Reducing KGD test cost via prediction testing

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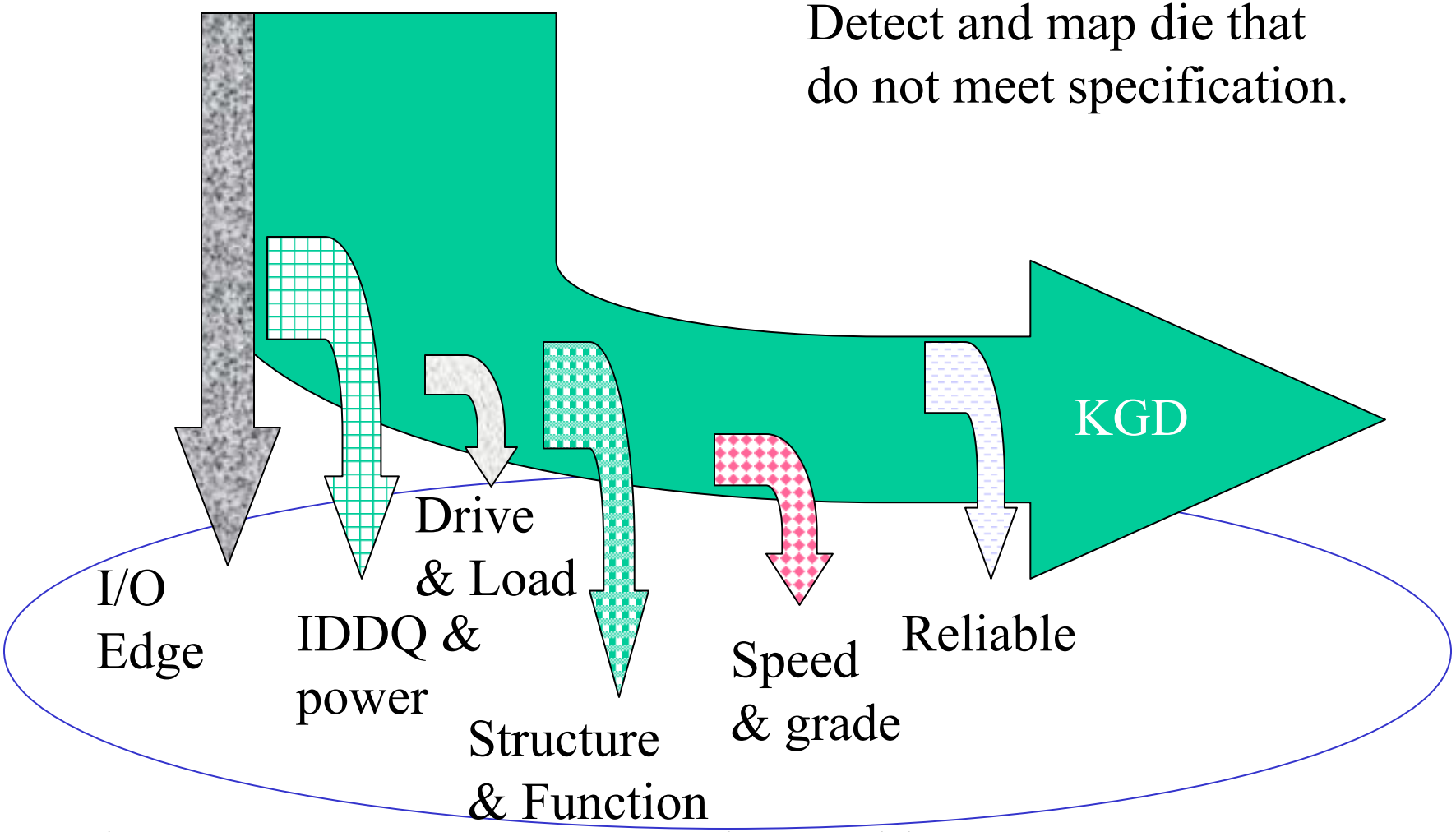
KGD test job

Wafer from fab

Detect and map die that do not meet specification.



KGD test options & cost

- Conventional test
  - Test "everything" to spec
  - Cost = Test time x cost/min
- Data based test
  - Use fab data to predict
  - Use profiling screen for suspicious product
  - Test function
  - Cost = Time x cost/min + Analysis/wafer or site

In practice, testing everything or every combination is not practical.
For test cost considerations, testing on complex circuits
is done to a confidence level or fault coverage.

