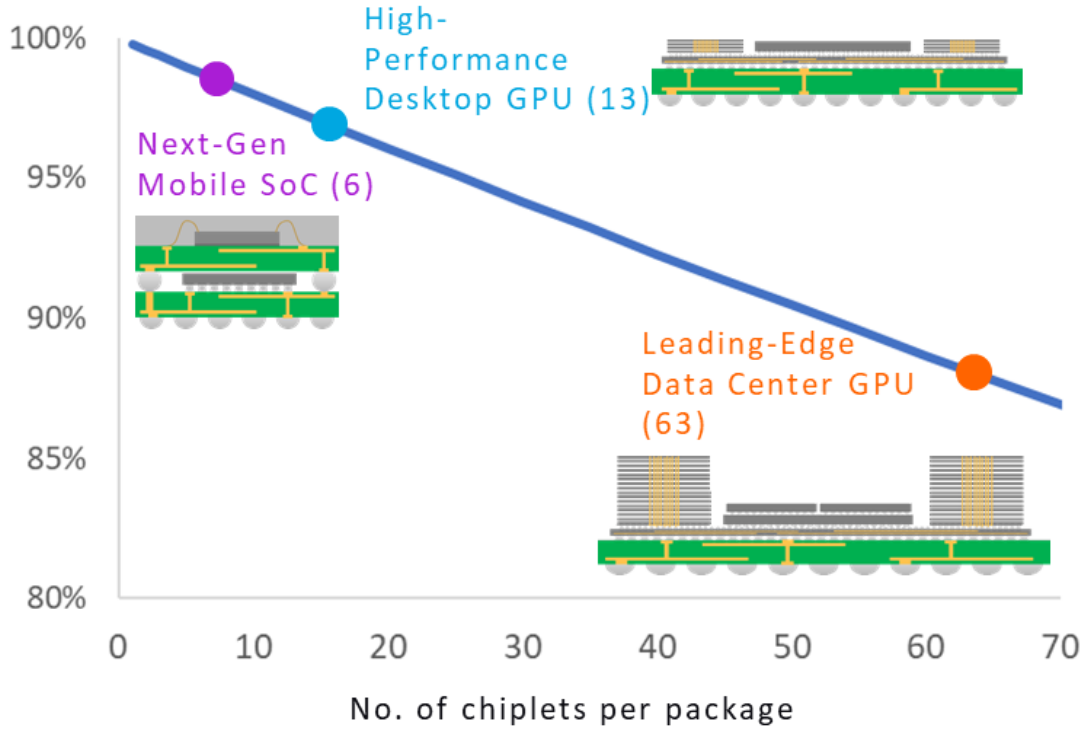
Escape modeling

Industry standard models: Williams-Brown, Seth-Agrawal



Package Yield Loss from Escapes

Yield @ **2000 DPPM** avg chiplet escape rate

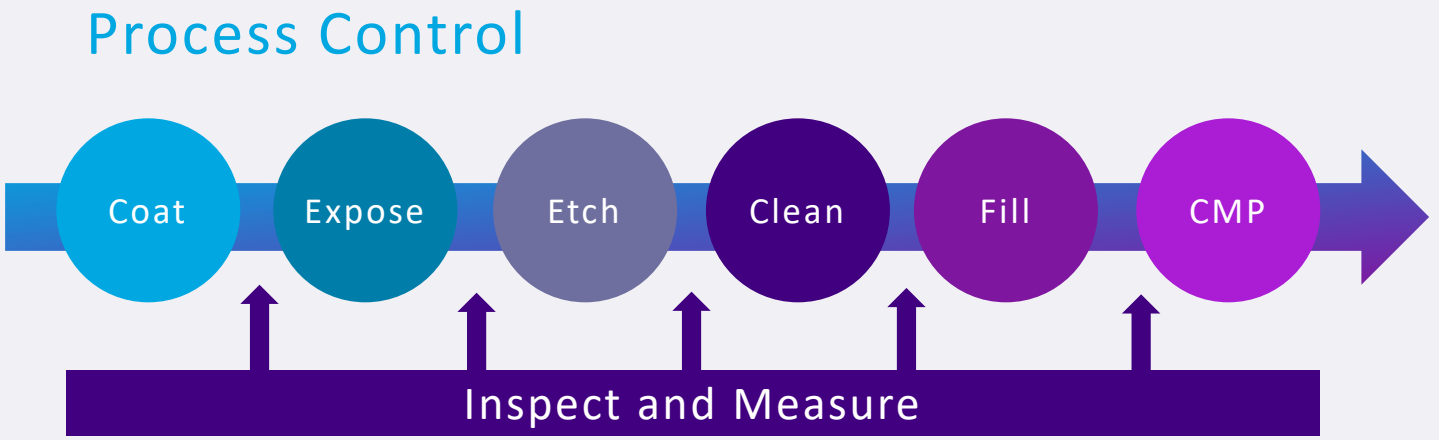


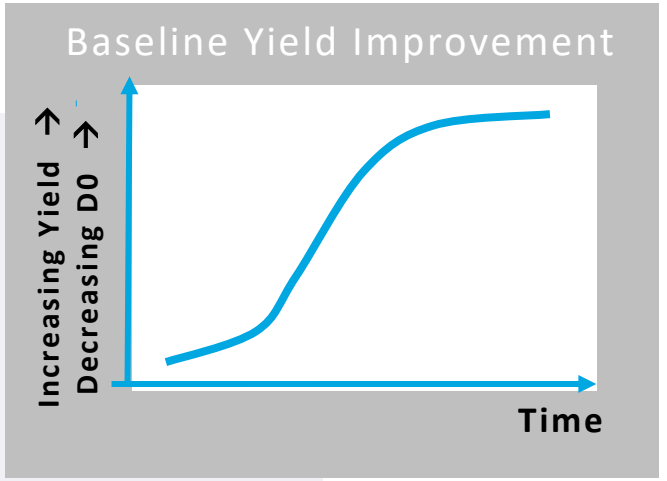
One Bad Die or Interface Kills All

Current methods

Existing Fab Methods for Quality and Reliability

Fewer defects = higher yield = better quality

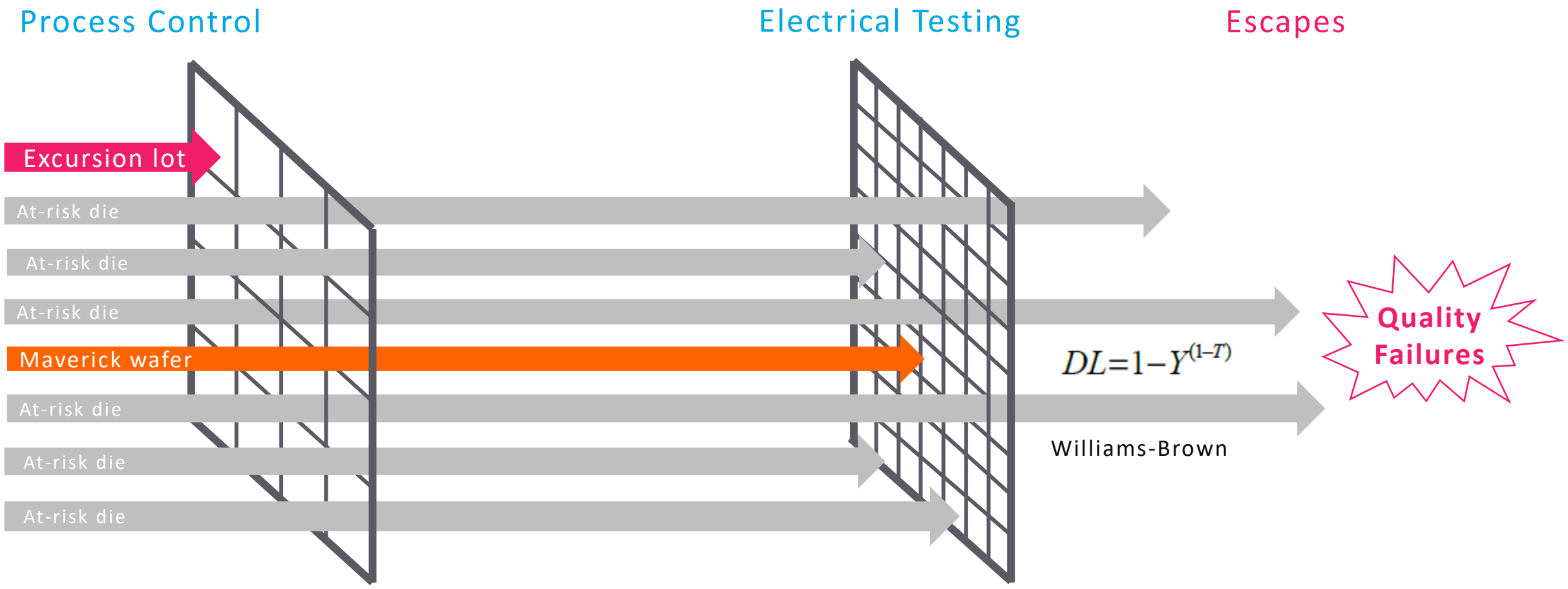




