Quality Fabrication

Can Quality processes in Semiconductor Fabs apply to Software R&D?

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Agenda

- Semiconductor Product Fab Manufacturing
- Fab Manufacturing Quality Management Processes
  - Map to CMM5
- Why is Manufacturing different than SW Development ?
- Opportunities

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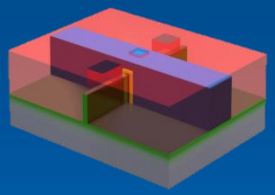
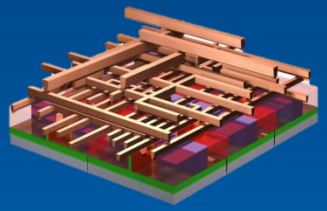
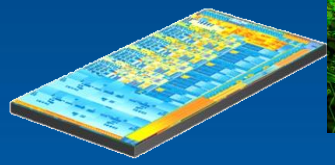
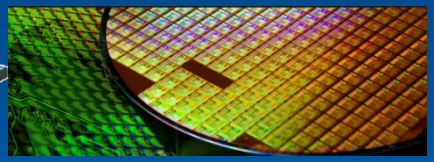
From a Pile of Sand to 500 products on a wafer with 1.5B transistors of 20nm dimension in 400 steps

Semiconductor Factory

- 20000sqm Clean room 200x100meters
- $5B Capital
- 500 Process Equipment Machines
- 50,000 Wafers per month
- 400 Manufacturing steps

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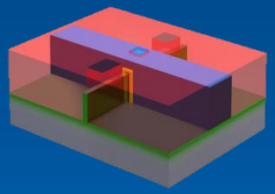
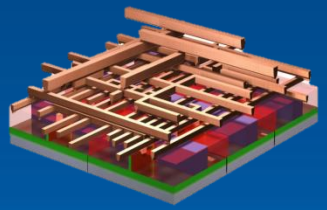
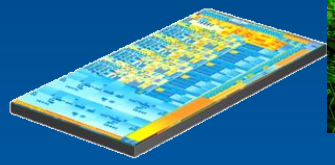
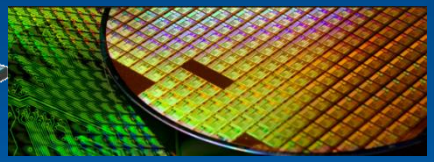
From a Pile of Sand to 500 products on a wafer with 1.5B transistors of 20nm dimension in 400 steps

Highly Sophisticated

Smallest Dimension

Very Large Scale Operation

Fast Change Rate

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Quality is #1 Priority in Semiconductor High Volume Manufacturing

Cost of excursion is $xM

100 impacted lots = 2500 wafers = 1M units > $20M Revenue

Poor quality impacts parts **Reliability**

Failing parts are measured at **PPM**

Standardized process is a must for HVM.

Quality must be controlled, standardized and managed!

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What can go wrong?

At 20nm -
Everything can go wrong!