Test equipment cost

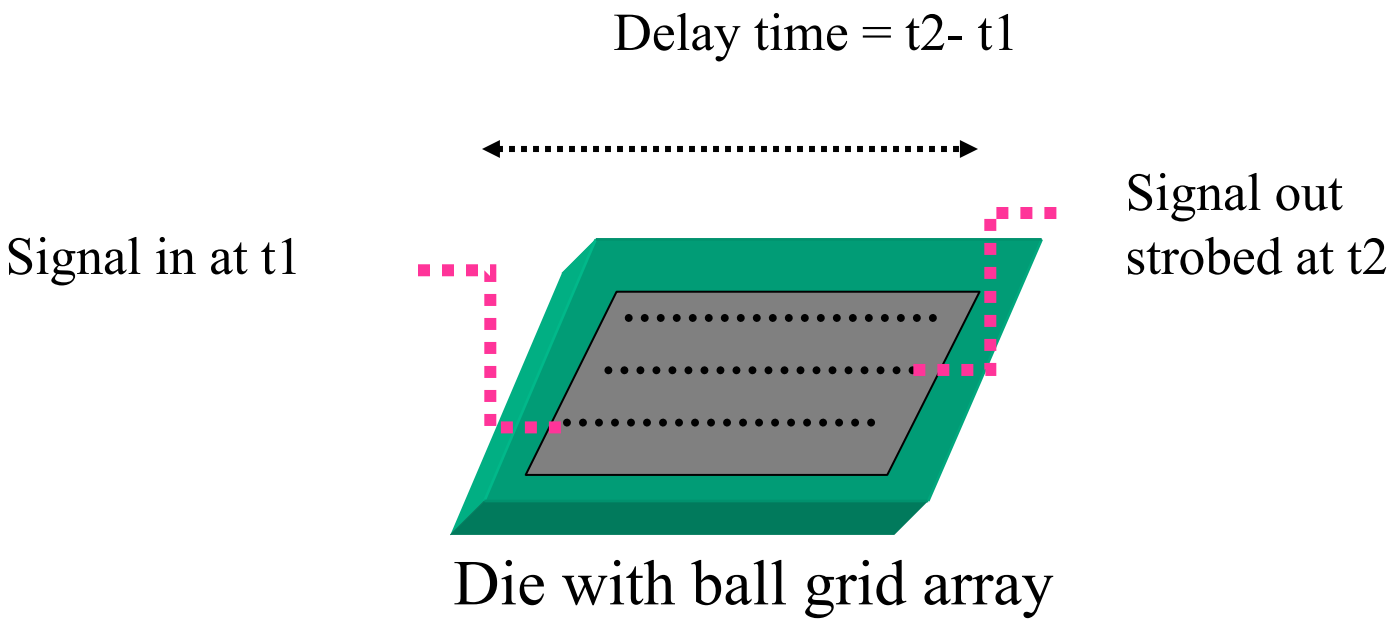
ITEM	High speed	Low speed
Tester base	$350,000	$350,000
Pin cost	$5,000	$2,000
300 pin tester	$1,850,000	$850,000
Prober	$300,000	$300,000
Total	$2,150,000	$1,150,000

Source: International Technology Roadmap, 2001 Edition

Generic test cost calculation

Tester & prober cost		2400000	Dollars
Amortization period		5	Years
Operation		365	days/year
Utilization per day		10	hours/day
		60	Min/hr
Overhead		100%	
Test cost per minute		$4.38	
Test cost per second		$0.07	

Conventional speed test



Tested on a few critical paths to determine die speed.
Other paths may have soft defects that change the delay.
High-speed test pins are needed to test current products.

Conventional test cost example

Assume 1 cm sq die on 200 mm wafer

0.5-minute to test a good die x $3.93/min = $1.96/die

Assume 200 good die per wafer

It costs **$393** to test the wafer using high-speed pins

Data based reduced time test cost

Assume 1 cm sq die on 200 mm wafer

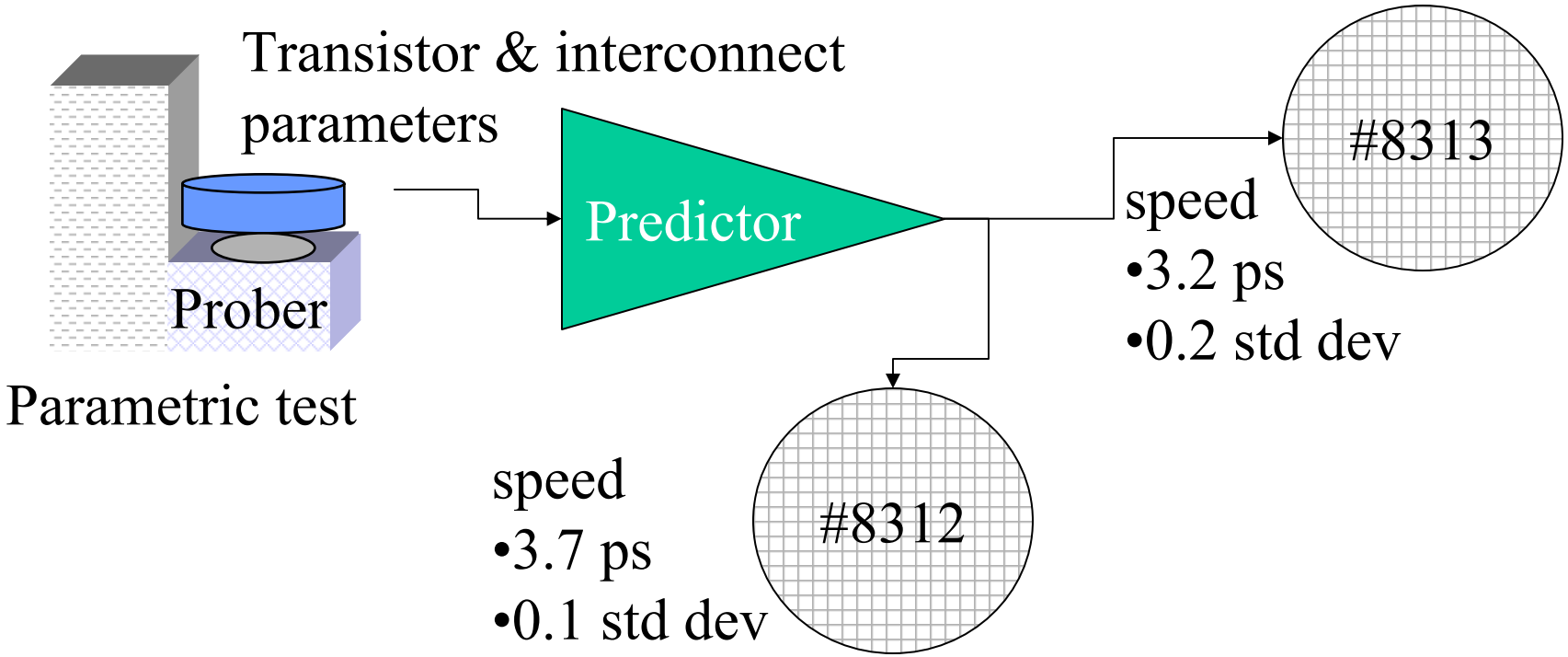
0.4-minute to test a good die x $2/min = $.80/die
Low speed test pings

Assume 200 good die per wafer

It costs **$160** to test the wafer using low speed test pins

But, how is this done?