- Samples small percentage of wafers to identify defect types and sources
- Looks back to process: variation & excursions, systematic defects, random defects from tools & materials

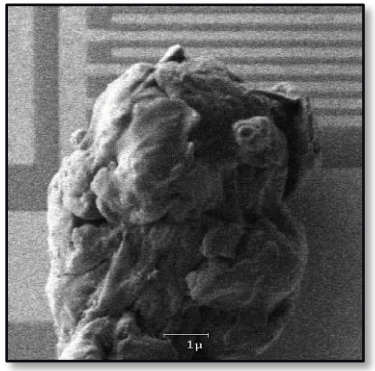
Not all wafers or die will be measured

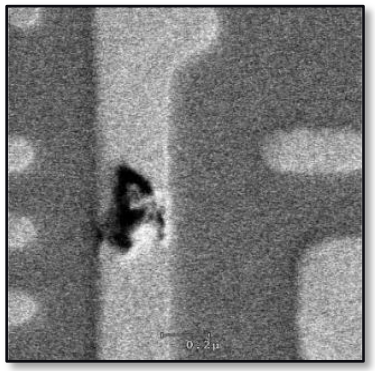
Current Method and Quality Escapes



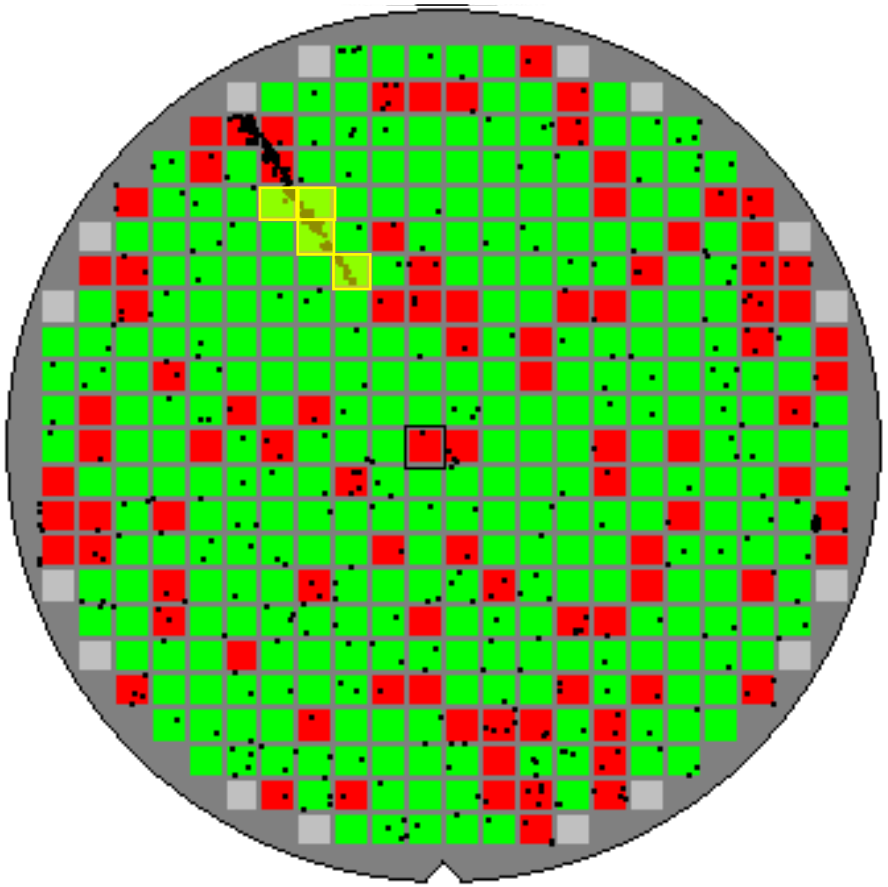
Low yields and incomplete test coverage allow escapes

