Practical Reliability Engineering for Semiconductor Equipment

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Practical Reliability Engineering for Semiconductor Equipment

- Abstract
  - Reliability data can be utilized to allocate efforts for improvements and presentation to customers. This talk presents several practical techniques used to gather reliability data for these purposes. These techniques are based on basic reliability engineering concepts and are applied in simple ways. Data will be shown for illustrative purposes without details about specific components or subsystems. This presentation will review definitions of several reliability engineering metrics. Examples will illustrate Pareto plots over various time intervals and availability with planned and unplanned downtime. Important metrics such as Mean Time Between Failure (MTBF) and Mean Time Between Assists / Interrupts (MTBA/I) are used for quantifying failure rates.
  - Data is collected and analyzed from various sources and tallied in a variety of ways. Repair data can be collected from service technician or customer field reports. Reliability data can be collected from in-house or customer-site machines. In-house inventory statistics can indicate which parts are being replaced most frequently, by part number or cost.
  - Failure Analysis Reports should be communicated within the organization in a way that is effective. Vendors often have to be engaged to improve reliability of components or subsystems. Information that will be presented may be applicable to several other industries.

Daniel J. Weidman, Ph.D.

- Dr. Daniel J. Weidman received his Bachelor's degree in Physics from MIT in 1985. He earned his Ph.D. in Electrical Engineering from the University of Maryland, College Park. He has authored or co-authored more than 20 journal articles and technical reports in publications and more than 60 conference presentations. He started working with electron beams more than 20 years ago, and has since returned to that industry. He brings a fresh perspective to reliability engineering in the semiconductor industry, because he has no formal training in reliability engineering and he had less than two years of experience in the semiconductor industry when he took a position as the Reliability Engineer at NEXX Systems.

- NEXX Systems is located in Billerica, Massachusetts, and designs and sells semiconductor manufacturing equipment. Dr. Weidman was the Reliability Engineer there for almost five years. Dr. Weidman has resumed working in the field of electron beams, at Advanced Electron Beams of Wilmington, MA. He is the Principal Process Engineer, and his responsibilities include reliability testing of the electron-beam emitters and high-voltage power supplies.

Practical Reliability Engineering for Semiconductor Equipment

- Goal and scope of this talk
  - Review basic reliability engineering concepts and show how they can be used successfully
  - Applicable to equipment in the semiconductor industry, and other industries

- Goal
- Reliability program
  - Immediate issues
  - Reactive reliability engineering
  - Proactive reliability engineering