Incoming Material PPB contamination

Clean Room contamination

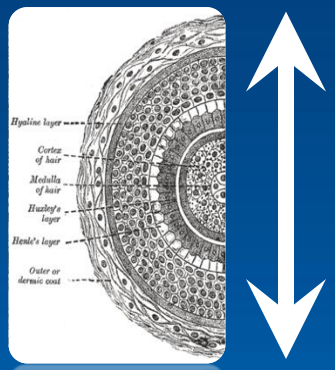
Equipment Issues

Human errors

And …

Process/Equipment random variations

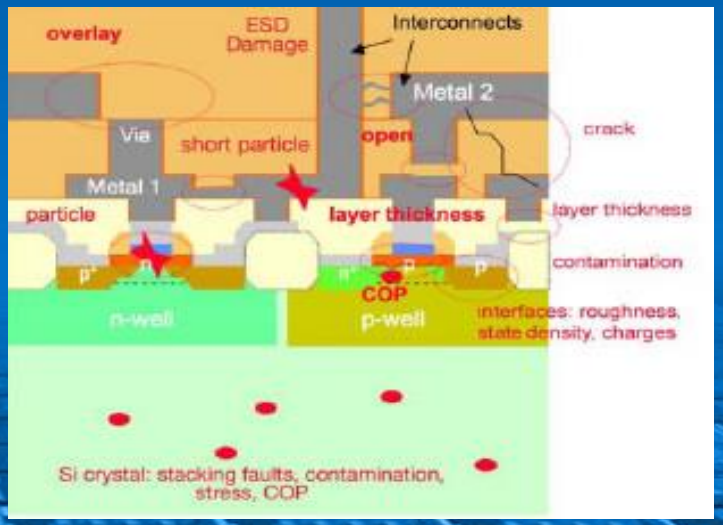
Human Hair diameter



= ~ 0.1 mm = 100 micron

= ~4500 Transistors !!!

A single transistor – Defects types



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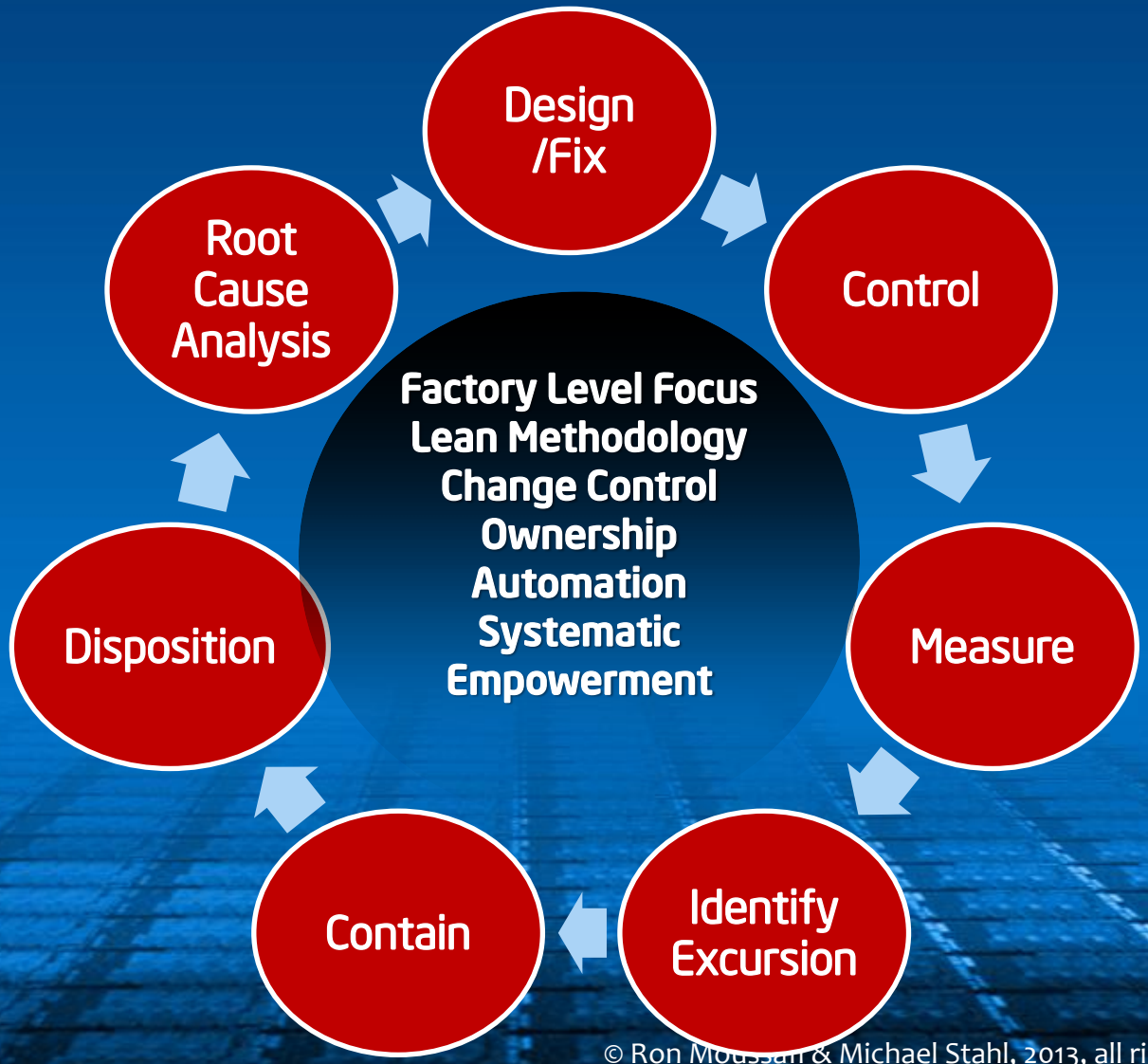
The Science and Art of Manufacturing Quality Management



