The Fab Experience
How I stopped whining and started to appreciate Process

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Agenda

- A little bit about Chip Manufacturing
- Fab Quality Management Processes
- Chip Manufacturing VS SW Development
- Opportunities
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Chip Manufacturing

- $5B Capital
- 20000 sqm Clean room
- 500 Machines
- 400 Manufacturing steps
- 50,000 Wafers per month
What can go wrong?

At 22nm?

EVERYTHING!

Human Hair diameter

= ~ 0.1 mm = 100 micron
= ~4500 Transistors !!!

EVERYTHING!
Excursion = $1,000,000s
Quality is #1 Priority in High Volume Semiconductor Manufacturing

Quality must be controlled, standardized, managed!
The Science and Art of Manufacturing Quality Management

Factory Level Focus
Lean Methodology
Change Control
Ownership
Automation
Empowerment

Design / Fix
Control
Measure
Contain
Identify Excursion
Disposition
Root Cause Analysis
The Science and Art of Manufacturing Quality Management

Factory Level Focus
Lean Methodology
Change Control
Ownership
Automation
Empowerment

Root Cause Analysis

Design/Fix

Contain

Identify Excursion

Disposition

Control

Process characterization
Specifications
Statistical Process Control
Advanced Process Control

Training
Change Management Process
Automation
Inspections
Control limits

Incoming material
Work in Process at each step
Correlation to Process, Equipment
Trends and SPC
Track Quality results indicators
Each individual/team has Quality goals and measurements

Risk level for each outlier
Identification of Systematic problems vs. random variations
Management attention

Clear procedures and process
Goal is to minimize effect, fastest recovery and minimal risk
Clear management R&R
Multi-Disciplinary Task Force

8D/7-Steps
Data Driven pareto
Inspection
Failure Analysis
Failure Pattern defined
“If it failed, there is a cause, someone owns it and it can be fixed” mentality

Risk Based Analysis
Sign off
Multi disciplinary team

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This is fine for the Fab...
... but in R&D we must

Innovate!
Quality Processes

DO NOT block innovation!
AND NOW FOR SOMETHING COMPLETELY DIFFERENT…
Software Quality

Your PC ran into a problem and needs to restart. We're just collecting some error info, and then we'll restart for you. (60% complete)

If you'd like to know more, you can search online later for this error PAGE_FAULT_IN_NONPAGED_AREA (win32.qt)
CMM – Capability Maturity Matrix

Characteristics of the Maturity levels

- **Level 1 Initial**
  - Processes unpredictable, poorly controlled and reactive

- **Level 2 Managed**
  - Processes characterized for projects and is often reactive

- **Level 3 Defined**
  - Processes characterized for the organization and is proactive.
  - (Projects tailor their processes from organization’s standards)

- **Level 4 Quantitatively Managed**
  - Processes measured and controlled

- **Level 5 Optimizing**
  - Focus on process improvement

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Manufacturing quality processes CLEARLY MEET CMM level 5.
Manufacturing Quality vs. CMM5

Managed (L2)
Defined (L3)
Q. Managed (L4)
Optimized (L5)
Manufacturing Quality vs. CMM5: L2

CMM5 L2: Managed

- Process follows Policy
- Practices defined and Managed
- Product meet Standards (project level)
- Process monitored, controlled & reviewed
- Risk management is mandatory
- SW practices: CM, QA, contractors management, project tracking and management, project planning, requirements management.
- Existing practices are retained in time of stress

Manufacturing Quality Management

- Specs, Training, Quality Policy enforced
- Managed reviews, meetings, procedures
- Defined Spec, Controls.
- Measurements taken, Automated, monitored.
- Well defined Risk Management procedures.
- Equivalent: Product data, Quality in-line and end of line, records for every step maintained, Specifications defined and measured
Manufacturing quality processes CLEARLY MEET CMM level 5.