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PVD Machine

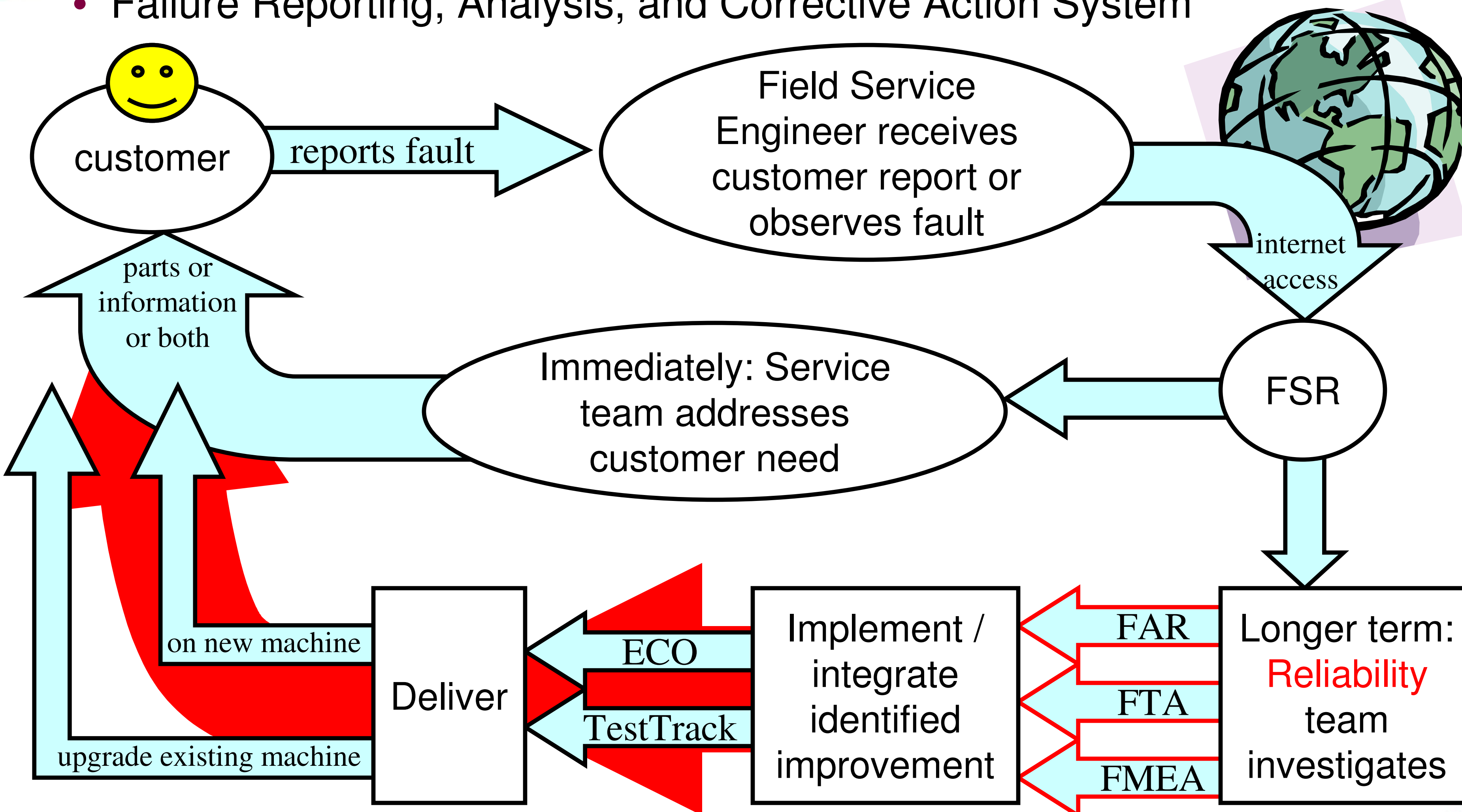
- Physical Vapor Deposition of thin metal film
- Wafers carried on trays to minimize handling & time to change size
- Up to five metals in a small footprint

Practical Reliability Engineering for Semiconductor Equipment

- Goal
- Reliability program plan
  - Immediate issues
  - Reactive reliability engineering
    - Overall process
      - Data gathering to record each issue
      - Data tallying
    - Reliability engineering metrics with examples