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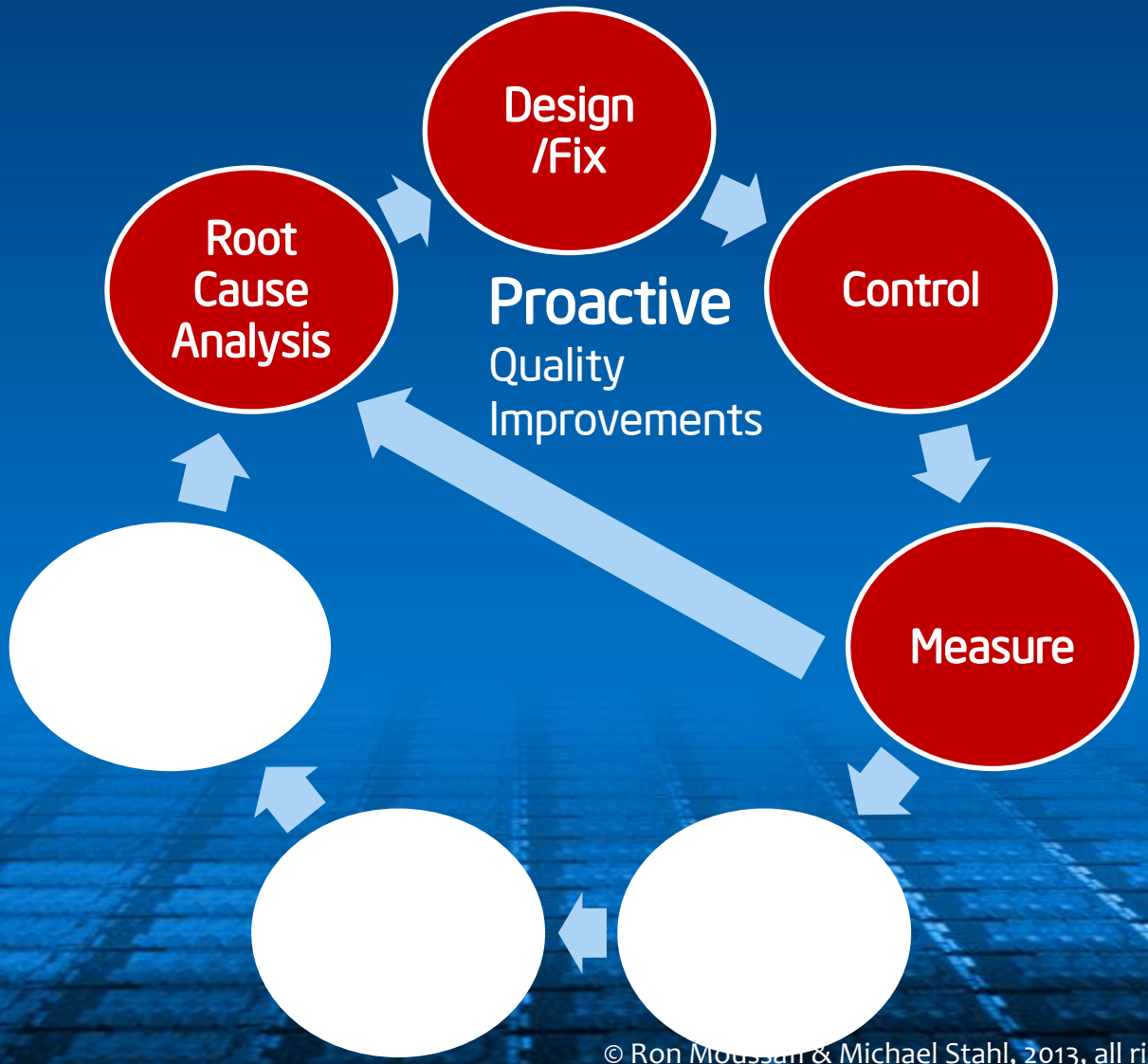
The Science and Art of Manufacturing Quality Management



