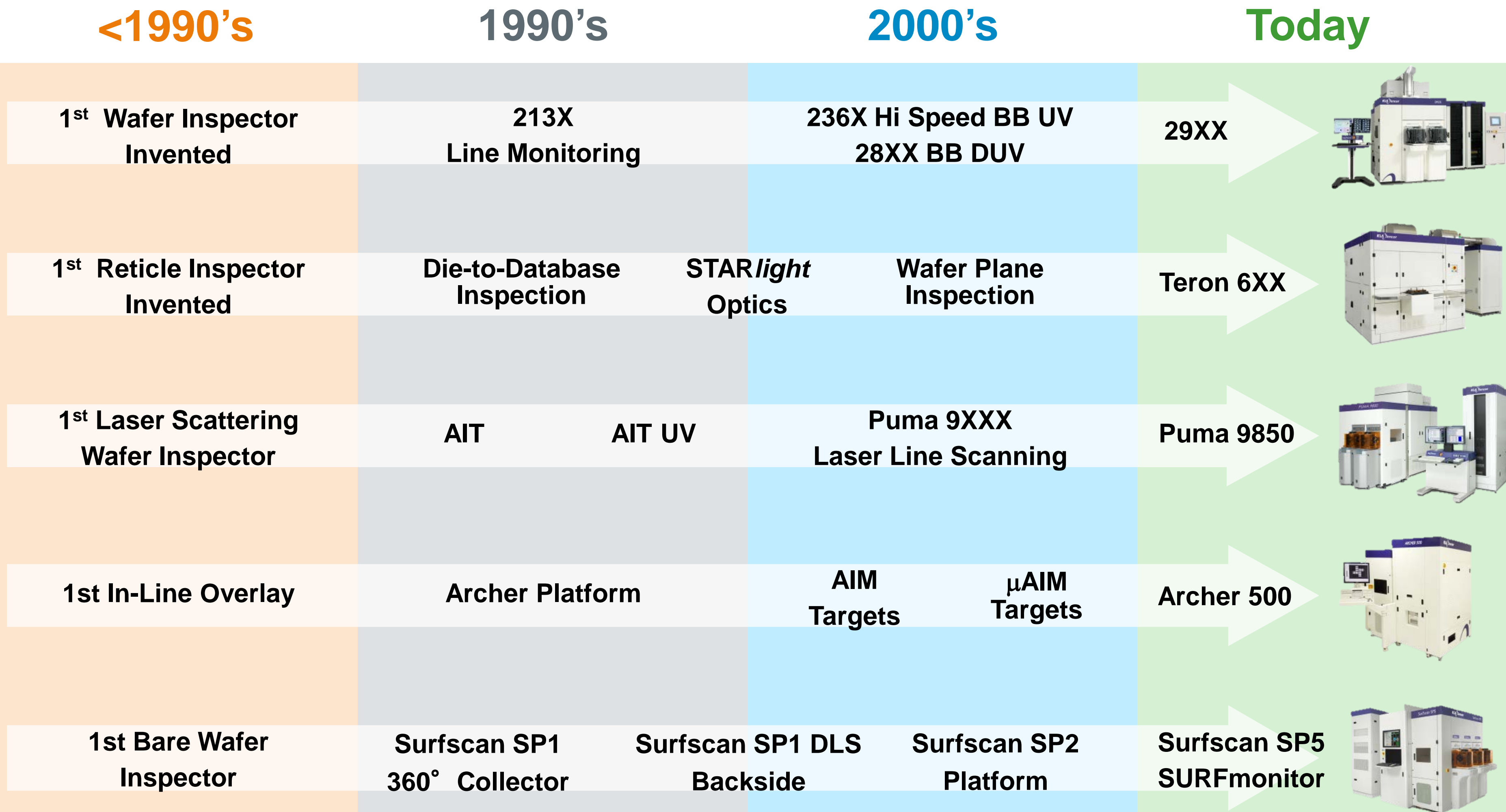
Agenda

- KLA-Tencor Introduction
- Value of Process Control
- Strategy for Future Process Control Challenges

KLA-Tencor

KLA-Tencor: Process Control Innovation Leadership

First to market. Winning performance. Continuous innovation.



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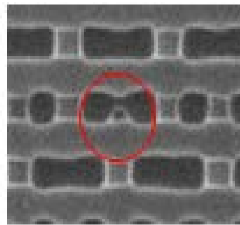
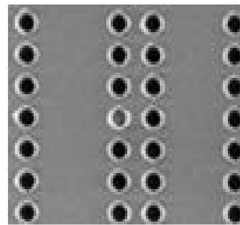
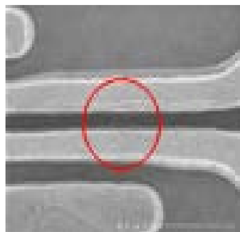
“We’re blind without you guys…”