Trust me on this one.
Are SW quality processes inadequate?

**Chip Manufacturing**
- Process targets
- Process flow
- Machine recipe
- Change Control Board
- In-line tests & monitors
- Recipe control
- Factory automation
- End of Line Tests
- Test sample plan
- Root-cause analysis

**Software Development**
- PRD, Requirements - KPI
- Architecture specs
- Design documents
- Reviews, RCR
- Unit tests, Static analysis
- Configuration management
- Build automation & CI
- Test and Test documents
- Risk Based Analysis
- Root-cause analysis

SW Development has Quality Processes equivalent to Manufacturing
With all these quality processes available...

How come almost no SW shop is at CMM5?!!!
Why do Software developers find it so hard...

...to do what Process Engineers think of as “way of life”?
Cost of Error

Fab

Software
**Cost of Error**

**Fab:**
- $ millions lost in the line
- $ millions of 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 costs of bugs
- Death by 1000 paper-cuts
Accountability; Ownership

Fab

Software
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: “fire and forget”
- Development “expected” to create bugs
- Test expected to catch them...
- Quality ownership is QA. Escapes are Test fault
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
World view

Fab

Software
Holistic view of the Process

Fab:
• The mission is Production
• Deep understanding that steps influence each other
• The end product is present on a daily basis
• Short feedback cycle

Software:
• The mission is Research & Development
• Decoupling is a value
• (Some) Developers don’t “see” the end product
• Long feedback cycle
Engineering self image

Fab

Software
# Recap

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<th>Fab Process</th>
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East is East, and West is West,
And never the twain shall meet...

The Ballad of East and West, Rudyard Kipling
Or maybe...

West

East
What can we (software) learn from the Fab world?
Cost of Error

• Devise methods to calculate the cost of bugs
• Track, publish the cost
• Associate cost to bug-injection point
• Make it visible & immediate

Who wants to “own” a $100,000 bug?
Gerard J. Holzmann

• American computer scientist, best known as the developer of the SPIN model checker.

• Leads the NASA JPL Laboratory for Reliable Software; a JPL fellow.

• Awarded the NASA Exceptional Engineering Achievement Medal.

• Writer of several books
Cost of Error

Gerard Holzmann - https://www.usenix.org/conference/hotdep12/tbd

An example of creating a direct link between mistakes and costs (min. 17:45 in the video)
Accountability; Ownership

• Everybody owns Quality, not just QA.
• Track documents’ delivery, accuracy (bugs!), current-ness
• Per module quality metrics
• Escapes analysis focus:
  – Why it happened
  – Not why Test missed it

Bugs are Excursions!
Accountability; Ownership

Gerard Holzmann - https://www.usenix.org/conference/hotdep12/tbd

An example how per-module, public quality metrics help achieve better quality (min. 34:25 in the video)
Culture

- “Zero tolerance” to non-compliance
- Everyone does it (not just the nerds)
- Enforcement support systems
- Reward high quality
  - Fire Fighting is good
  - No fire – Better

Once started...
... it’s easier to maintain
Culture

An example of imposing “everyone has to do it” attitude to agreed-upon processes (min. 23:40 in the video).

Gerard Holzmann - https://www.usenix.org/conference/hotdep12/tbd
Enforcement
Enforcement
Holistic view of the Process

- Think “Software Production”
- Keep the product flexible; Keep the process repeatable
- Fix Root Causes
- While (1) {
  Control();
  Measure();
  Improve();
}
Summary

Some aspects of Fab quality management are relevant to Software.

Adopting any or all will improve software quality:

- Know the cost of non-compliance
- Set and enforce ownership expectations
- Build a Quality Culture
- Think “Software Production”
Closing Thoughts

Process adherence removes daily annoyances
Closing Thoughts

Process adherence protects from silly mistakes
Closing Thoughts

Process adherence allows fast changes
Adherence to process leaves more time for Innovation
Thank You!
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