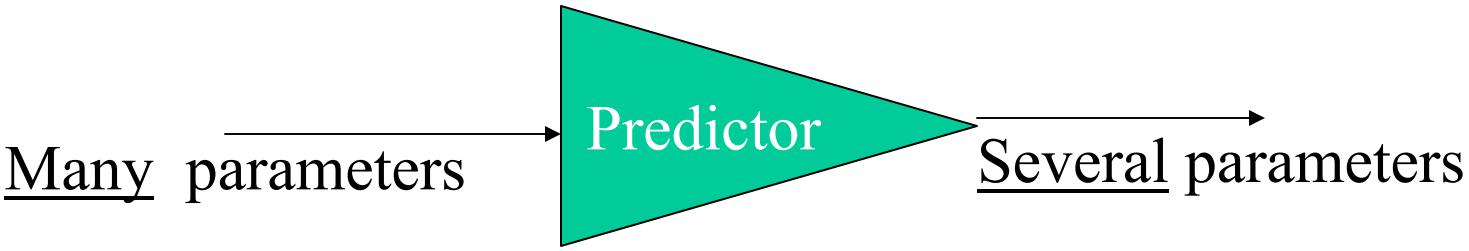
Data based or prediction speed “test”



Soft speed fails may be detected by profiling with other parameters

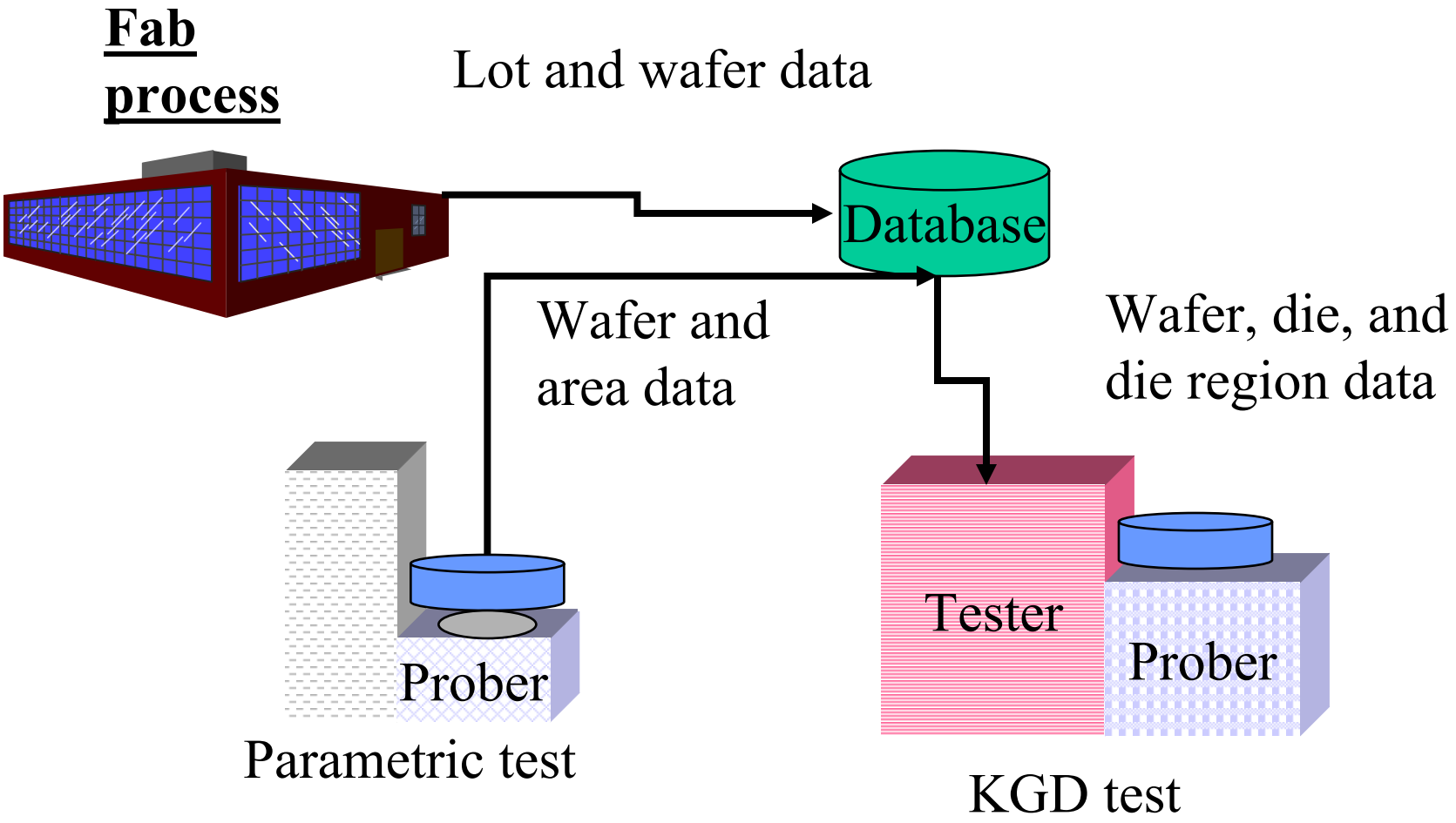
Same technique can be used to “test” drive/load, voltage range, grade

What is a predictor?



A *non-linear* regression model built using input data from fab and parametric test and out data from characterization of the device.