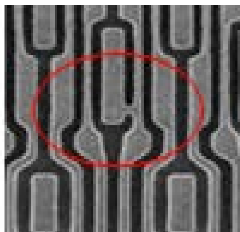
Defect / Yield

You can’t fix what you can’t find


Blocked Implant

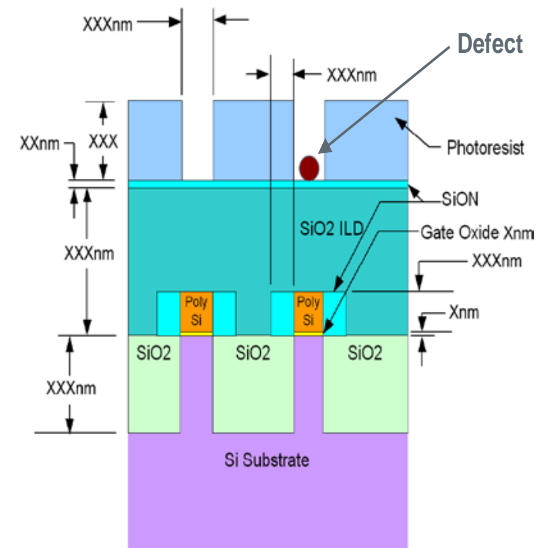

Blocked Contact


Trench Bridge


Cu Bridge

Metrology / Performance

You can’t control what you can’t measure



Find And Fix Today’s Critical Problems

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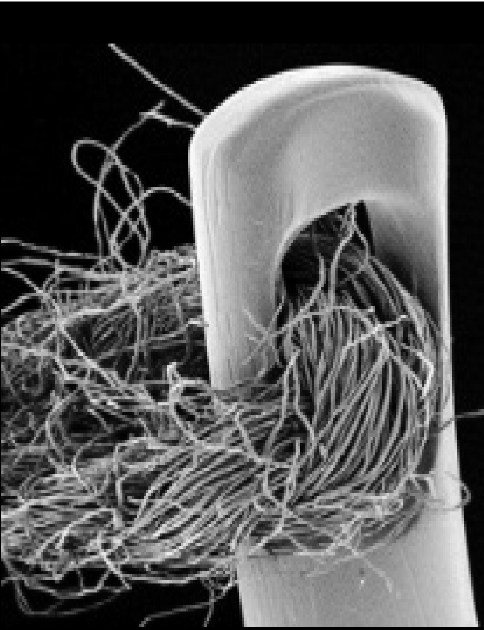
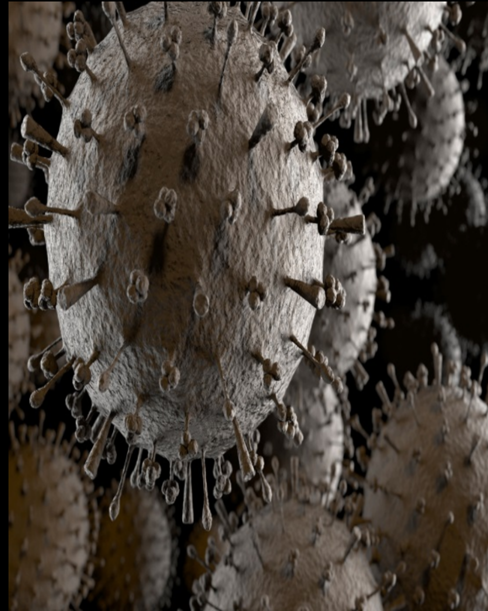
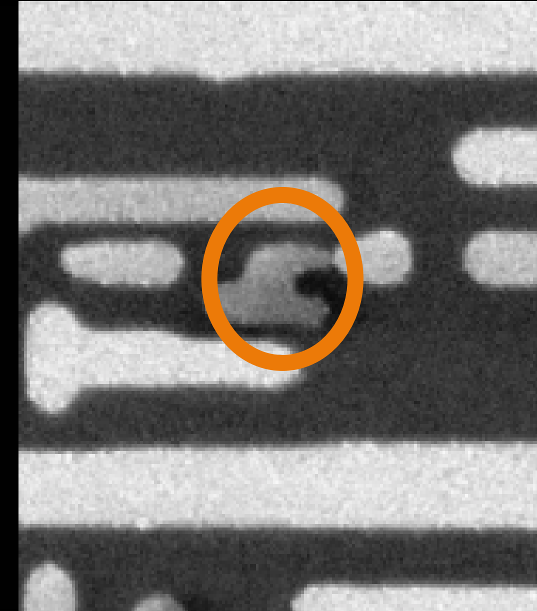
We Must Find, Classify & Measure Really Small Defects







Eye of Needle	Flu Virus	DNA Strand	Semiconductor Defect
2,000,000nm	100nm	6nm	10nm Size

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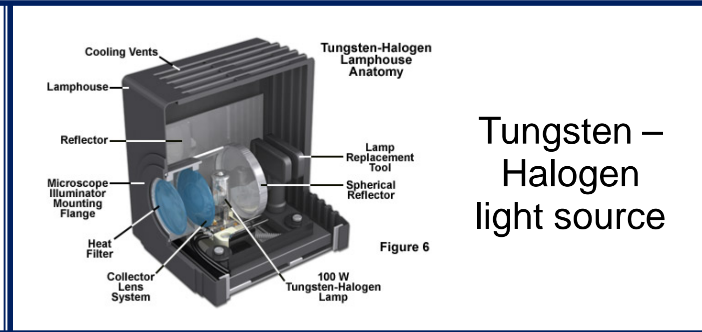
Innovation in Optical Wafer Inspection
To Get to 10nm Solution in <30 years

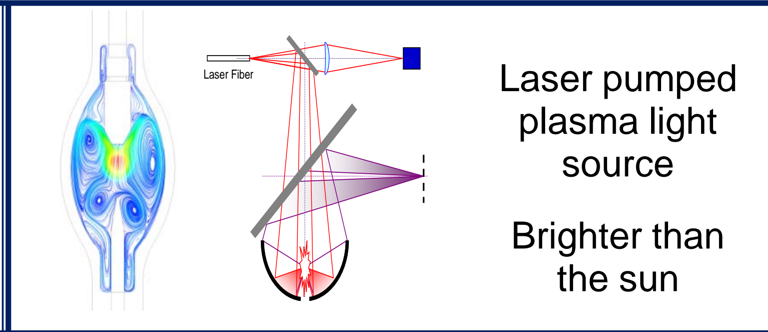
Illumination

1985



Tungsten – Halogen light source

2015



Laser pumped plasma light source

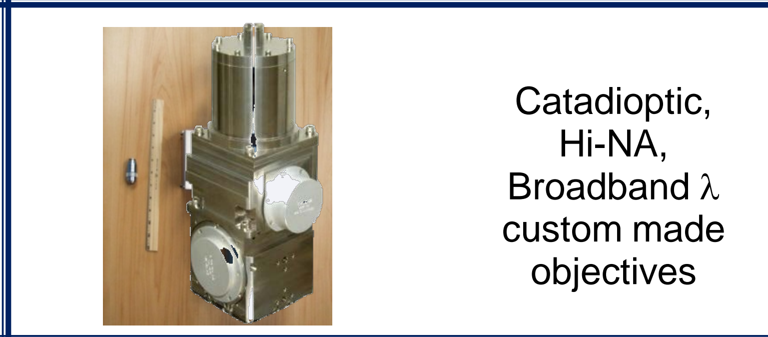
Brighter than the sun

Optics

1985

Off-the-shelf microscope objectives

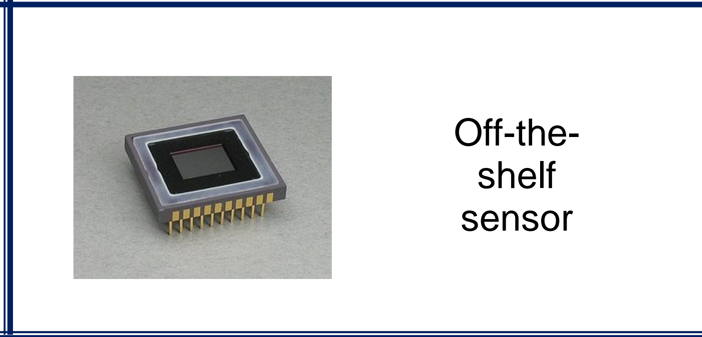
2015



Catadioptic, Hi-NA, Broadband λ custom made objectives

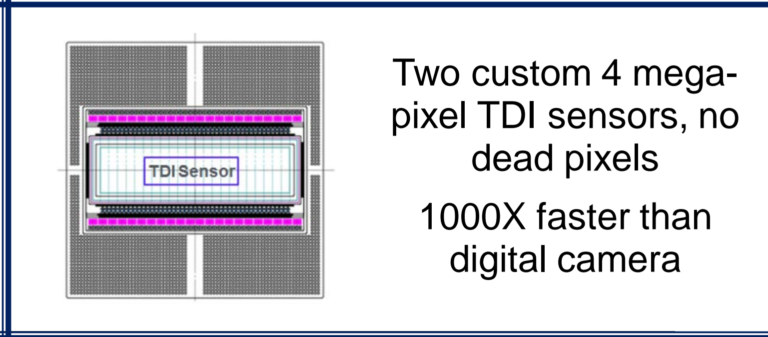
Sensor / Imaging Speed

1985



Off-the-shelf sensor

2015



Two custom 4 mega-pixel TDI sensors, no dead pixels

1000X faster than digital camera

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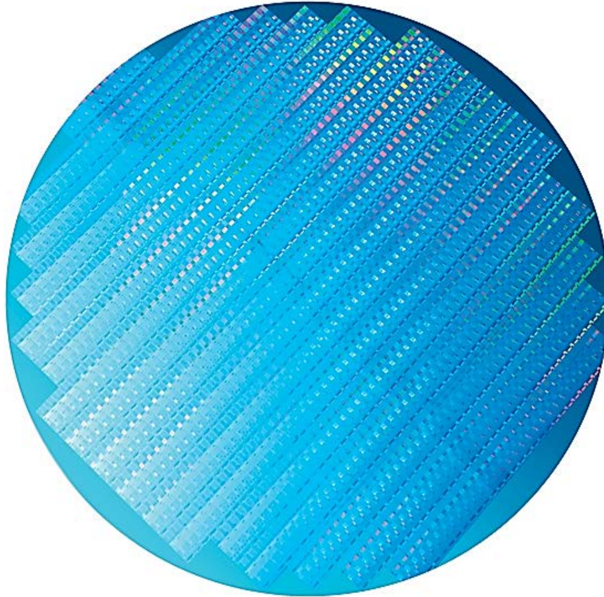
A world on a wafer…

This is a disk…..