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Manufacturing Quality Management – the challenge

Control

400 steps, 500 tools, 1500 people

Chemicals

Clean Room condition

Suppliers

Design/ Fix

Need systematic fix

No repeated events

Controlled and sustainable

Ensure no residual affect

Measu

Huge amo
paramet

Factory Level Focus
Lean Methodology

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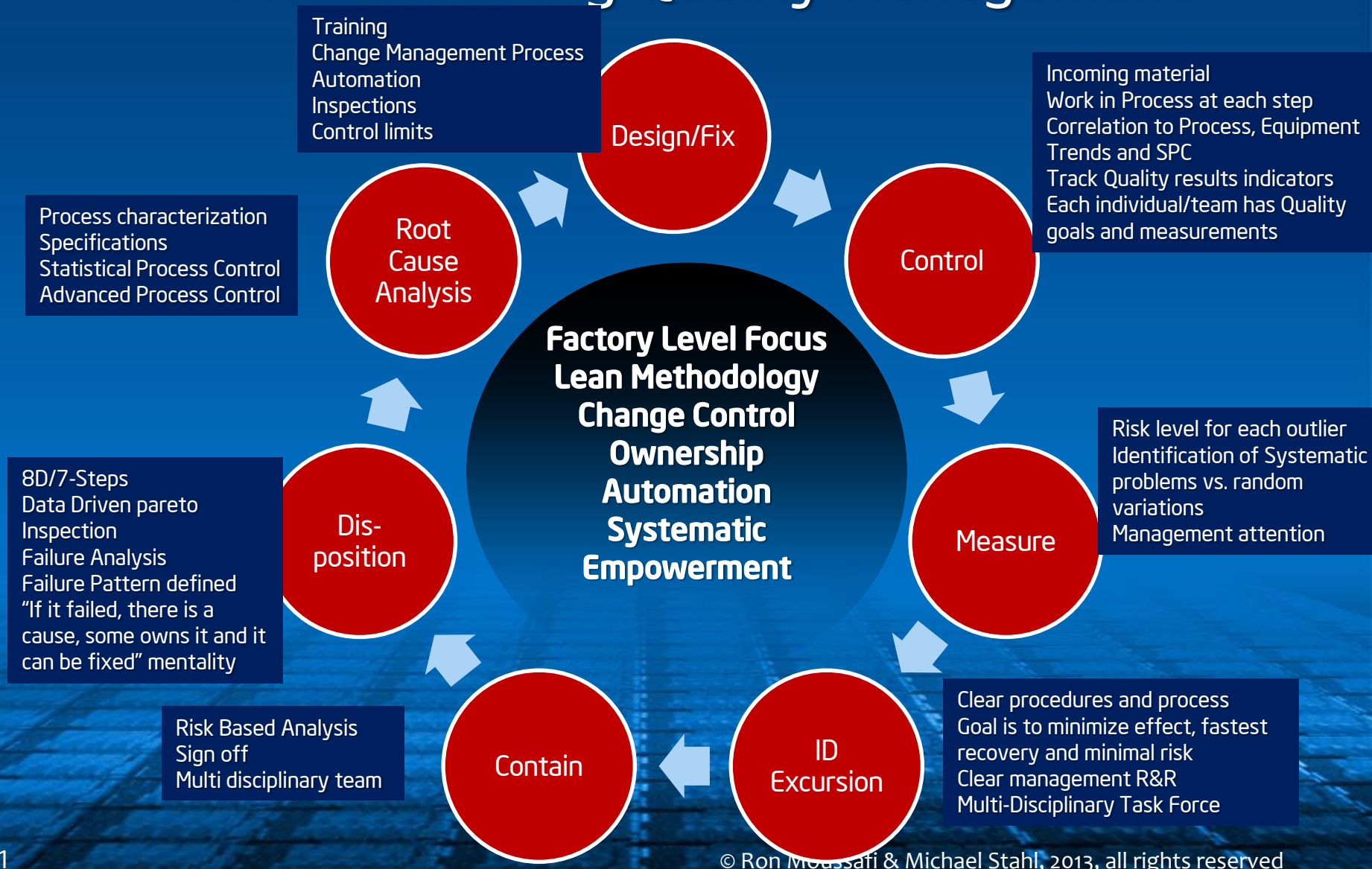
The Science and Art of Manufacturing Quality Management