Data sources for data based KGD testing



Data based test, test generation cost estimates

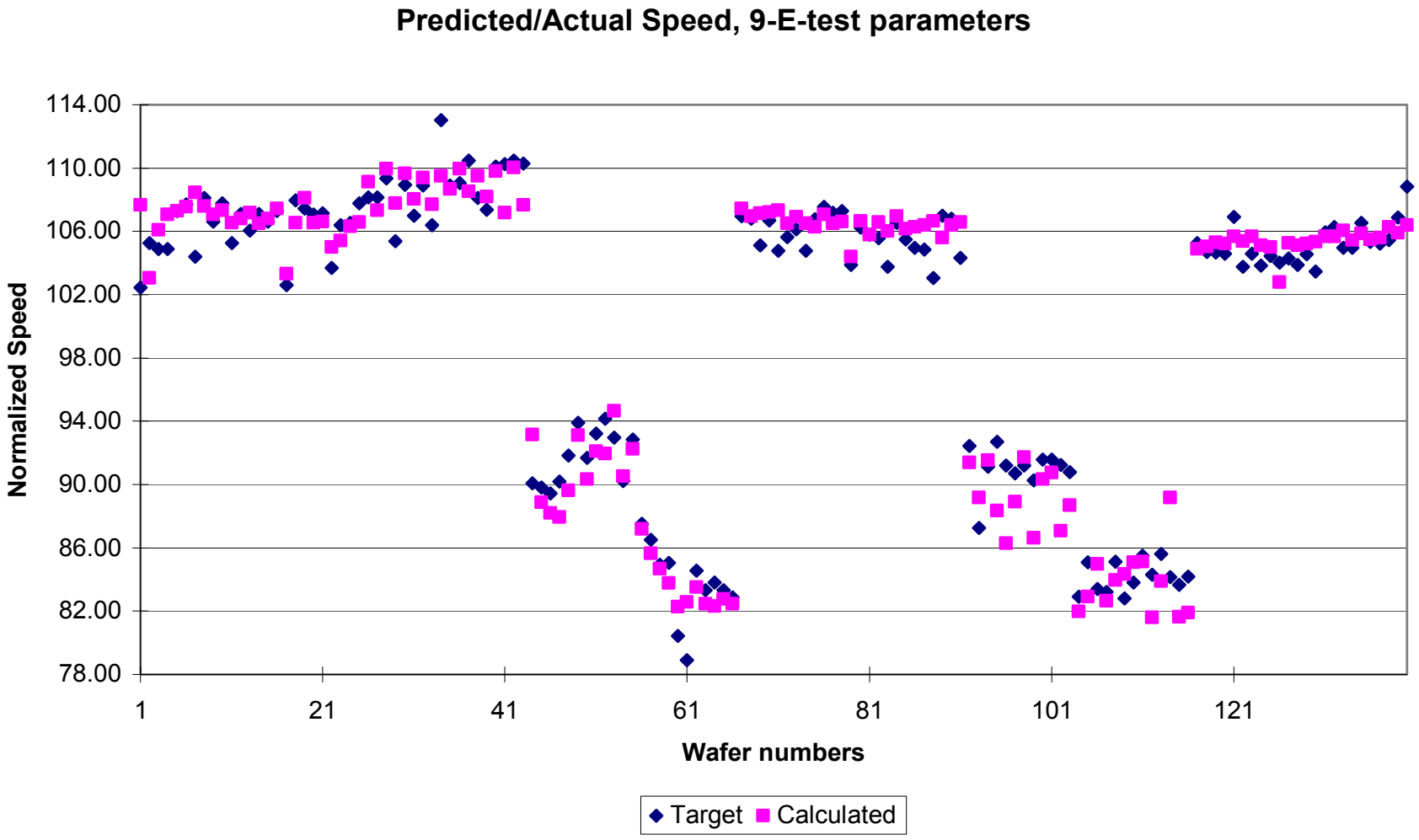
FACTOR LEVEL	
Non-linear model building software	$5,000-$25,000
Integration of modeling software with CIM system	$100,000
PRODUCT LEVEL	
Prediction or profile modeling, NRE	$5,000
Data scrubbing	
Modeling	
Variable reduction	
Testing	

Example prediction test cost per wafer

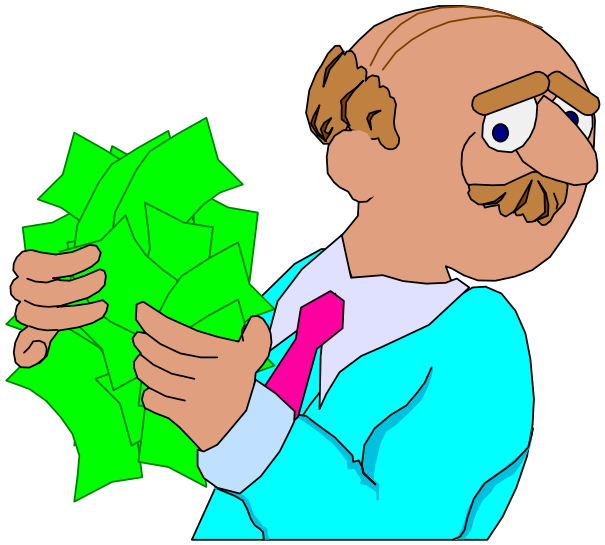
Integrated prediction system	$125,000
Production rate, Wafers/year	60, 000
Prediction test cost	$2/wafer *
Overhead to operate	100%
Loaded prediction test cost	$4/wafer

* Assume prediction system needs to be re-integrated each year.

Example from prediction test



How to find suspect material?