70,000,000,000,000,000 nm^2

70 E15 square nanometers

And this is a sphere…..

5,000,000,000,000,000 ft^2

5 E15 square feet

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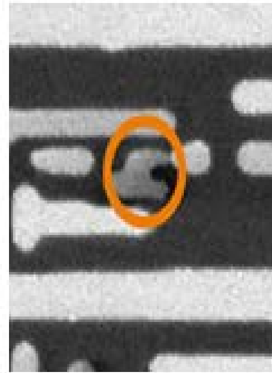
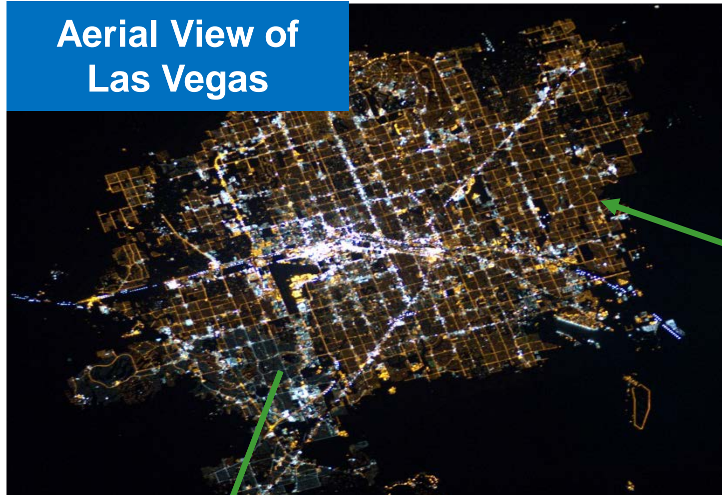
A world on a wafer…

If this is a 300mm wafer…..

This mouse is about ~10 nm2



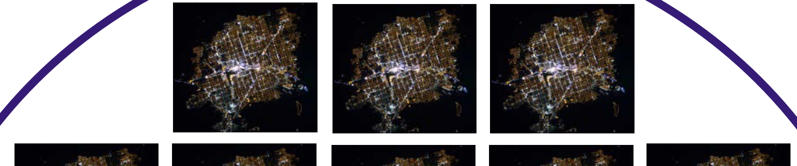
What Must Our Systems Do?



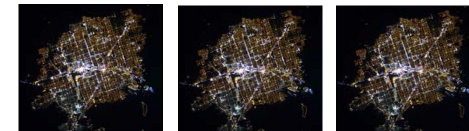
One Chip

Our Tools Will Find Defects the Size of a Small Coins on the streets of Las Vegas from many miles in space…in Seconds

Wafer



- Scale of data : up to 20TB of data / wafer
- Massive "Intelligent" Data Compression necessary
- Statistical Machine Learning Essential



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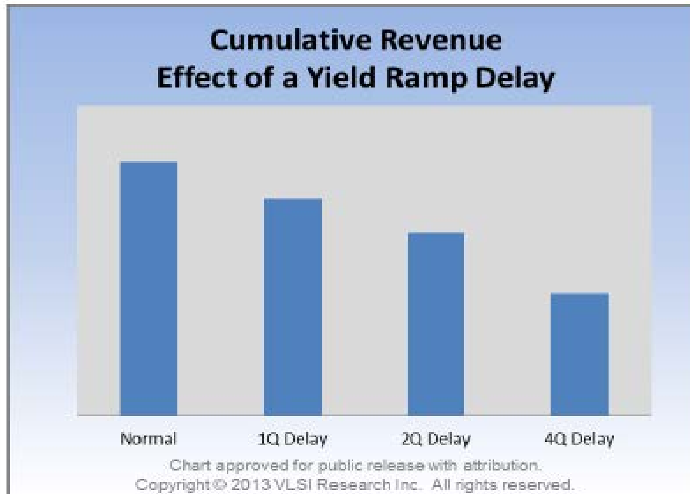
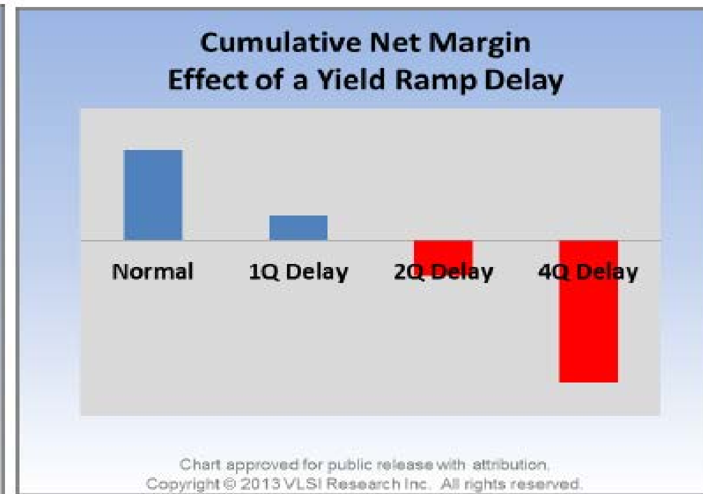
The Value of Process Control
is Delivered in Many Forms

Delay in Yield Ramp Denies Profits
Preventing investment in R&D and future nodes





Credit: VLSIresearch

VLSIresearch ... intelligence to make better decisions faster

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26 March 2013

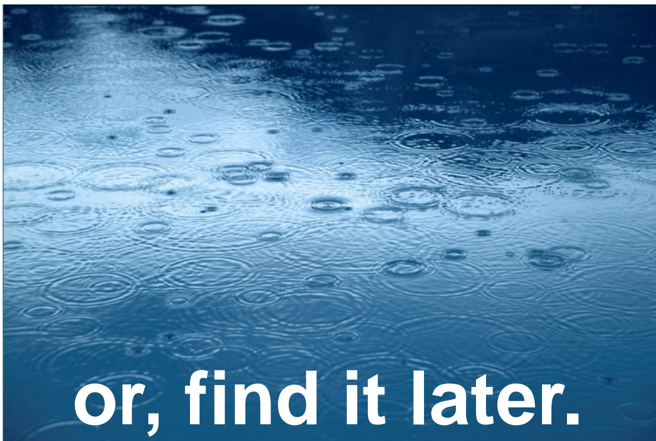
KLA-Tencor

The Ten Fundamental Truths of Process Control

For Any Industry

1. **You can't fix what you can't find. You can't control what you can't measure.**
2. **It is always more cost-effective to over-inspect than to under-inspect.**
3. **The most expensive defect is the one that wasn't detected inline.**
4. **Fab managers don't like surprises: always quantify your lots at risk when making changes to your process control strategy.**
5. **Variability is the enemy of a well-controlled process.**
6. **Time is the enemy of fab profitability.**
7. **Improving yield also improves device reliability.**
8. **Process control requirements increase with each design rule.**
9. **High-stakes problems require a layered process control strategy.**
10. **Adding process control *reduces* production costs and cycle time.**

The Most Expensive Defect is The One That Wasn't Detected In-Line…



Cost vs MTTD

For 3 Different Wafer Costs

Cost ($M / Yr)