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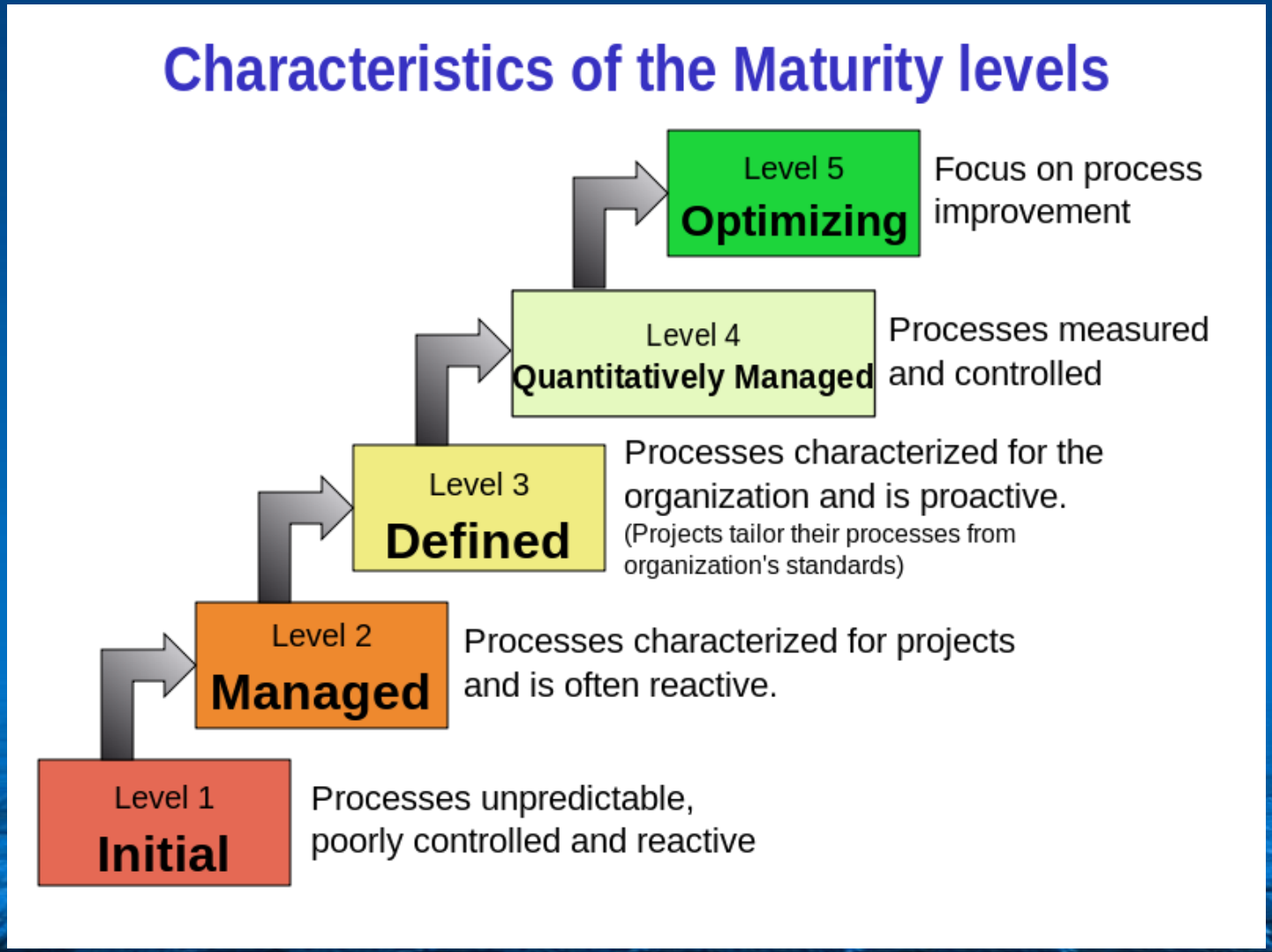
Now to SW Quality – Using CMM5