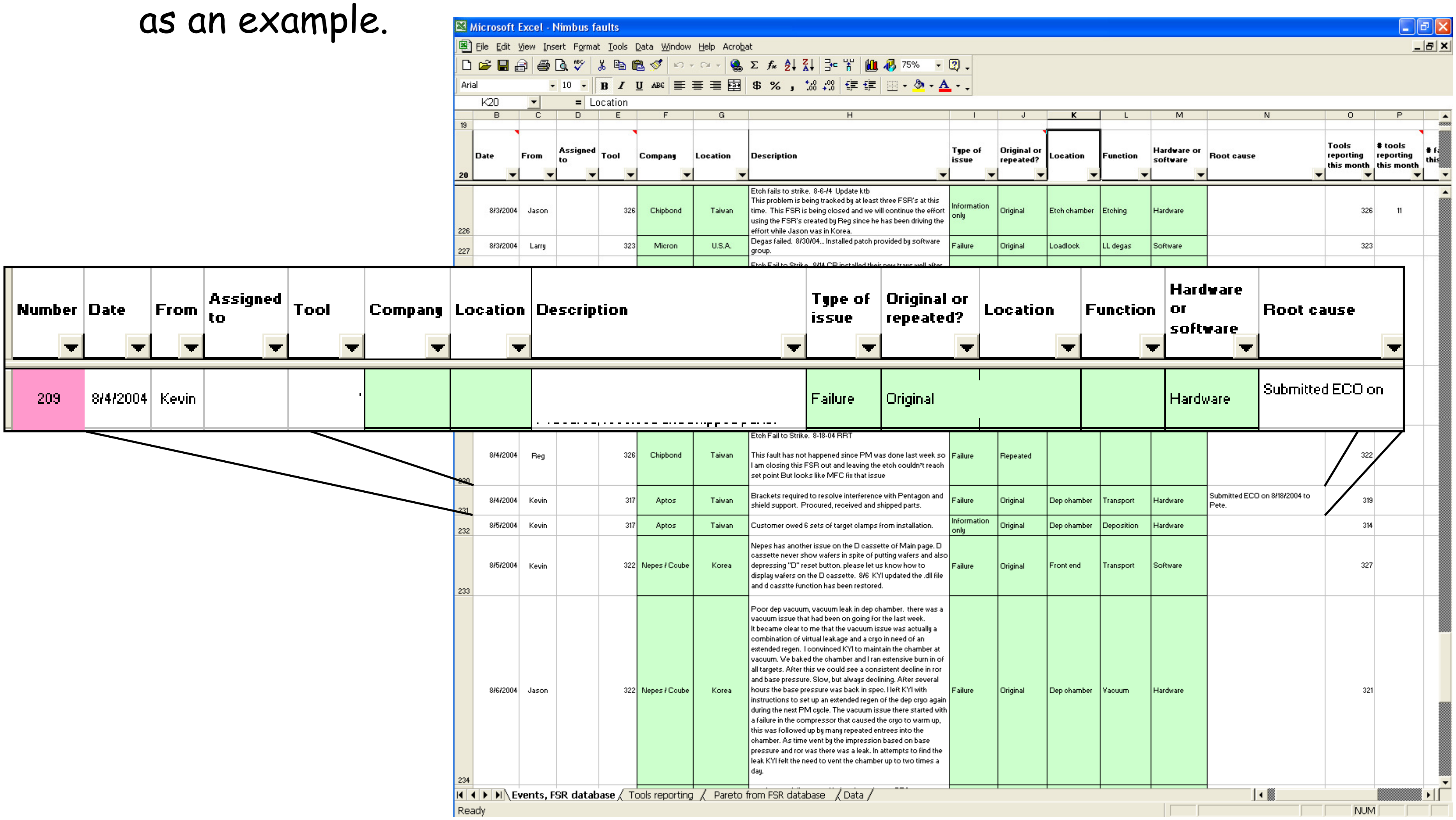
Reliability program

- Failure Reporting, Analysis, and Corrective Action System



Machine faults from customers

- About 300 service reports per product line per year
  - Copied from FSR database, pasted into Excel, and reviewed.
  - 9 entries are shown as an example.



Number	Date	From	Assigned to	Tool	Company	Location	Description	Type of issue	Original or repeated?	Location	Function	Hardware or software	Root cause
209	8/4/2004	Kevin						Failure	Original			Hardware	Submitted ECO on