100
90
80
70
60
50
40
30
20
10
0

$10,000
$5,000
$2,000
$1,000

0 10 20 30 40 50 60

Mean Time to Detection (Days)

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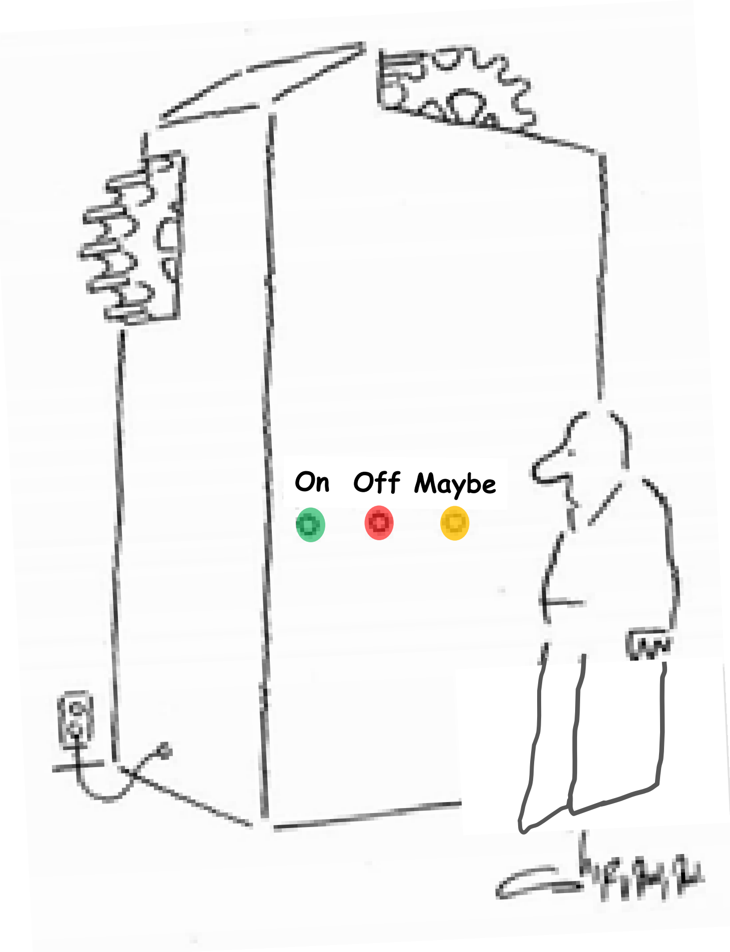
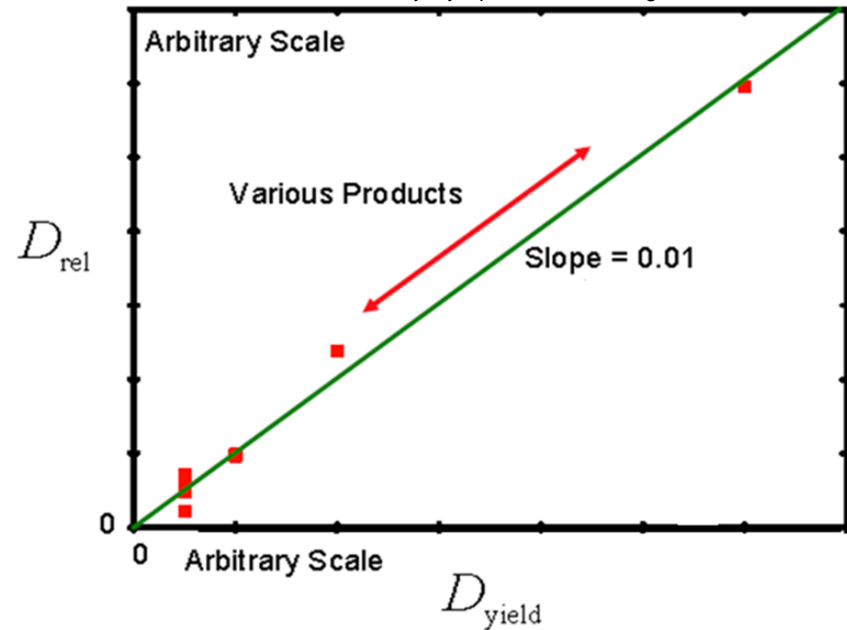
Improving Yield Will Also Improve Device Reliability…



Shirley, C. Glenn (**Intel**). "A Defect Model of Reliability" 33rd Annual International Reliability Symposium, Las Vegas, NV 1995.



Strong Correlation Between Yield and Reliability

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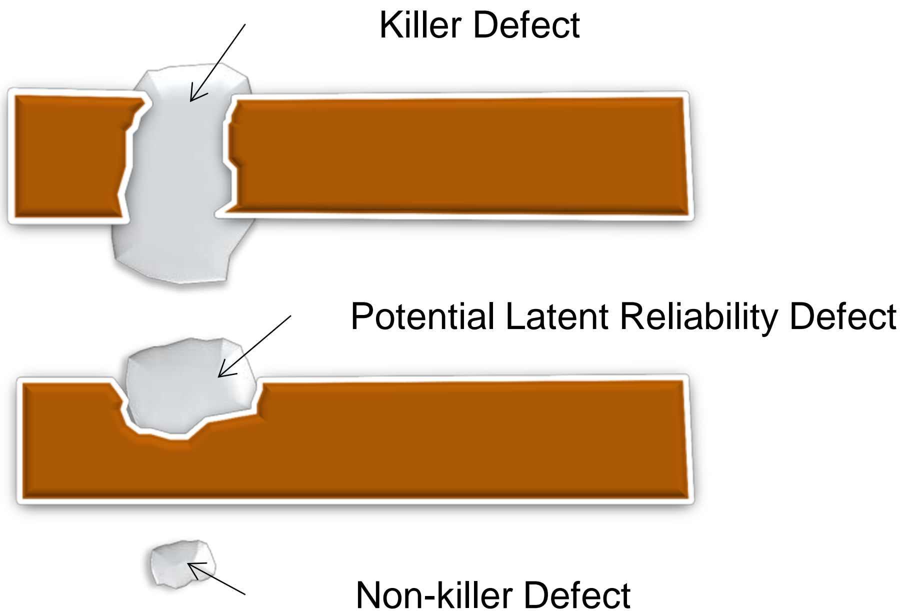
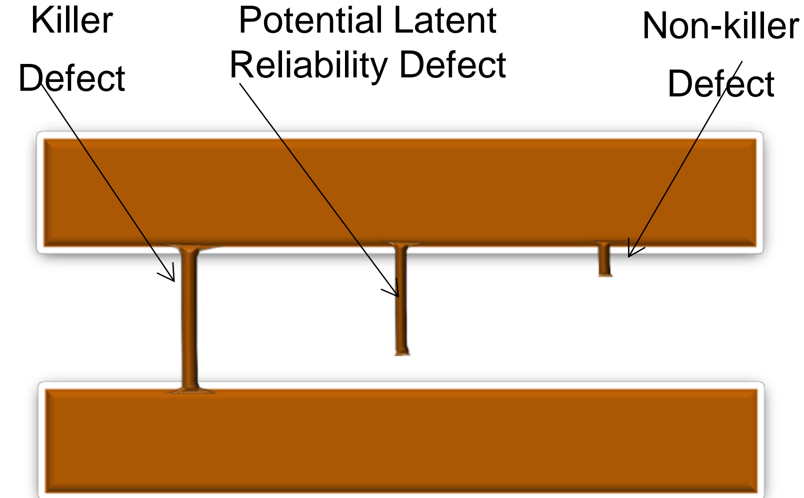
Reliability is Critical