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Manufacturing Quality vs. CMM5

Manufacturing quality processes clearly meet CCM5 level 5.

Managed (L2)

Defined (L3)

Quantitatively Managed (L4)

Optimized (L5)

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Silicon processing VS Software quality processes

Si Processing	Software development
Process targets	PRD, Requirements - KPI
Process flow	Architecture specs
Machine recipe	Design documents
Change Control Board	Reviews, RCR
In-line tests & monitors	Unit tests, Static analysis
Recipe control	Configuration management
Factory automation	Build automation, Continuous Integration
Inline and EOL Test documents	Test and Test documents
Test sample plan	Test cycles, Risk Based Analysis
Root-cause analysis	Root-cause analysis

SW Development has Quality Processes equivalent to Manufacturing

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With all these quality processes available...

How come

almost no SW shop

is at CMM5?!!!

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Why do Software developers find it so hard to do

what Process Engineers think of as "way of life"?

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Cost of Error

Fab excursion:

- $ millions in the line
- $ millions of immediate lost revenue or recall costs
- Months to recover

Software:

- Hard to quantify cost of bad requirements, design
- Bug-fix timeline is short – small pain
- Hidden cost of bugs
- Death by 1000 paper-cuts

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Accountability; Ownership

Fab:

- Root-cause analysis culture: Every Problem has an Owner
- Quality is owned by … Everybody! (QA owns the process)
- Risk of personal consequences

Software:

- Design documents: "send and forget"
- Development: "expected" to create bugs
- Test: expected to catch them…
- Quality ownership is QA. Escapes are Test fault

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Culture

Fab: Quality and Compliance are Values

- "Zero tolerance" to non-compliance
- Enforcement support systems
- Everyone does it (לא רק הפריירים)

Software: Flexibility is a Value

- Process seen as "stifling innovation"
- Management tolerates non-compliance
- Strict process is NOT a must for having a product
- The "Yes-but" phenomena

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Holistic view of the Process

Fab: Everyone knows:

- Steps influence each other: A change here… will impact there…
- Quality policy defined and drives compliance

Software:

- Decoupling is a value
- Developers don't "see" the end product as a whole

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Engineering self image

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Recap

	Fab Process	Software
Cost of Error:	Very clear	Hidden; Distributed
Ownership:	Very clear	Unclear; Delegated
Compliance:	A Value	Not a value
Process view:	Holistic	Decoupled
Self Image:	Scientist	The Lone Ranger

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What should we adopt from the fab?