Microsoft Excel - Nimbus faults

K20 = Location

Row	Date	From	Assigned to	Tool	Company	Location	Description	Type of issue	Original or repeated?	Location	Function	Hardware or software	Root cause	Tools reporting this month	# tools reporting this month
226	8/3/2004	Jason		326	Chipbond	Taiwan	Etch fails to strike. 8-6-/4 Update ktb This problem is being tracked by at least three FSR's at this time. This FSR is being closed and we will continue the effort using the FSR's created by Reg since he has been driving the effort while Jason was in Korea.	Information only	Original	Etch chamber	Etching	Hardware		326	11
227	8/3/2004	Larry		323	Micron	U.S.A.	Degas failed. 8/30/04... Installed patch provided by software group.	Failure	Original	Loadlock	LL degas	Software		323	
230	8/4/2004	Reg		326	Chipbond	Taiwan	Etch Fail to Strike. 8-18-04 RRT This fault has not happened since PM was done last week so I am closing this FSR out and leaving the etch couldn't reach set point But looks like MFC fix that issue	Failure	Repeated					322	
231	8/4/2004	Kevin		317	Aptos	Taiwan	Brackets required to resolve interference with Pentagon and shield support. Procured, received and shipped parts.	Failure	Original	Dep chamber	Transport	Hardware	Submitted ECO on 8/18/2004 to Pete.	319	
232	8/5/2004	Kevin		317	Aptos	Taiwan	Customer owed 6 sets of target clamps from installation.	Information only	Original	Dep chamber	Deposition	Hardware		314	
233	8/5/2004	Kevin		322	Nepes / Ccube	Korea	Nepes has another issue on the D cassette of Main page. D cassette never show wafers in spite of putting wafers and also depressing "D" reset button. please let us know how to display wafers on the D cassette. 8/6 KYI updated the .dll file and d casstte function has been restored.	Failure	Original	Front end	Transport	Software		327	
234	8/6/2004	Jason		322	Nepes / Ccube	Korea	Poor dep vacuum, vacuum leak in dep chamber. there was a vacuum issue that had been on going for the last week. It became clear to me that the vacuum issue was actually a combination of virtual leakage and a cryo in need of an extended regen. I convinced KYI to maintain the chamber at vacuum. We baked the chamber and I ran extensive burn in of all targets. After this we could see a consistent decline in ror and base pressure. Slow, but always declining. After several hours the base pressure was back in spec. I left KYI with instructions to set up an extended regen of the dep cryo again during the next PM cycle. The vacuum issue there started with a failure in the compressor that caused the cryo to warm up, this was followed up by many repeated entrees into the chamber. As time went by the impression based on base pressure and ror was there was a leak. In attempts to find the leak KYI felt the need to vent the chamber up to two times a day.	Failure	Original	Dep chamber	Vacuum	Hardware		321	