The same defect types that impact yield also impact reliability.*





By Definition:
- Killer Defects: device fails at t = 0 (probe)
- Latent Defects: device fails at t > 0 (burn-in → ~6 months)

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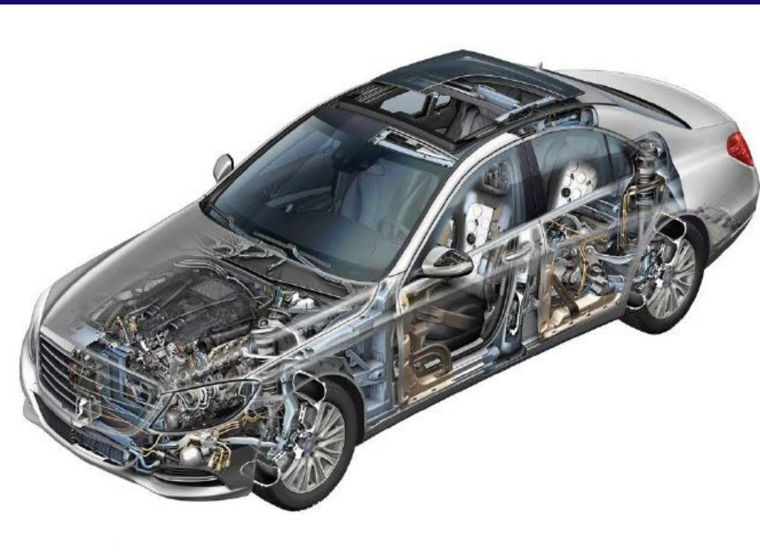
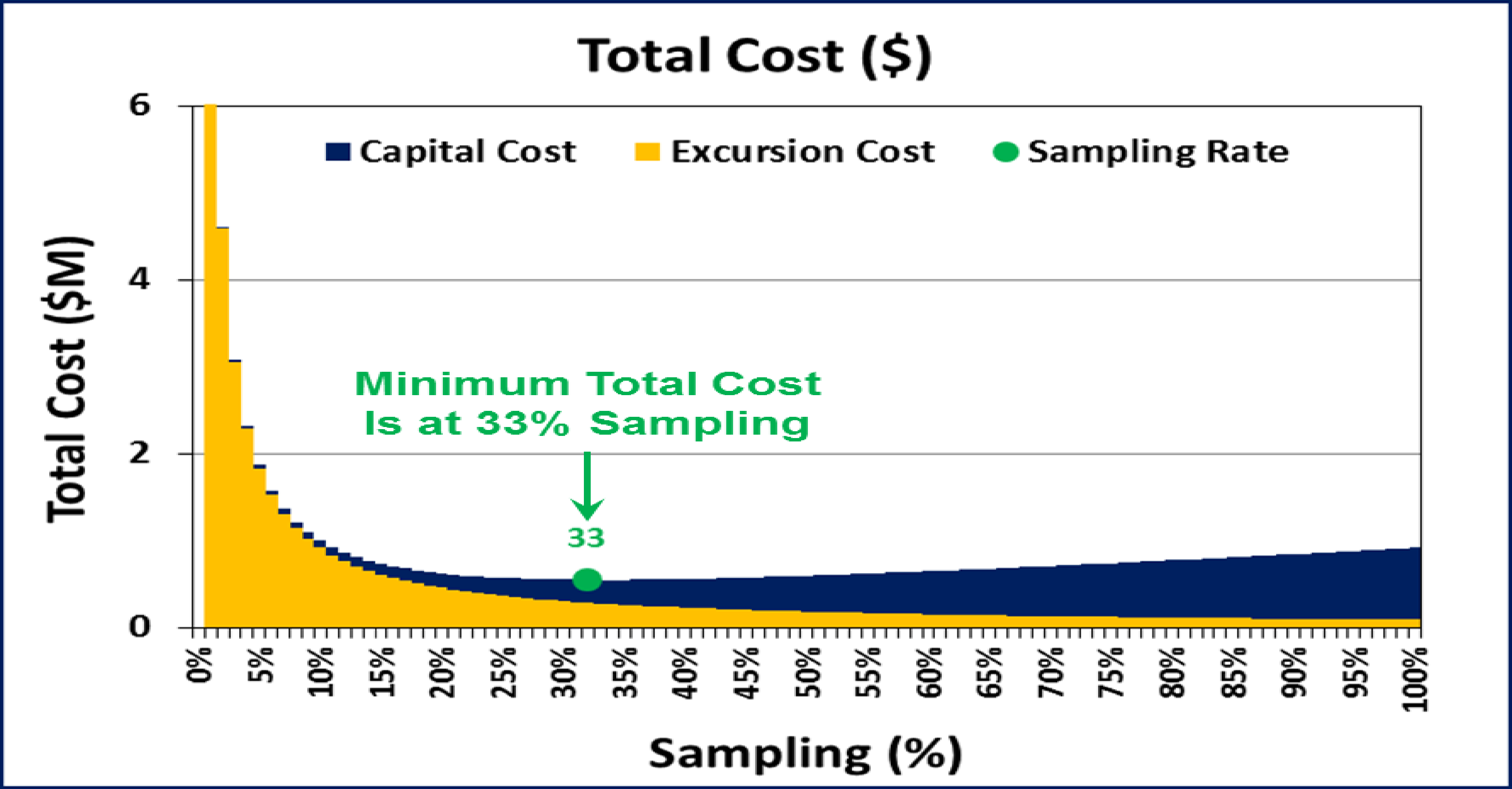
Reliability is Critical