Manufacturing defect data



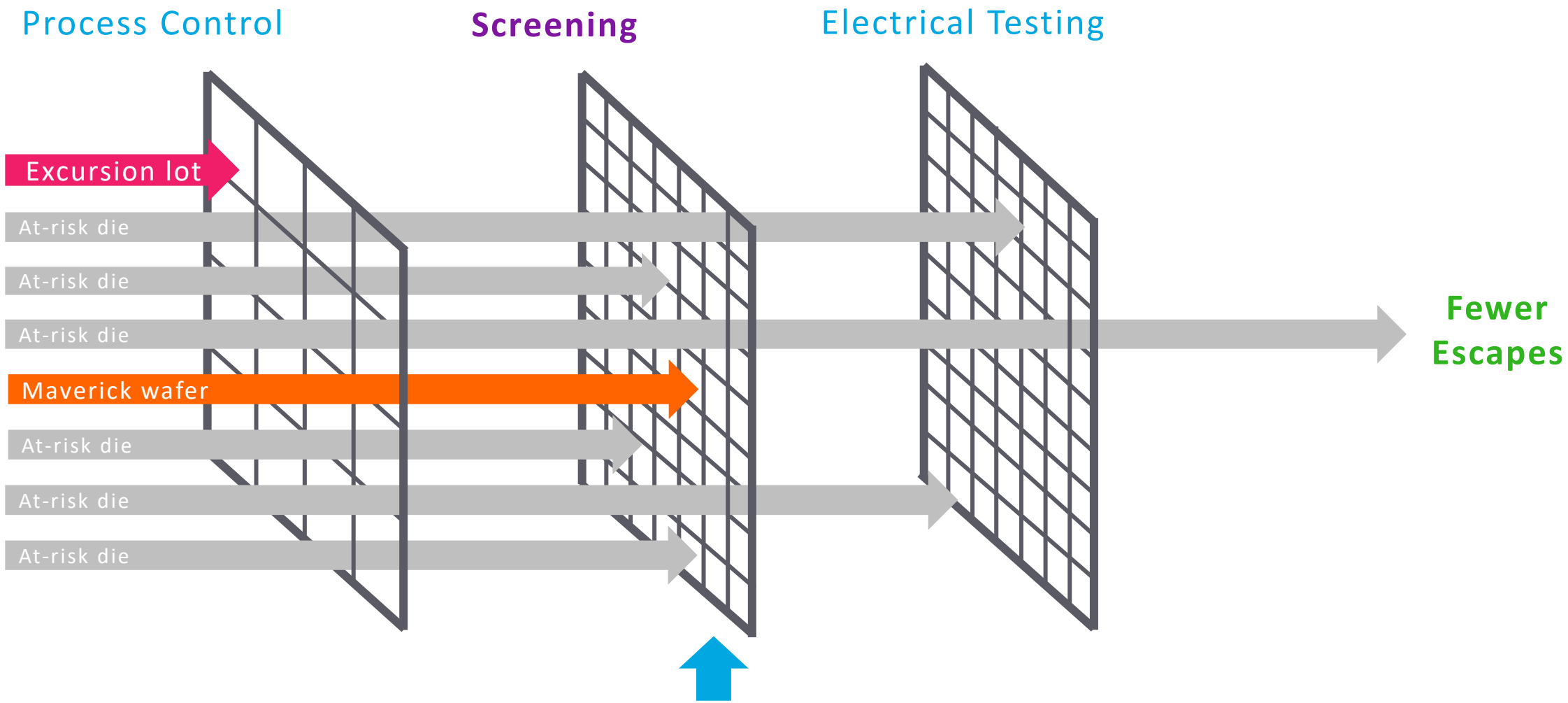


Stacked EWS and Defect Map



Useful KGD determination data

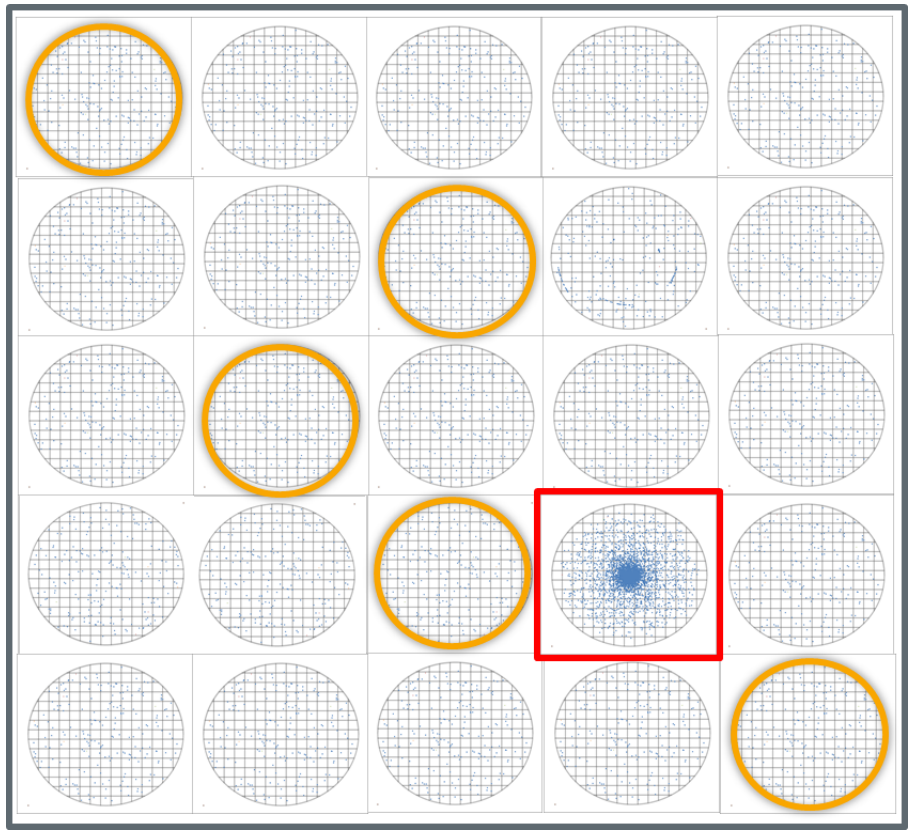
Optical Inspection Screening Adds Another Layer of Protection



Screening Challenges

- Economics
  - Fast enough to cover the WIP at multiple layers
  - Acceptable cost of ownership
- Data quality
  - **Underkill:** Sensitive enough to see the defects
  - **Overkill:** Runtime defect categorization
  - **Actionable**: Data volume cleaning, distillation and normalization. Customized limits. Open format.