Events, FSR database / Tools reporting / Pareto from FSR database / Data

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      - Uptime and Availability
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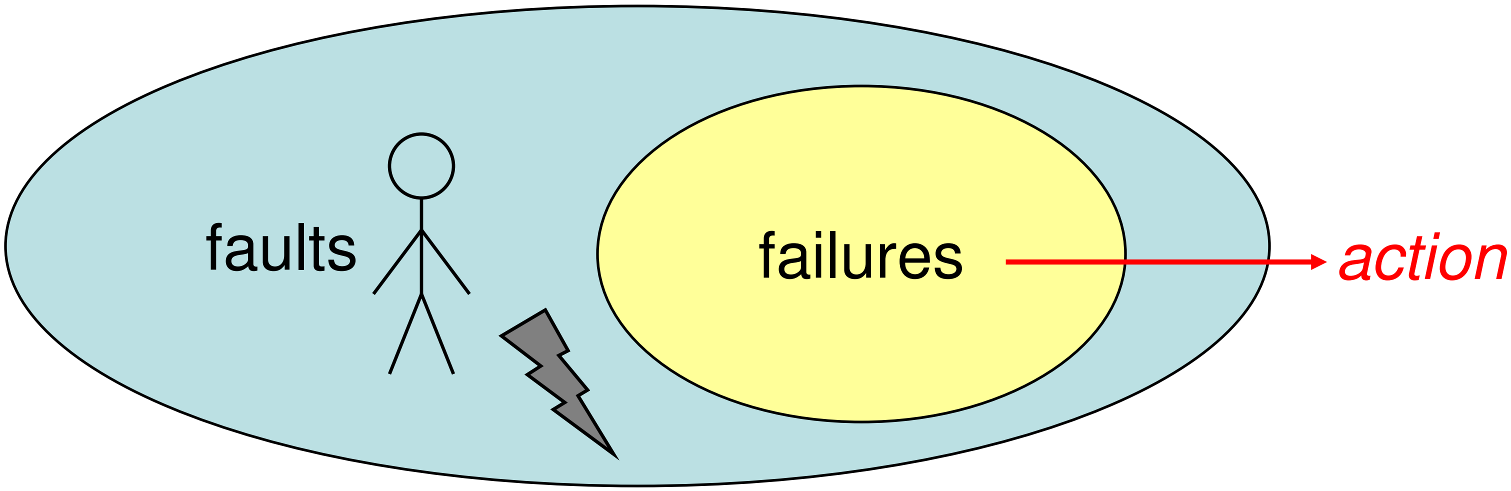
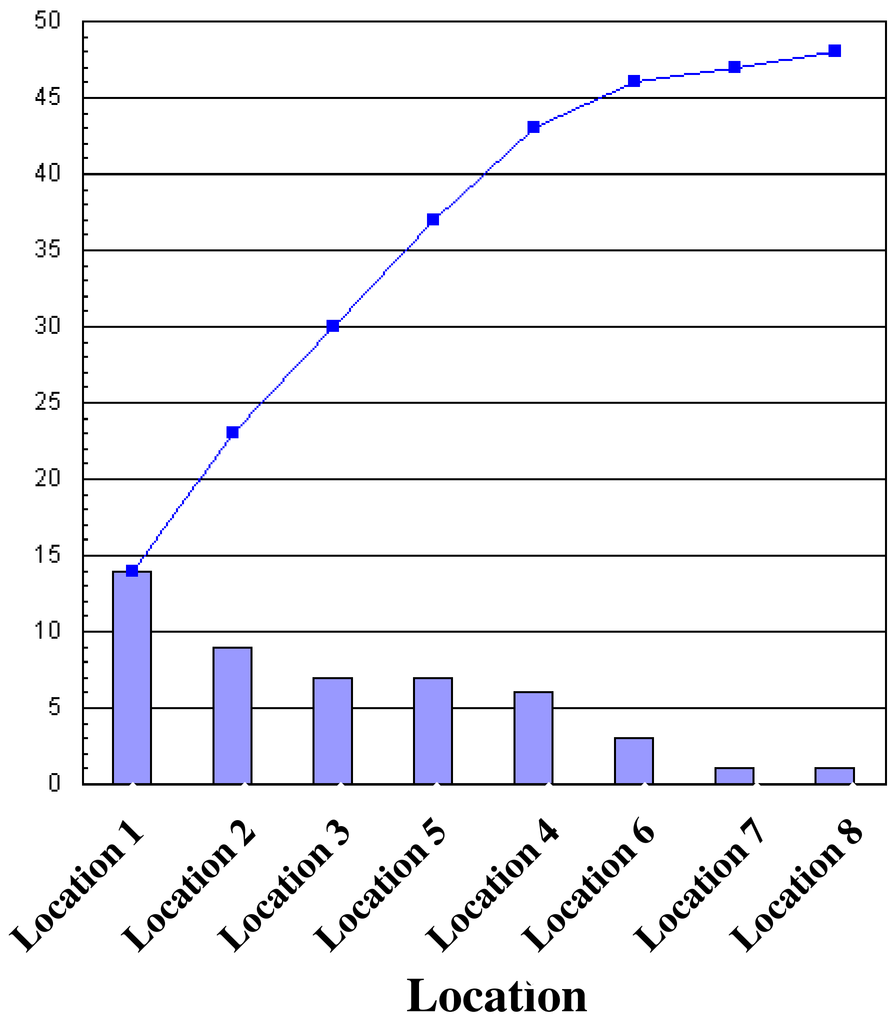
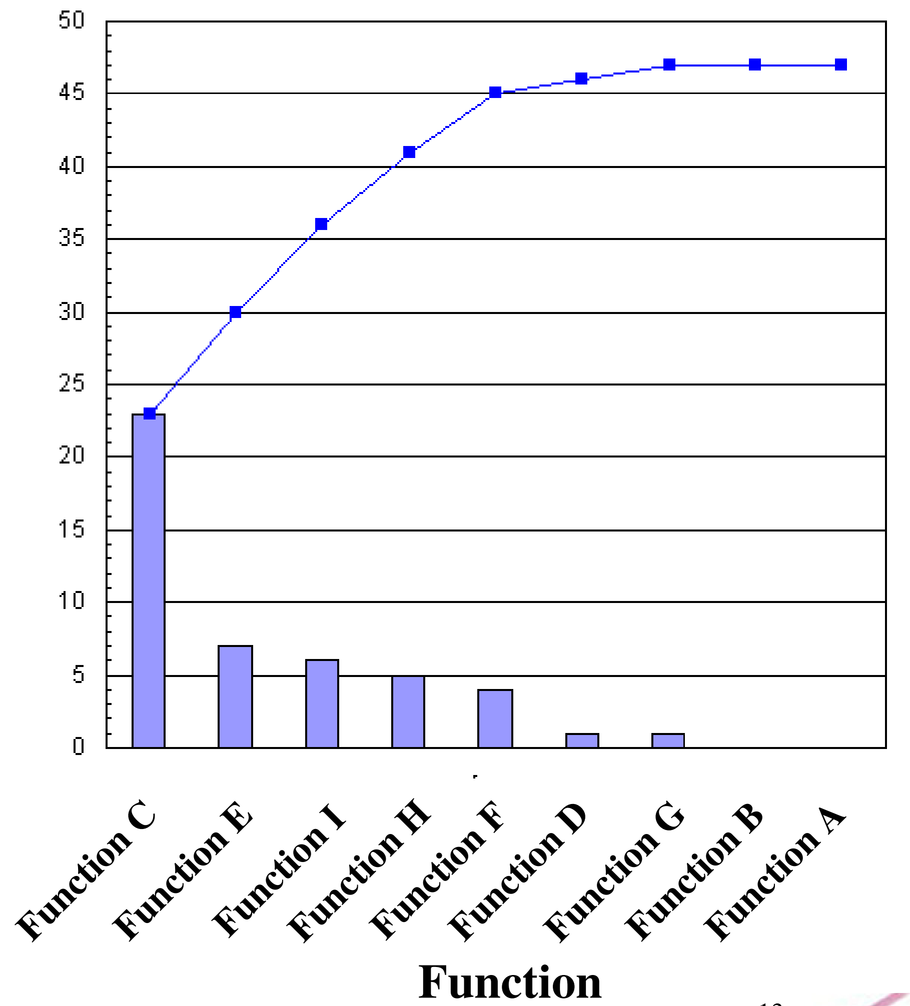
Reliability definitions: faults