Devices Cannot Fail –There is No Room for Maybe



It is More Cost-Effective to Over-Inspect Than Under-Inspect…



If it's worth achieving, it's better to over-achieve than under-achieve

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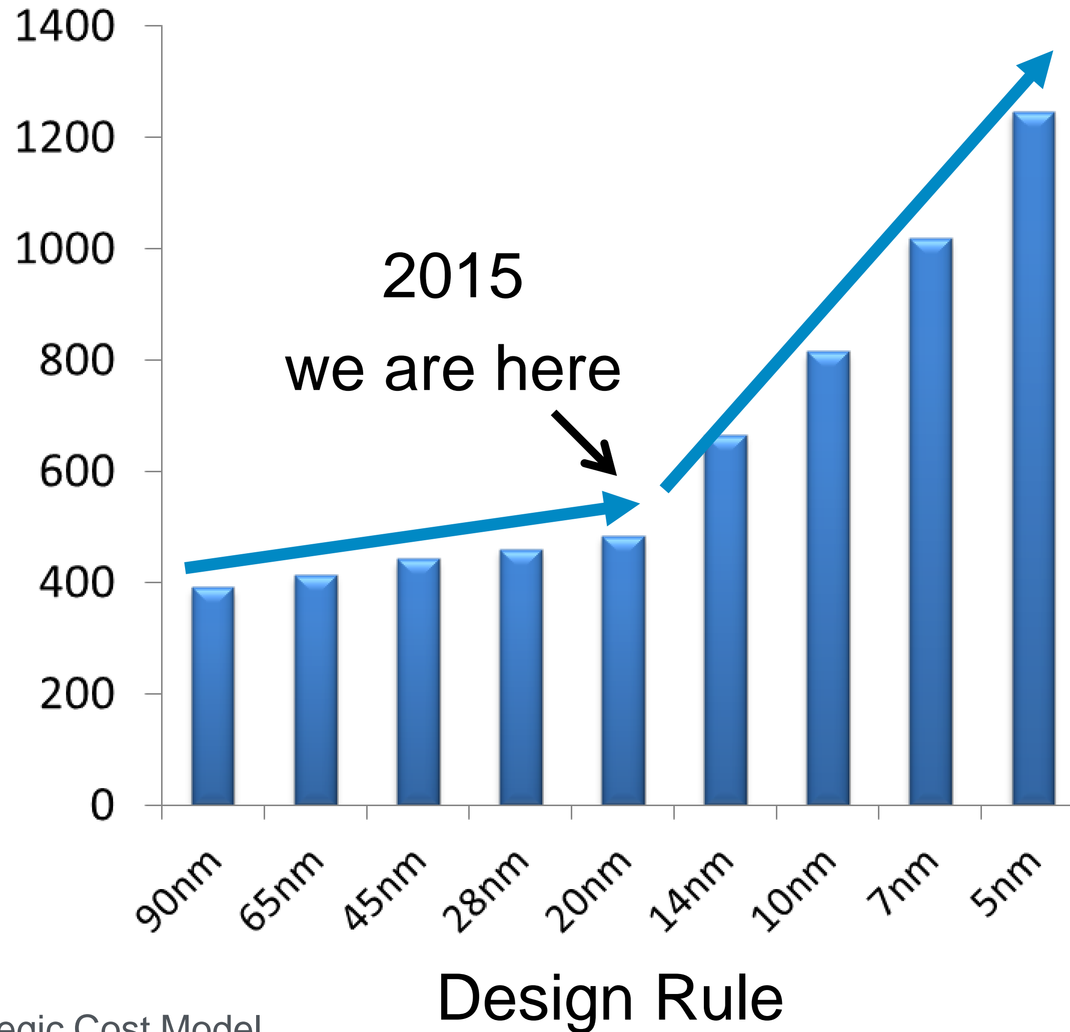
The Number of Process Steps is Exploding

Number of Process Steps
(logic/foundry)



Source: IC Knowledge Strategic Cost Model

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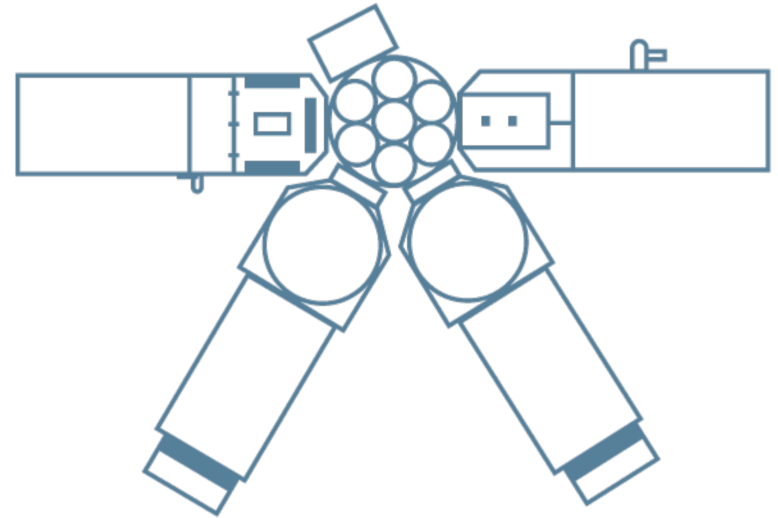
All Process Steps

As the number of process steps increase, <u>ALL STEPS</u> must be held to a tighter standard for:

1. **Excursions (wafer yield)**
2. **Defect density (die yield)**
3. **Variability (C_{pk})**



Cleaner Unit Processes are Required

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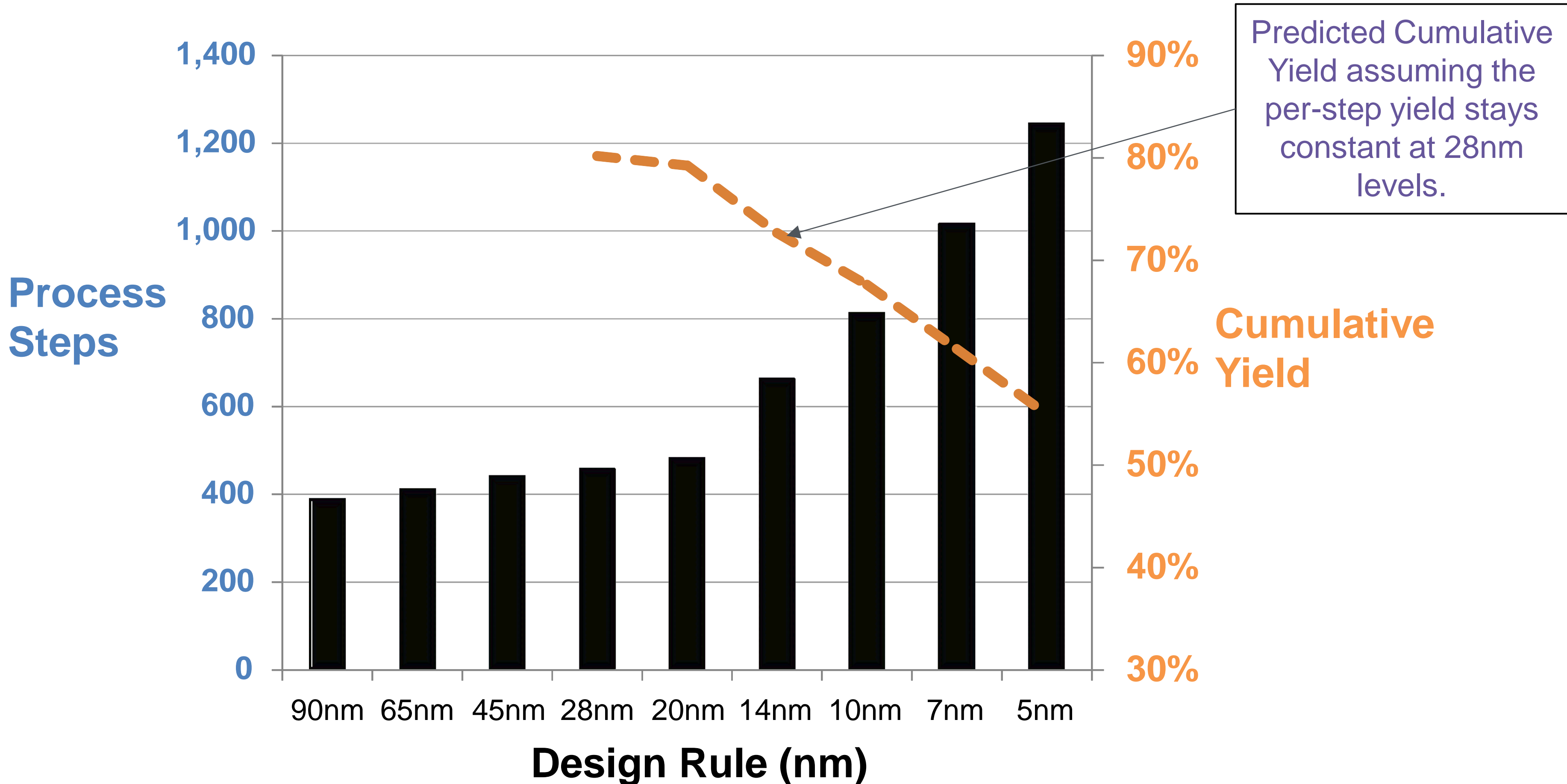
Number of Process Steps