Single Maverick Wafer Excursion



Legacy 5 wafers per lot sample

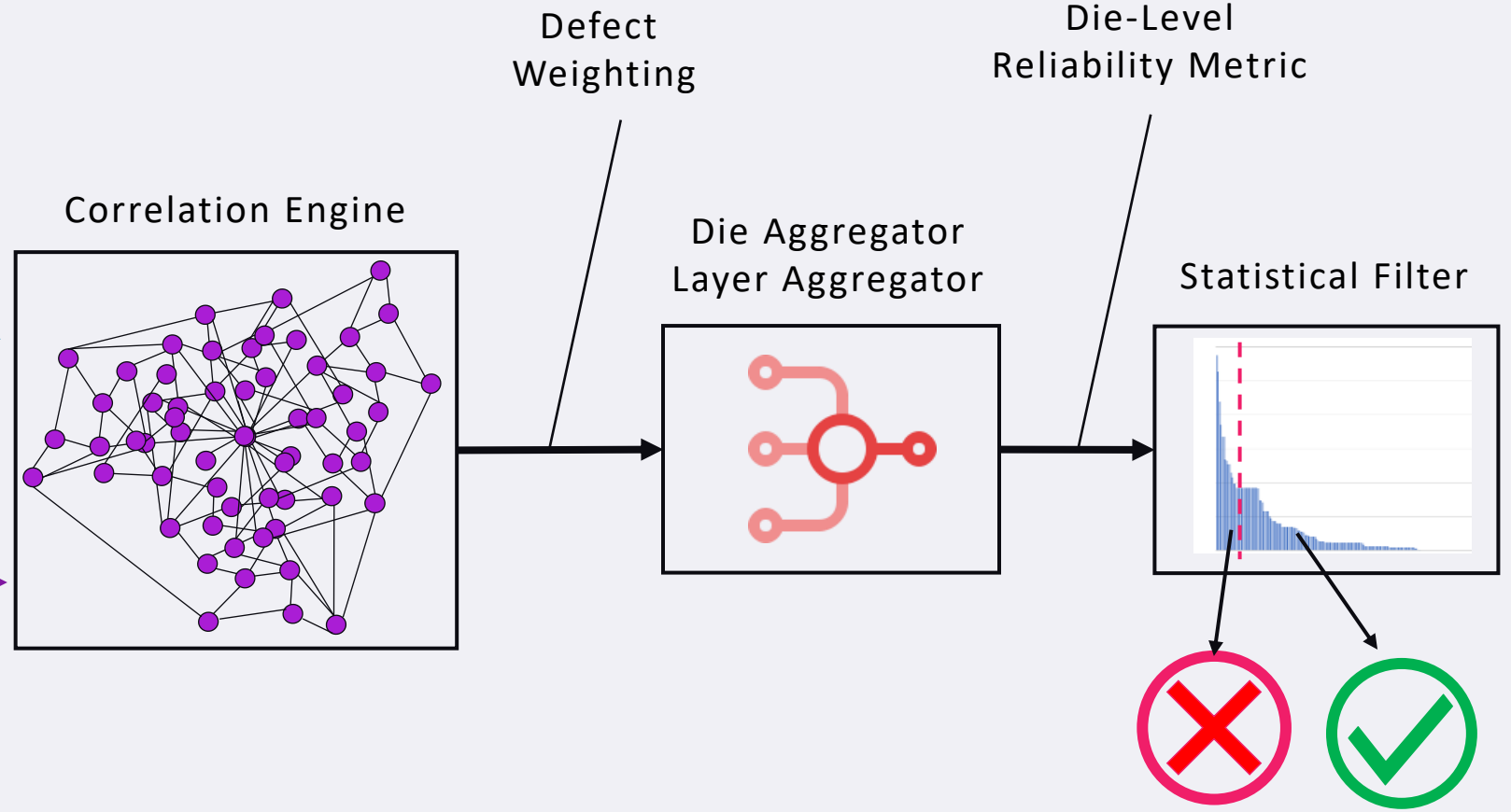
Single wafer excursion

Designing a solution

I-PAT®: Inline Defect Part Average Testing

Inspection and Metrology Attributes

Examples of Yield or Potential Reliability Failures



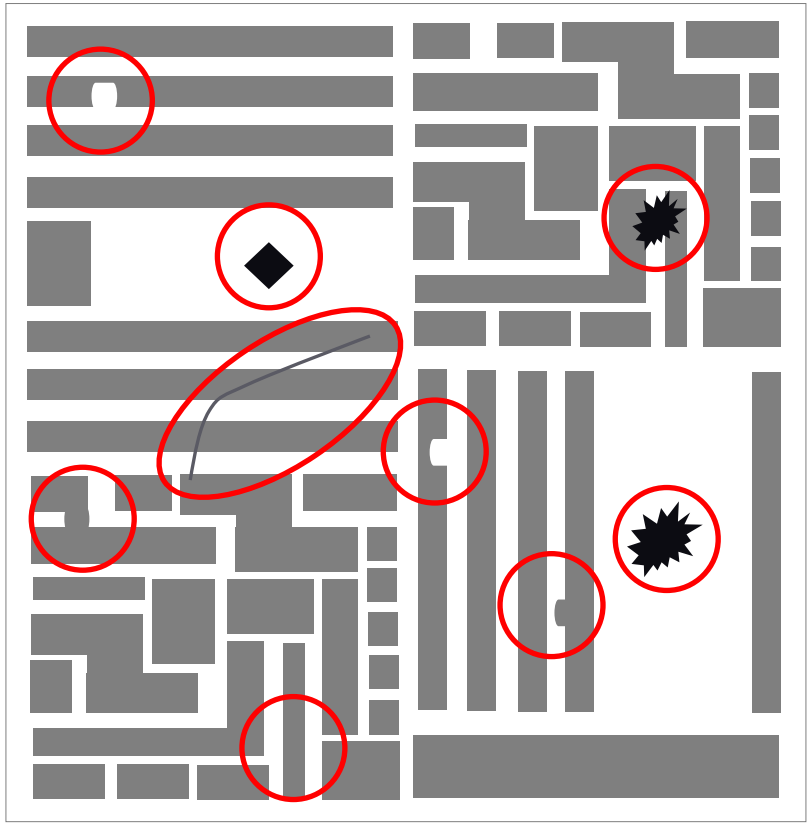
Each die receives a score based on cumulative defectivity.
Statistical methods are used to identify outliers

For more details, see references [8] – [15]