- Fault: anything that has gone wrong
- Failure: an equipment problem
- All failures are faults
- Examples: If a transport system stops due to
  - particles that are normal to the process, then it is a failure (and a fault).
  - a left wrench inside, then it's a fault but not a failure.

Pareto plots



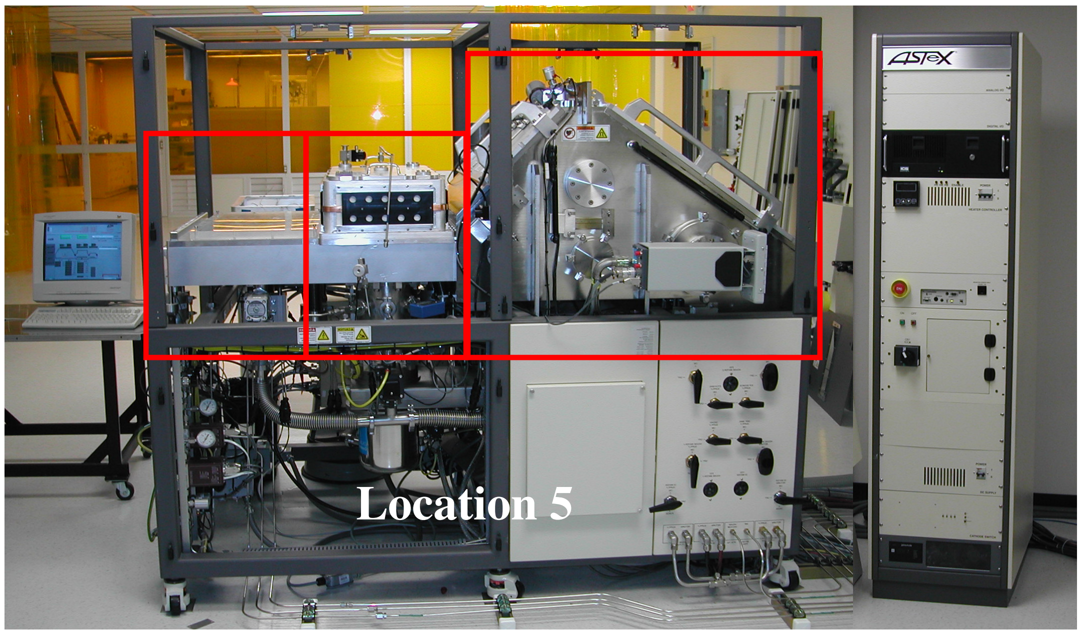