Cumulative Yields will drop unless there is an improvement in step yield

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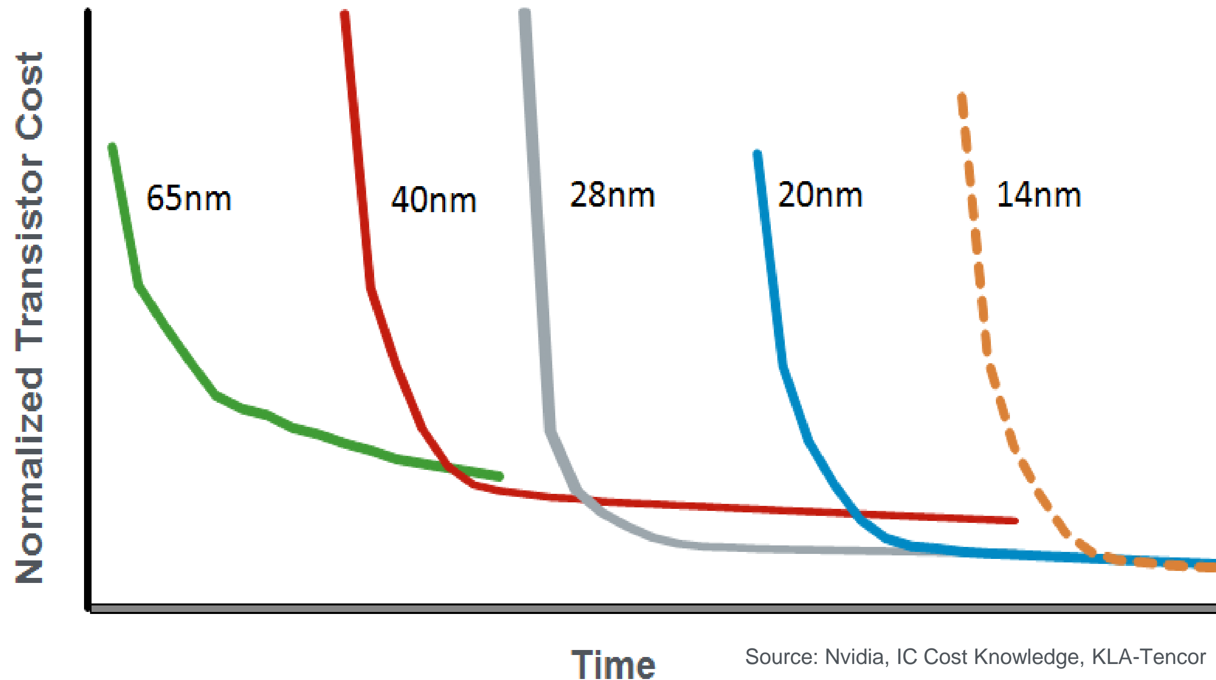
Challenges to Moore's Law

- Many new materials and technology challenges
- Lithography / Patterning
- Rising fab, design, development and litho costs
- Transistor costs if yields aren't achieved

Transistor Cost Improvements Slowing



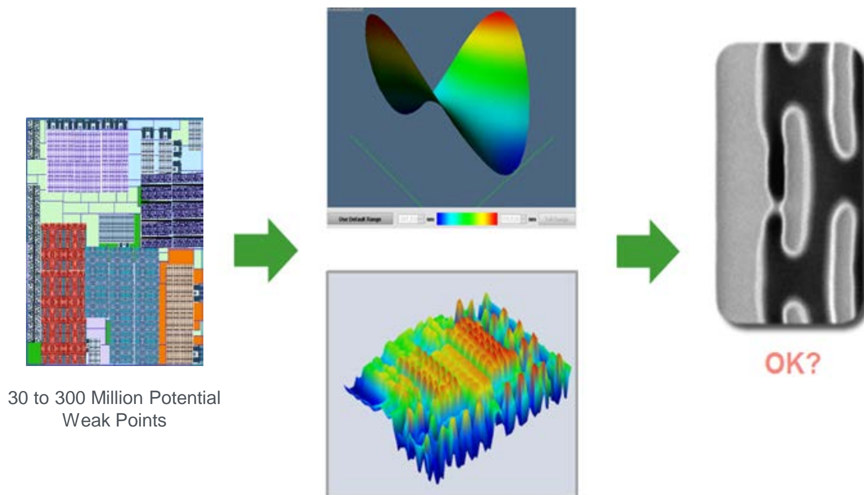
Transistor Costs

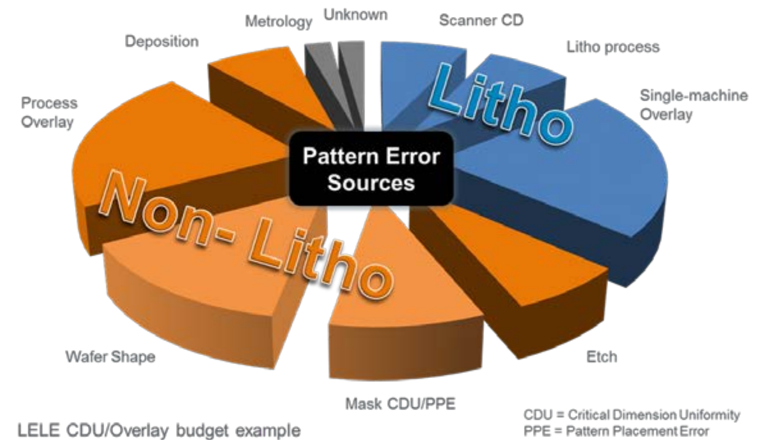
1. **Scaling Factor**
2. **Manufacturing Costs**
3. **Yields**

Accelerating Yield is the Best Solution to Achieving Cost Goals of Moore's Law

Problems for IC Manufacturers Continue to Grow

How Robust is My Design and Process Window?





Technology Node	28	20	14	10
Overlay budget	9nm	6nm	4.5nm	3.5nm
CD specs	4.5nm	3nm	2nm	1.3nm

- **Is My Design Robust?**
- **Where are the Weak Points?**
- **What is the Impact of Process Variance?**

- **What is My Process Window?**
- **What are the Sources of Error?**
- **What is the Impact of Process Variance?**