Categorize the defects

Runtime Information about each defect on the wafer

Not all defects are equal



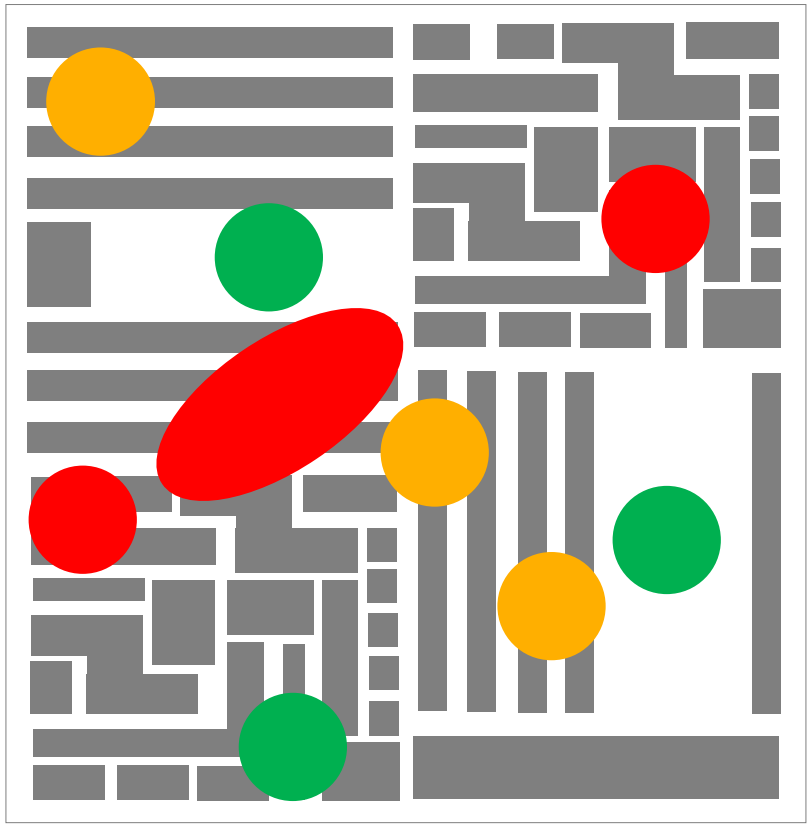
User trainable categories or “bins”

- Extract defect attributes (digital thumbprint)
  - System:
    - Sensor and channel data
  - Physical
    - Embedded/surface
    - Size/aspect ratio
    - Location/region
    - Open vs. dense
    - Intensity/signal vs. background
    - Contrast/polarity
    - ….