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Cost of Error

- Track, publish accumulated cost of bugs
- Associate cost to bug-injection point

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Accountability; Ownership

- EVERYBODY owns Quality, not just QA.
- Track document's accuracy, update status
- Report and track documents' bugs
- Escapes analysis by Dev (not just Test)
- Root cause analysis of excursions

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Culture

- "Zero tolerance" to non-compliance
- Everyone does it (לא רק הפריירים)
- Enforcement support systems
- Reward high quality (Fire Fighting is good. No fire – Better)

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Holistic view of the Process

- Stress the value of a repeatable PROCESS (the product stays flexible)
- Continuous Improvement feedback loop. Examples:
  - Time to resolve bugs
  - % bugs from missing Requirements
  - Rework rate

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Closing Thought

There is NO School for High Volume Chip Manufacturing

- OJT is everything
- Easy to set standards, rules

There IS a School for Software Engineering

- New hires THINK they understand quality product design
- Less acceptance of Software Quality processes

Adding Software Quality to CS / CE syllabi will improve the situation!!!

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Summary

SW Quality – it's not a dream, but it requires Org level effort

- Mindset drives Methodology drives Practices
- Quality as a Value, Quality Culture, Quality Management
- Ownership. If I can fix it, I own it.
- Measurement drives improvement
- Continuous Improvement feedback loop a must
- Adding SW quality to academic curricula will help

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Linked slides

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Manufacturing Quality vs. CMM5 L2

CMM5 L2: Managed	Manufacturing Quality Management
• Process follows Policy	✓ Specs, Training, Quality Policy enforced
• Practices defined and Managed	✓ Managed reviews, meetings, procedures
• Product meet Standards (project level)	✓ Defined Spec, Controls.
• Process monitored, controlled & reviewed	✓ Measurements taken, Automated, monitored.
• Risk management is mandatory	✓ Well defined Risk Management procedures.
• SW practices: CM, QA, contractors management, project tracking and management, project planning, requirements management.	✓ Equivalent: Product data, Quality in-line and end of line, records for every step maintained, Specifications defined and measured.
• Existing practices are retained in time of stress	✓ Done.

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Manufacturing Quality vs. CMM5 L3

CMM5 L3: Defined	Manufacturing Quality Management
▪ Process Characterization	✓
▪ Standards, Procedures, Tools and Methods defined (@ org level)	✓
▪ Input, Entry Criteria, Activities, Verification, Exit Criteria, Output, Roles, Measures Defined	✓ All process steps, Roles, Criteria defined.
▪ Risk management methods are the same for all the org	✓ Factory level practices, across disciplines and teams.
▪ Peer review, intergroup coordination, SW product engineering, integrated SW management, training program,	✓ Checkout process for manual activities, Training with Read and understood process, cross functional team.
▪ Processes are managed proactively	✓
▪ Consistency across the org	✓

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Manufacturing Quality vs. CMM5 L4

CMM5 L4: Predictability	Manufacturing Quality Management
• Quantitative Quality Objectives	✓ At all levels of organization and across all process steps.
• Statistical Process Performance for PLC	✓ SPC embedded in characterization and control
• Process breakdown to sub-processes with quantified relations	✓
• Risk management data is analyzed and norms are set. Risk is managed according to the norms.	✓ Data collected, analyzed and act upon through QA processes and enforced through management reviews.
• SW QA management	✓ QA department and management processes.
• Process performance is predictable (based on measurements and statistics)	✓ High predictability with clear out-of-control measures and containment processes.

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Manufacturing Quality vs. CMM5 L5

CMM5 L5: Predictability	Manufacturing Quality Management
• Continuous Improvement Process	✓
• Cause analysis for Process variations	✓
• Innovative solution for Process Improvements	✓ Standard solutions, process improvement, new control systems and Automation implemented.
• Measureable improvement goals and results	✓
• Cross Projects Organizations goals and initiatives	✓ Factory level and cross factory level goals and improvements.
• Risk are dealt with strategically (e.g. plans for reduction of risk by dealing with the root cause)	✓ Proactive Quality improvement program are managed at factory level. 7-Steps/8D methodology.
• Process change management; technology change management; Defect prevention	✓ Clear risk based Change Control. Defect analysis and prevention process
• Inherent process variations are studies and understood	✓

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