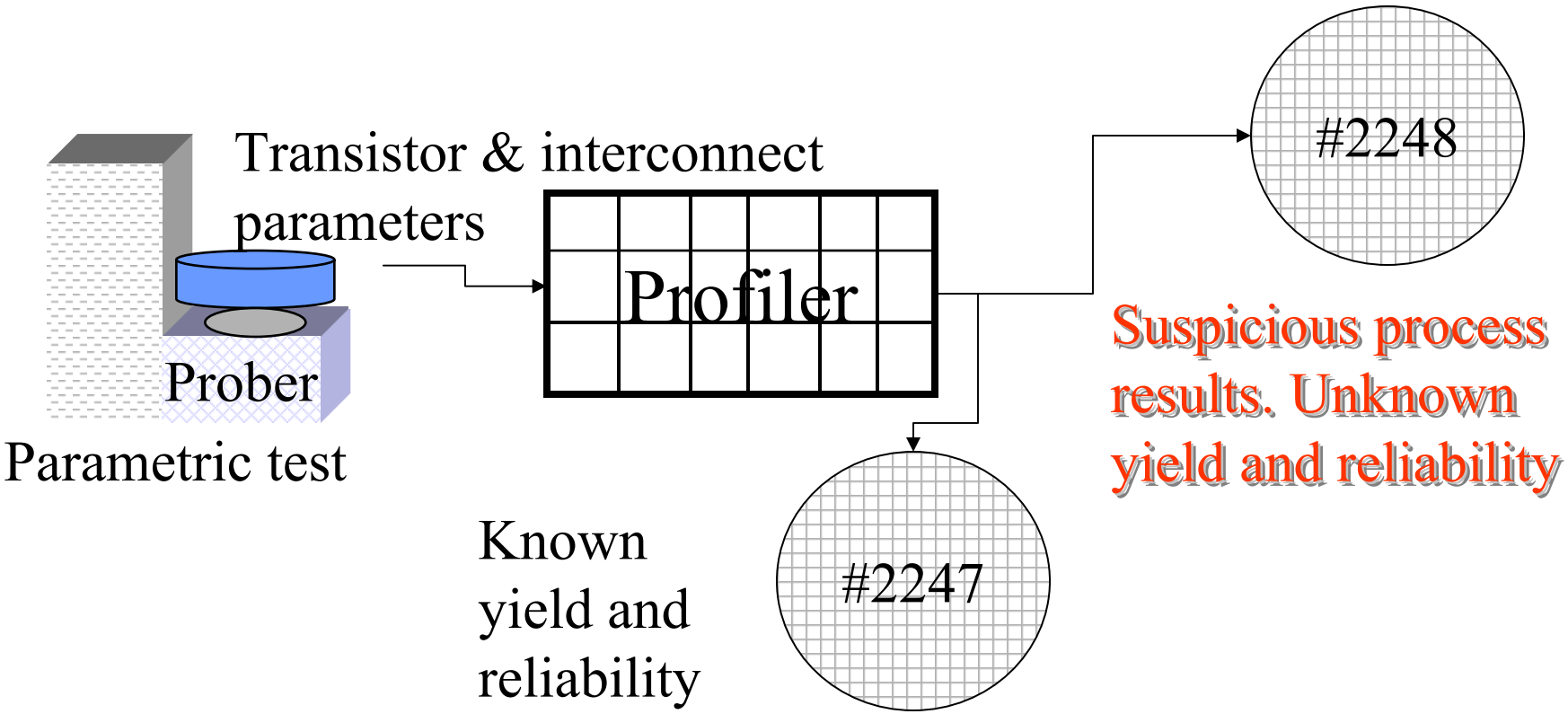


Given that speed and other parameters can be predicted by wafer, what can be used to find wafers and die that do not fit into their neighbors characteristics?
That is, how to find wafers and die are in specification but who's results is suspect.

This is done by profiling.

The police cannot do this, luckily we can

N-dimensional profile wafer sorting

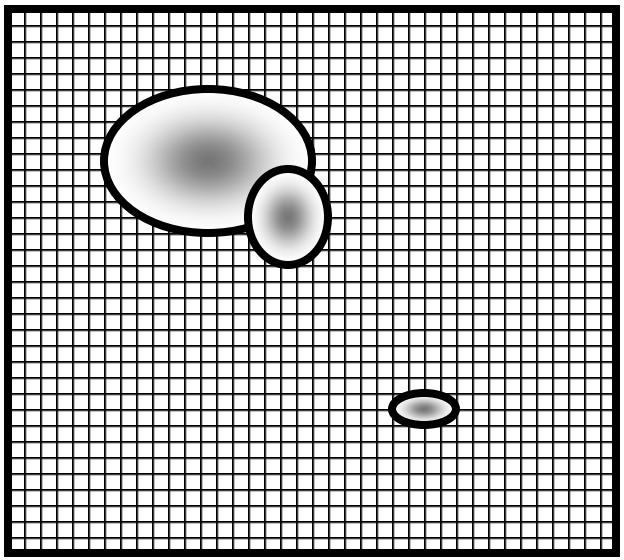


In a similar way, a profiler based on KGD test data can be used to detect and remove suspicious die from the wafer map. This can be done off-line without adding to test time.