- Create expert training set with weightings

Assess their impact

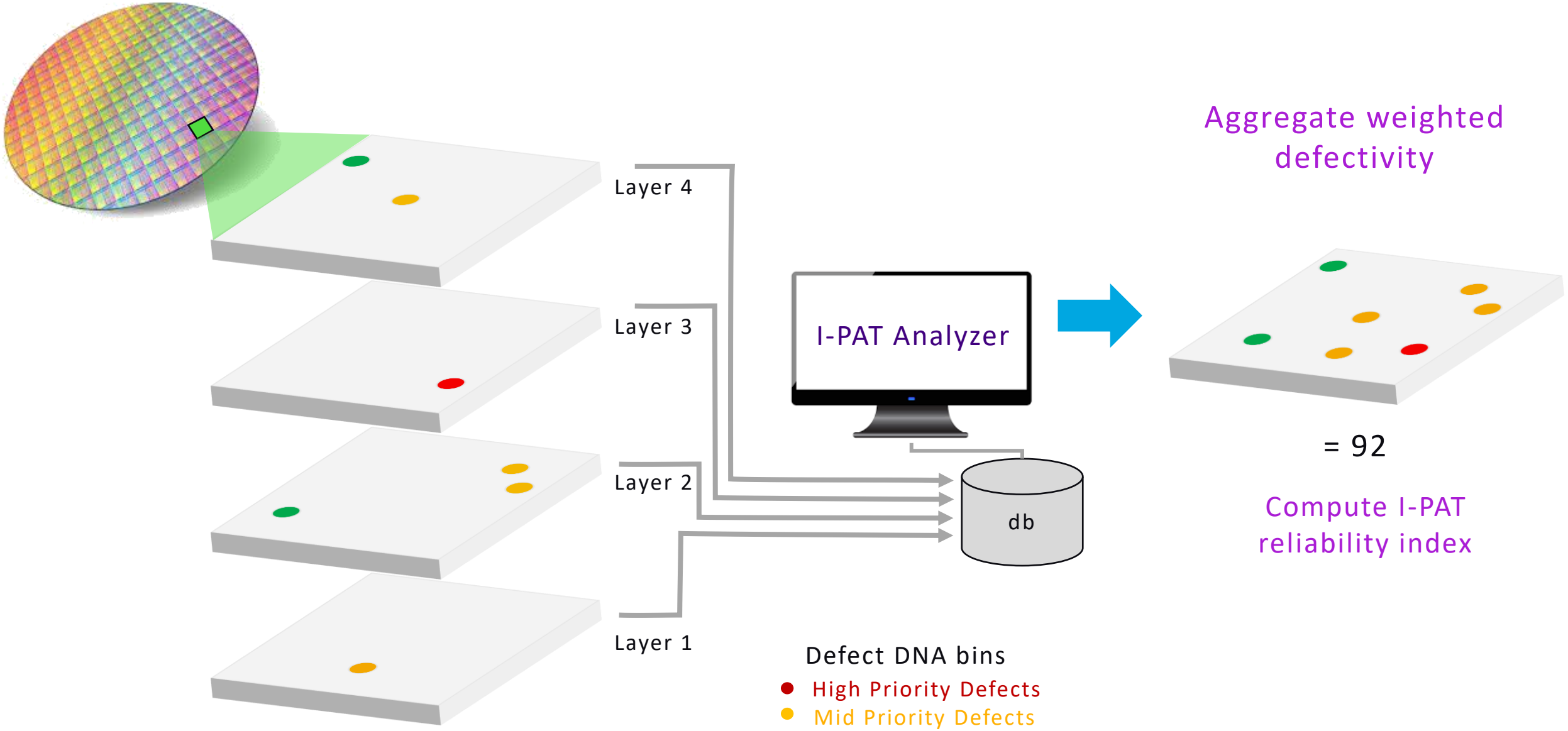
Information about Each Defect on the Wafer



- High Priority Defects
- Mid Priority Defects
- Low Priority Defects

- Runtime Binning
- Machine vision + AI assigns defects to user-trained categories
  - Impact, not source
  - No SEM review