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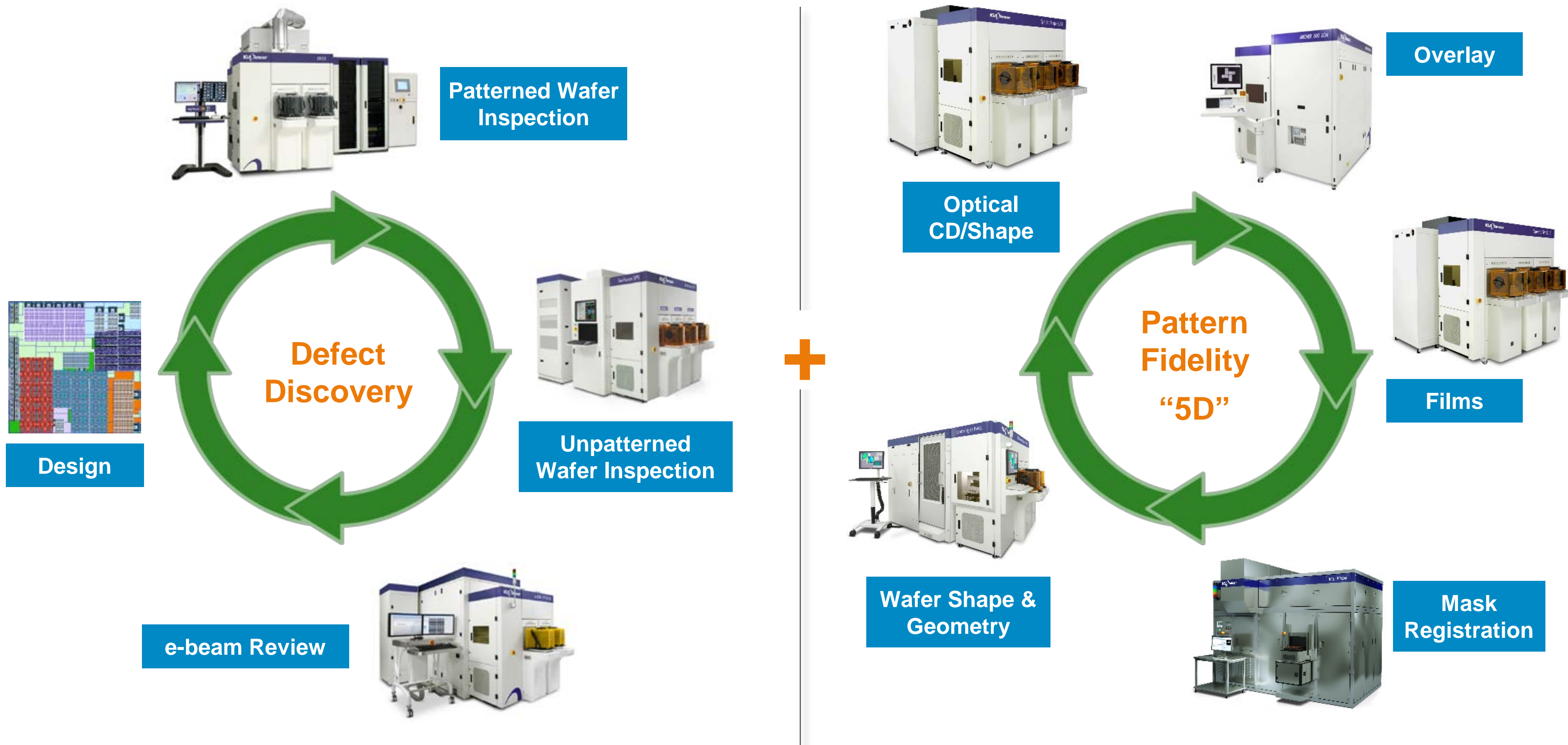
Strategy & Structure: Growing Investment in System of Systems



Process Window Discovery, Expansion and Control

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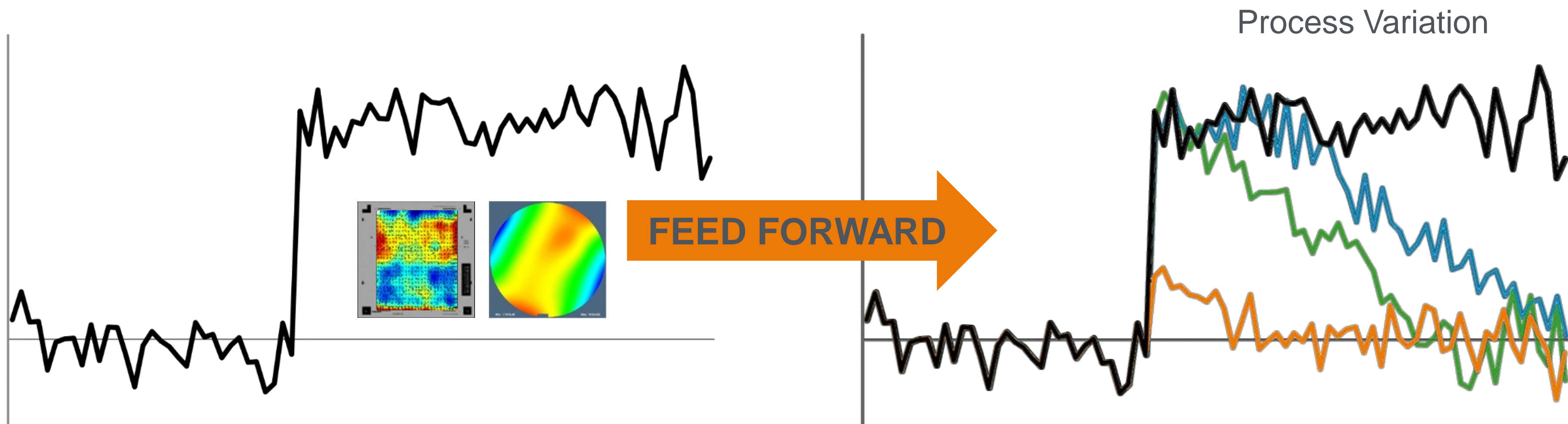
Intelligent Feed Forward and Feedback Required for Pattern Control



Existing feedback loops

Optimized feedback loops

Feed forward loops

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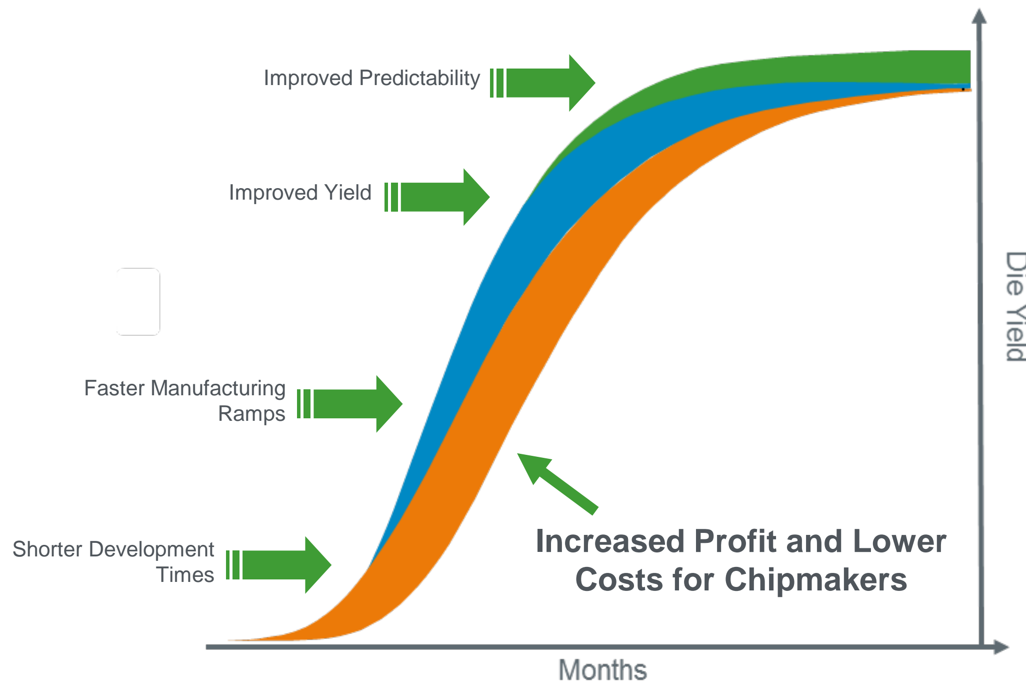
Process Control Critical to IC Industry Success

Investment in Process Control Provides Strong ROI



Source: KLA-Tencor

- Process Control Helps
  - Ramp Yields Faster
  - Lower Costs
  - Improve Cycle Times
  - Lower Risks
  - Provide More Predictable Delivery
  - Increase Profits

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