What's a profiler

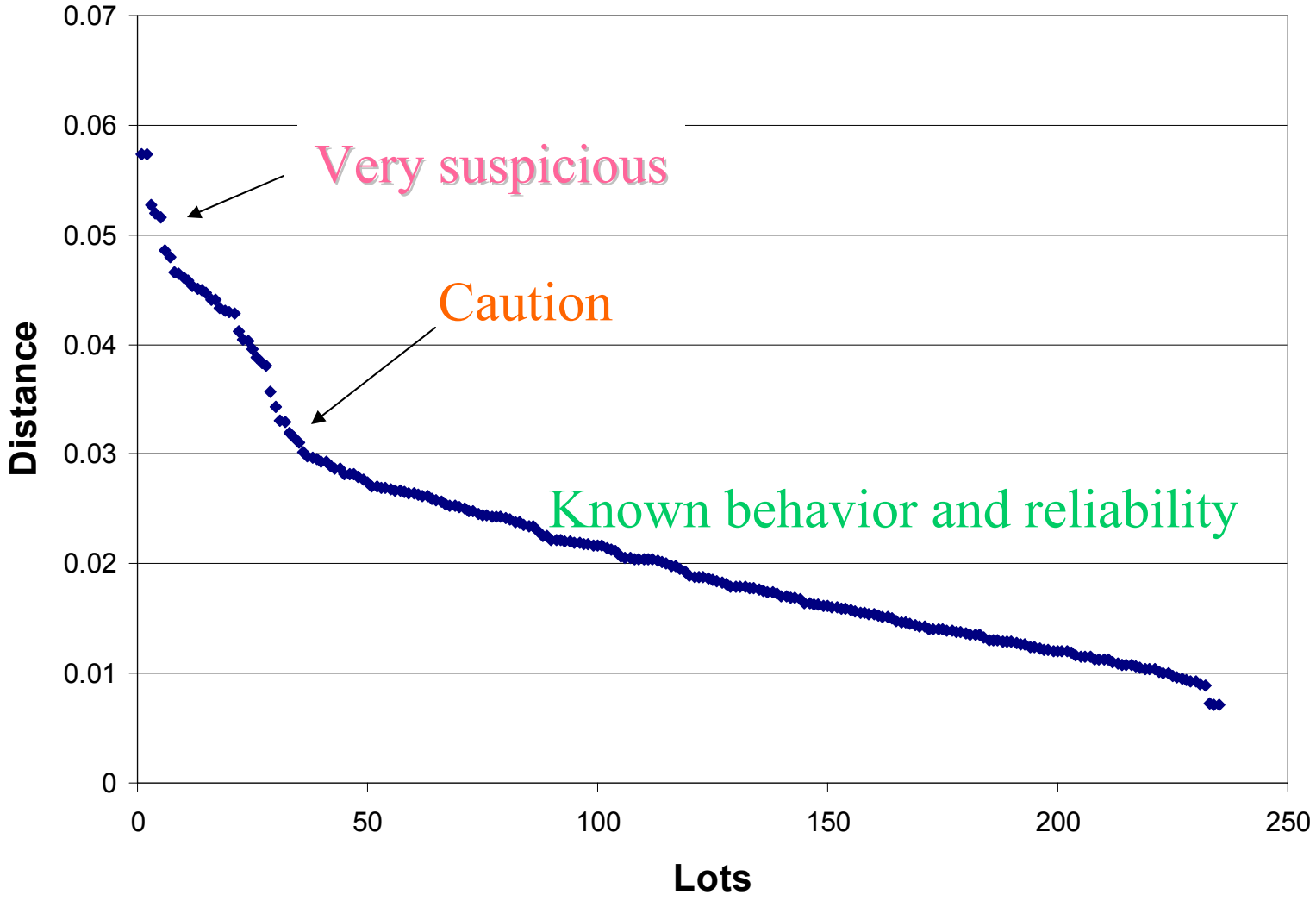
A major cluster of product with overlapping minor cluster and a third cluster that is different.

All parts may be in spec.

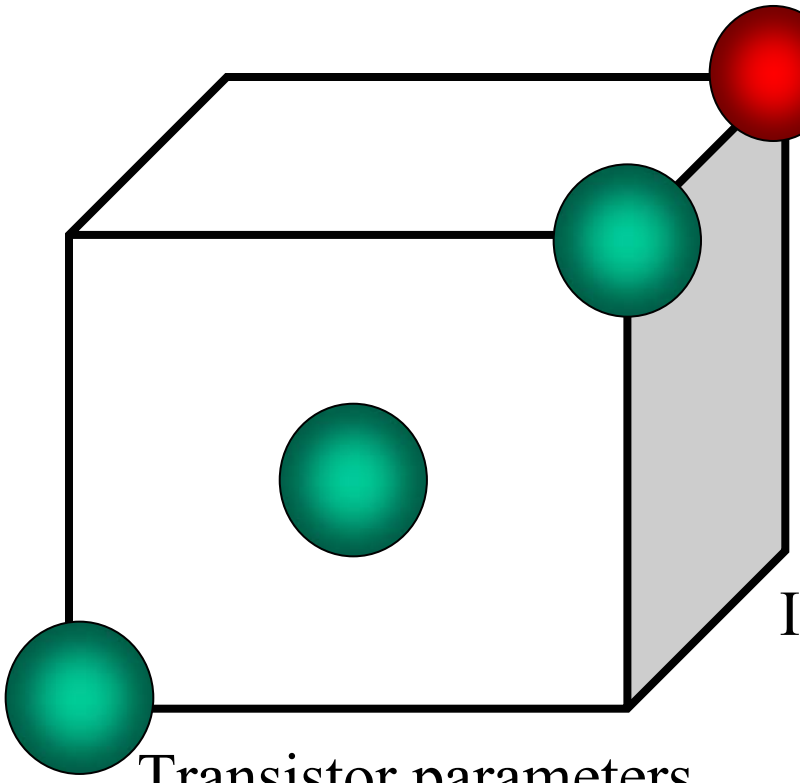


A profiler is a software module that uses many parameters to come up with a model of a situation or activity. It finds clusters of related parameters within a population. It is used in other industries for fraud detection, complex process monitoring, and finding similar groupings in a large population.