I-PAT: Aggregate score for every die



Analyze the Population

User trained weightings

Example die

I-PAT Reliability Index	175	64	61	13	2

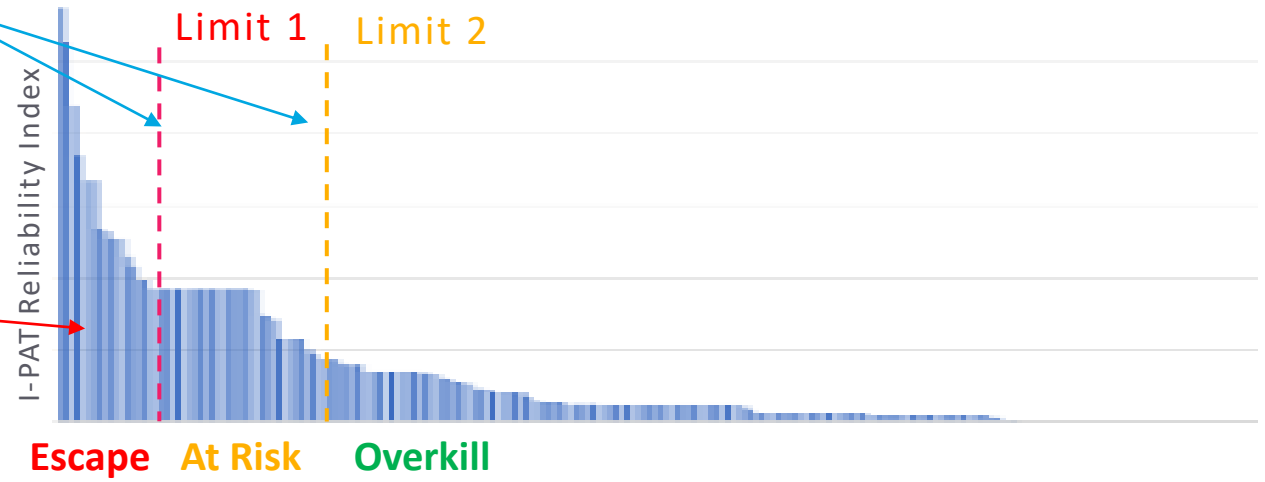
Statistically Filter population

Pareto of each die's score

User defined limits

JEDEC compliant

I-PAT Outliers



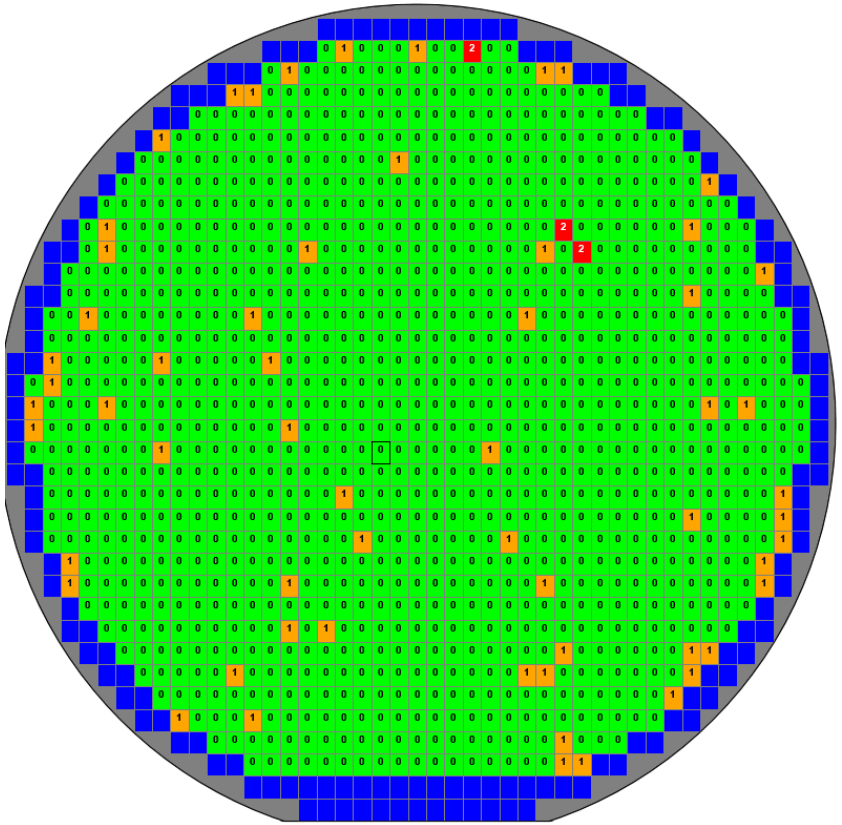
I-PAT Analyzer:
Export data to fab outlier reduction system

Open Format
KLARF 2.x

I-PAT data at the wafer level

- Numeric scoring by die
- User selectable limits
- Data granularity
  - Total score
  - FE vs BE
  - By layer
  - By die region
- Fab IP friendly

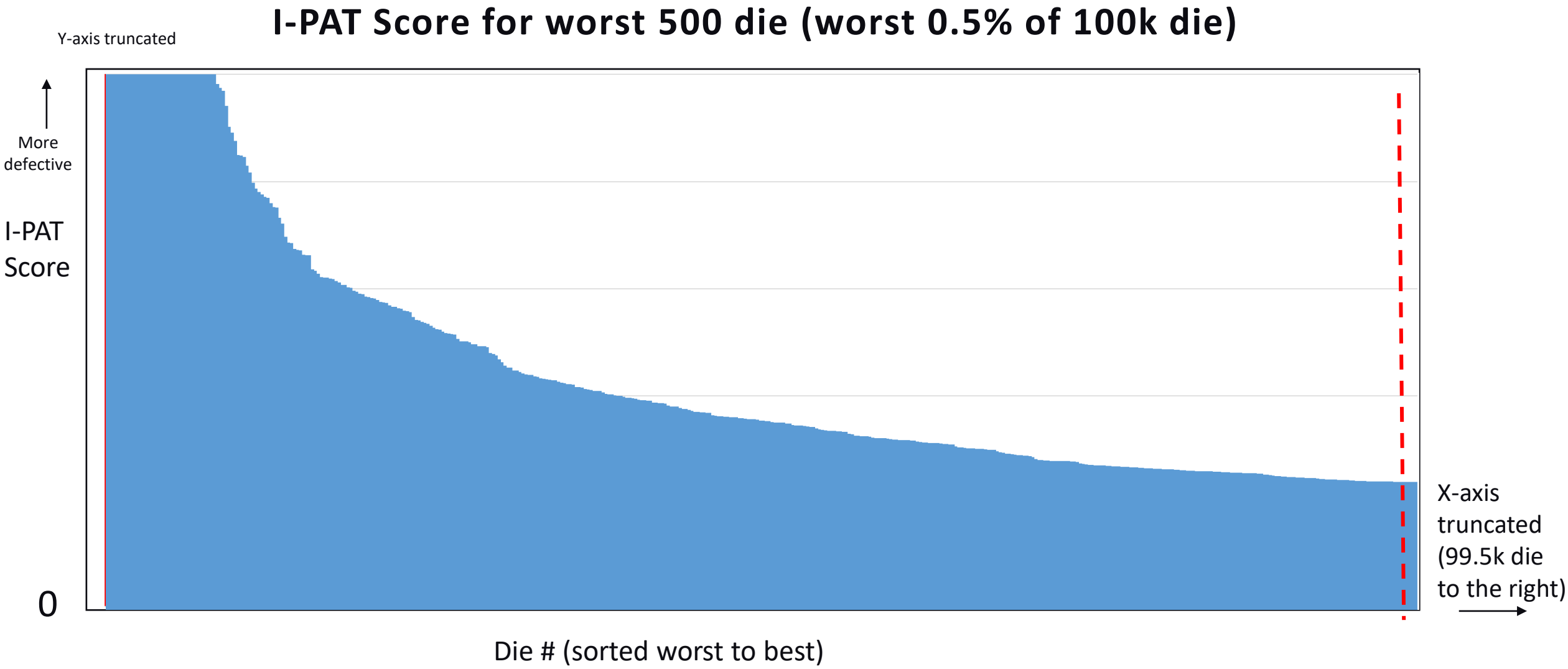
Reduces Noisy Fab Data to Actionable Information