Process profiling results by fab lot



Corners processing for data



Clusters of data around corners

Interconnect parameters

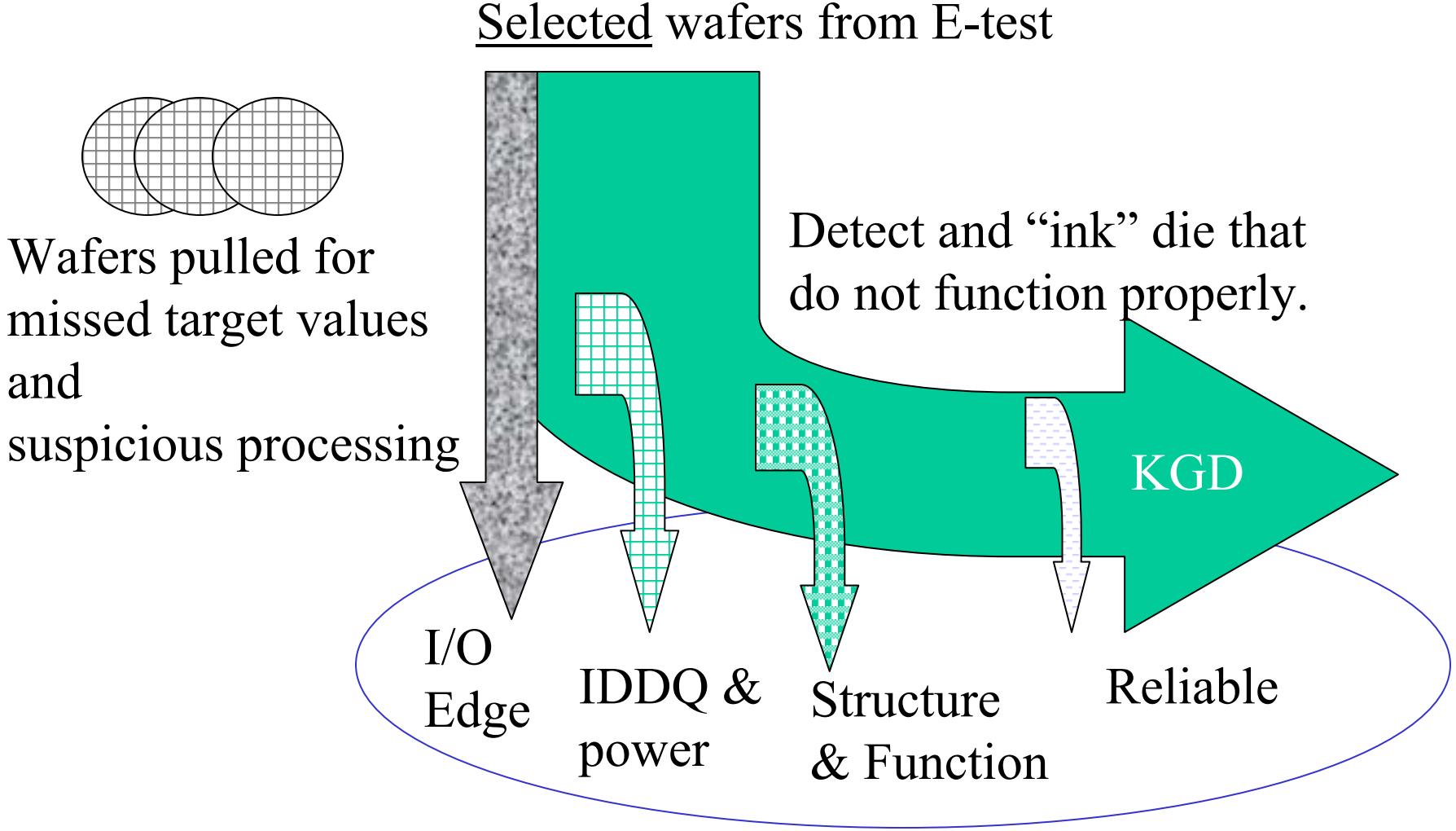
Transistor parameters

Corner and nominal processing are used in product qualification. Test data from qualification can be used to generate prediction and profiling models

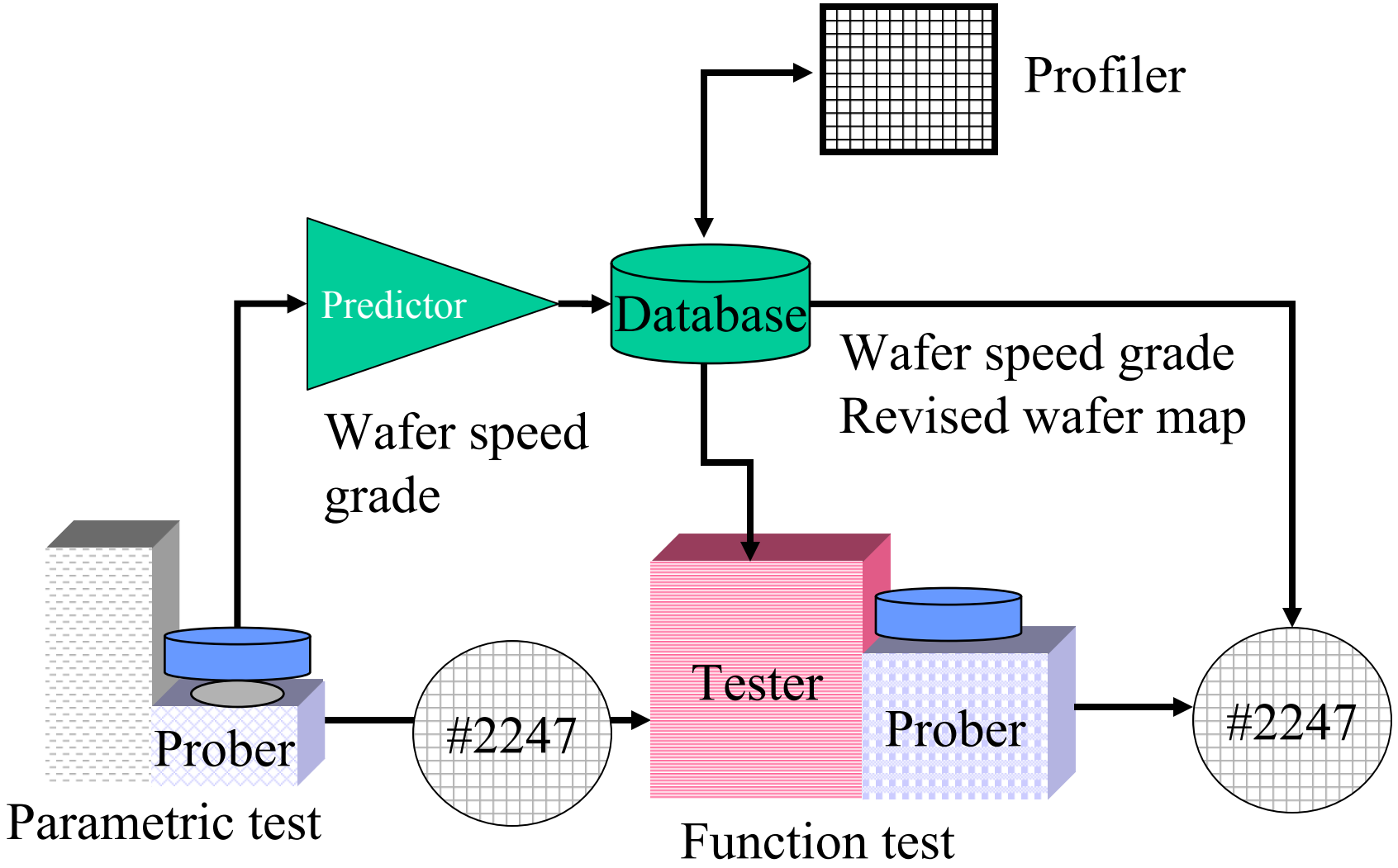
Test flow comparison

- Conventional test
  - I/O
  - IDDQ to fixed limit
  - Drive & load
  - Structure & Function
  - Speed & Grade
  - Stress voltage on oxide
    - Retest function
- Data-based test
  - I/O
  - IDDQ mavericks
  - Structure & Function
  - Stress voltage on oxide
    - Retest function
  - Guilty by association
    - Suspicious wafers removed at parametric test
    - Suspicious die “inked” out based on test values

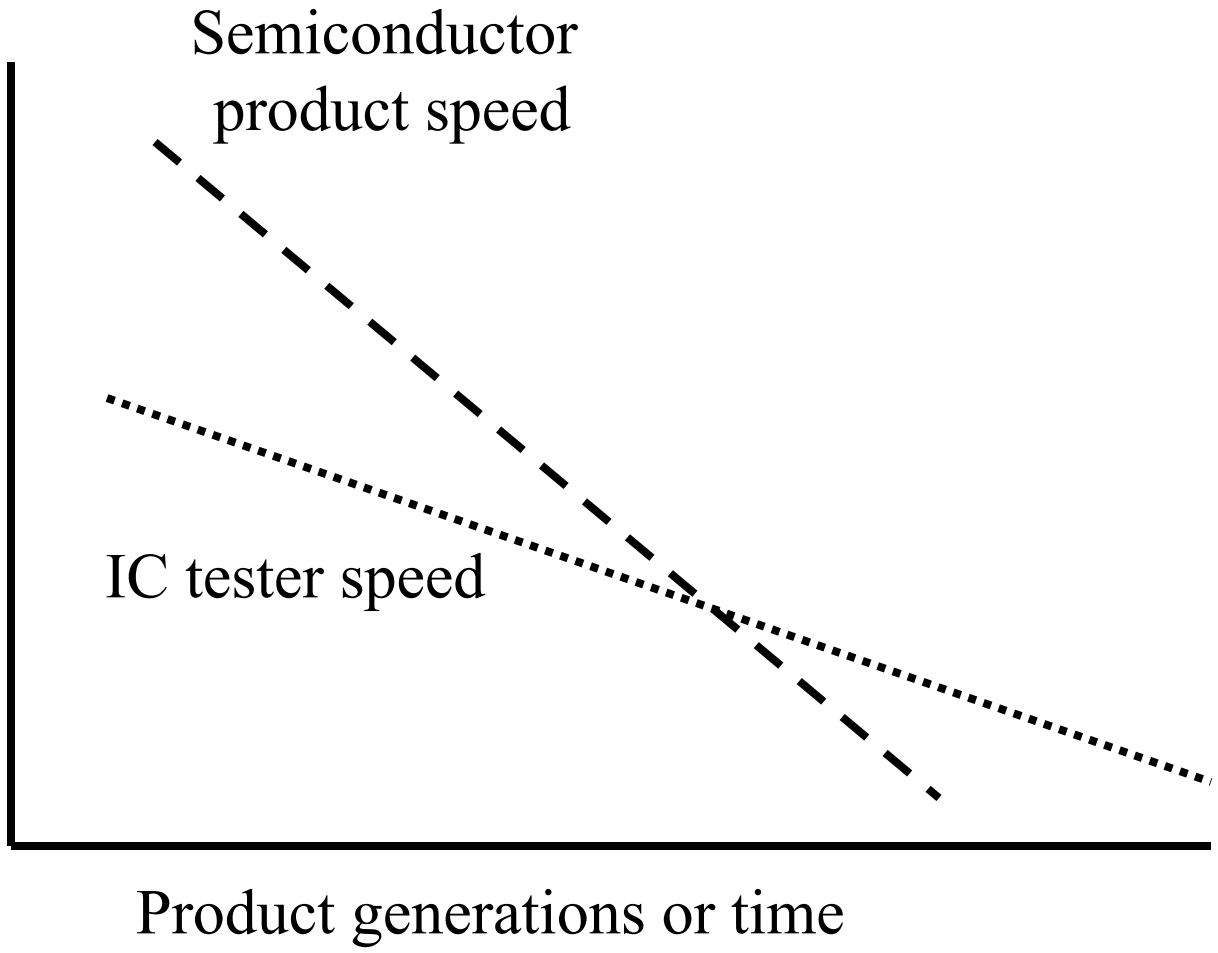
Data based wafer testing overview



Simplified prediction test flow



Forced into prediction testing



Prediction test cost reduction summary

- Conventional test cost is a linear result of tester cost and test time
- Prediction test can reduce test cost by reducing tester cost and test time
- Profiling can be used to remove suspicious wafers and die from production
- Prediction test may be a way around the mismatch in product and tester speed