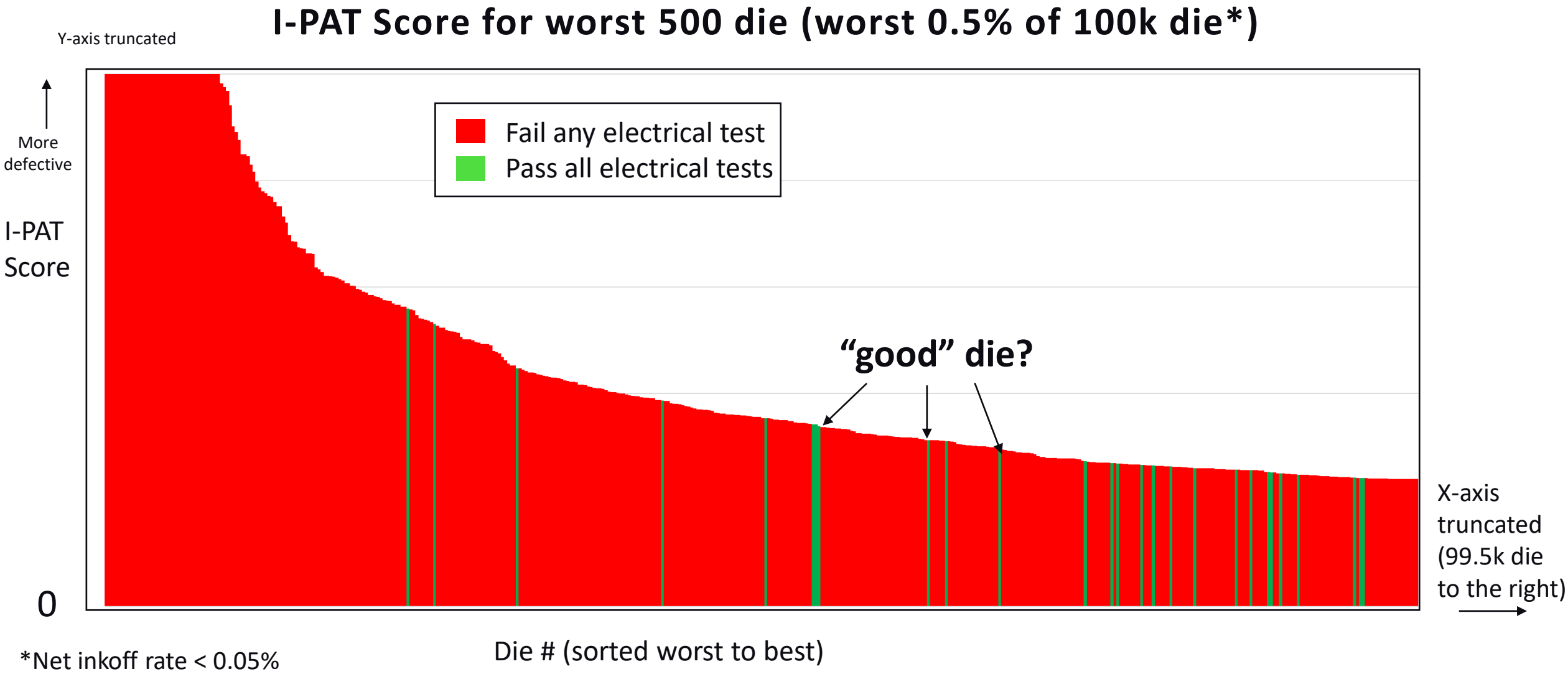
Low defectivity “Good” Die
Moderate defectivity “At Risk” Die
High defectivity. Inked out Die

Case Study

Escape Reduction: Recognizing Bad Die



Escape Reduction: Recognizing Bad Die

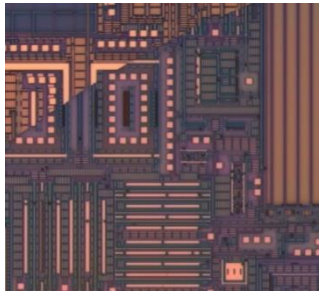
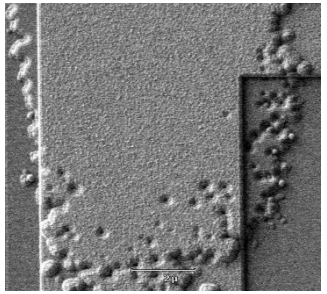
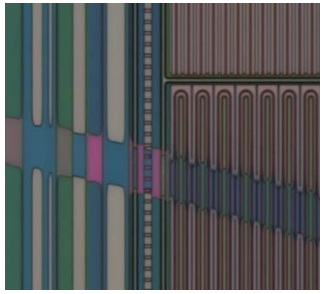


*Net inkoff rate < 0.05%

32 highly defective die pass all tests

Applying I-PAT to KGD: (large die population)

- 76,000 die HV Analog die, multi-layer inline defect (I-PAT) screening

The most defective outlier die are scrapped

I-PAT Die Score

At-risk die:

- Bin/repurpose
- Burn-in
- Scrap

Low Risk Die

KGD candidates**?**

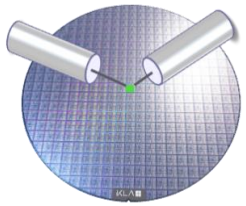
56K die with negligible defectivity not shown

Most defective

Least defective

Worst 20,000 Die

I-PAT + Test: Better KGD decisions together

Test score	I-PAT score	
		
✓	✓	**Confident good. KGD? Skip burn-in?**
	X	**Known Bad Die. Scrap sooner to save package, FT costs.**
?	✓	**Possibly good. Burn-in?**
	?	**Probably bad. Bin/Scrap**
	X	**Scrap**

Communication challenge: Connecting/incentivizing stakeholders

Thank you

Questions?

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