Machine cross-section

Front end: Location 1

Location 2 Location 3 Location 4

Location 8

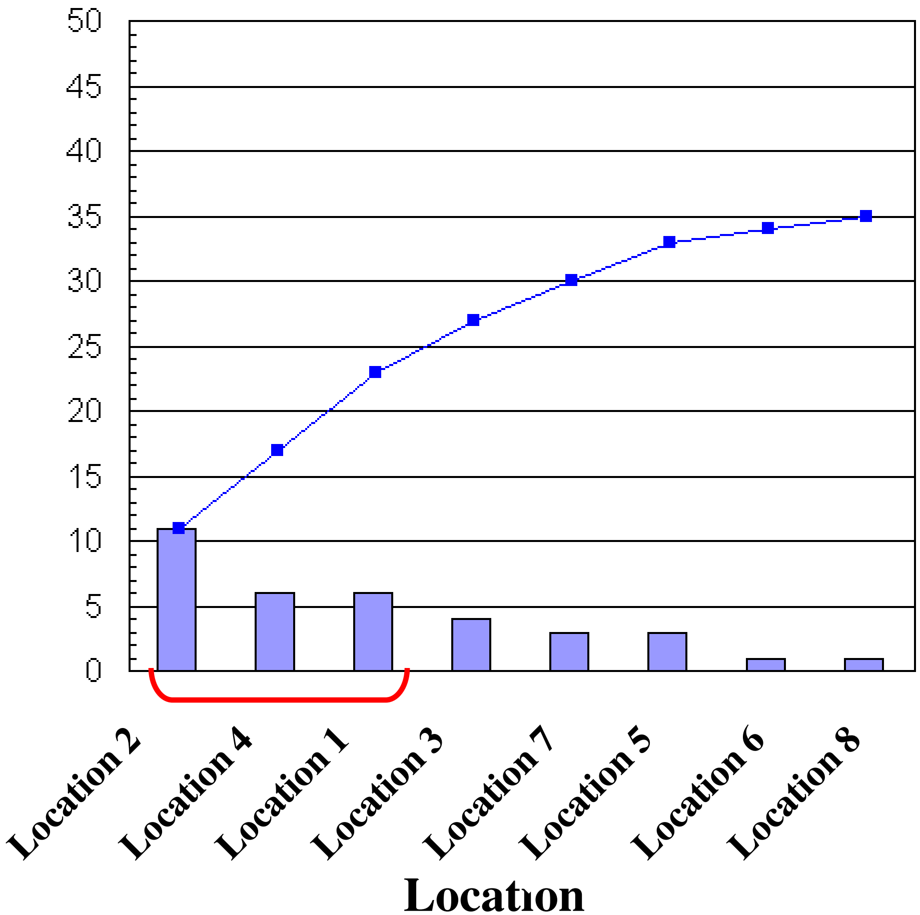


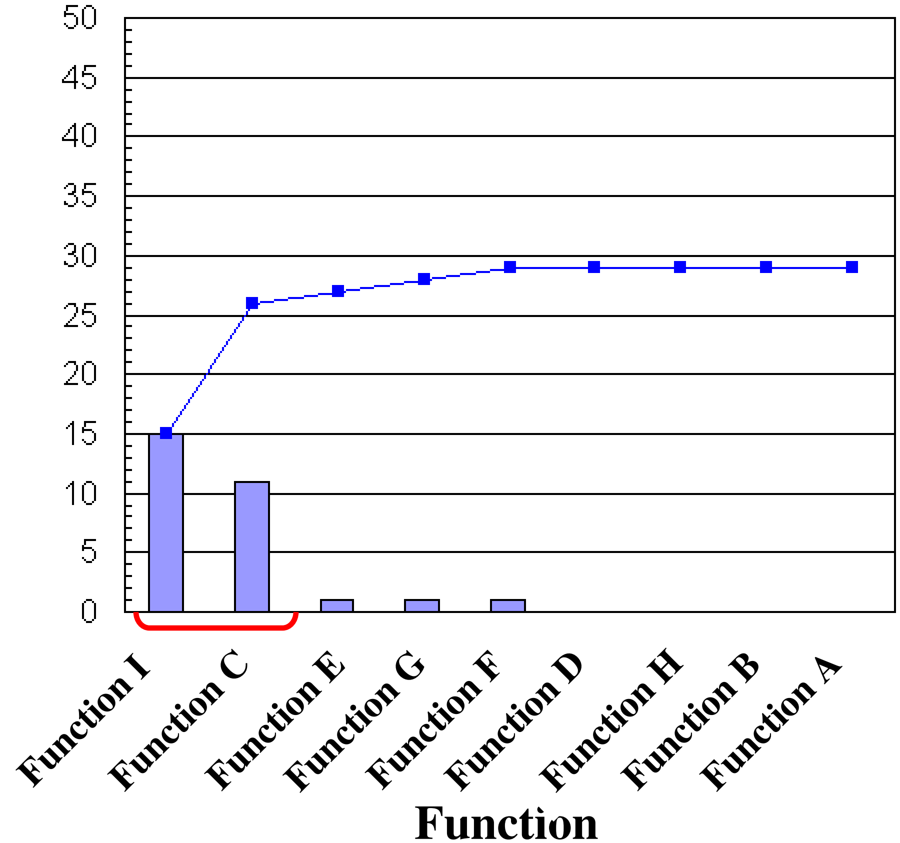
Location 6

Location 6
for new control system
sn323 et seq.

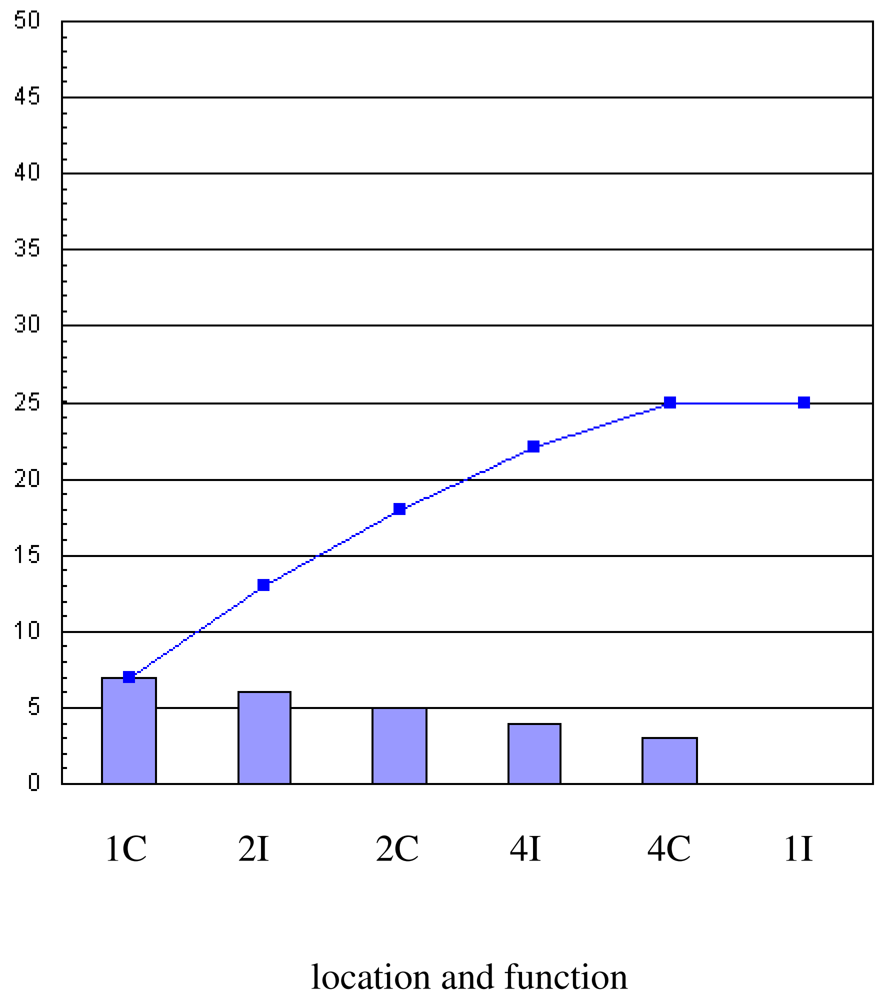
Chase: Location 7

Faults on all machines in one quarter



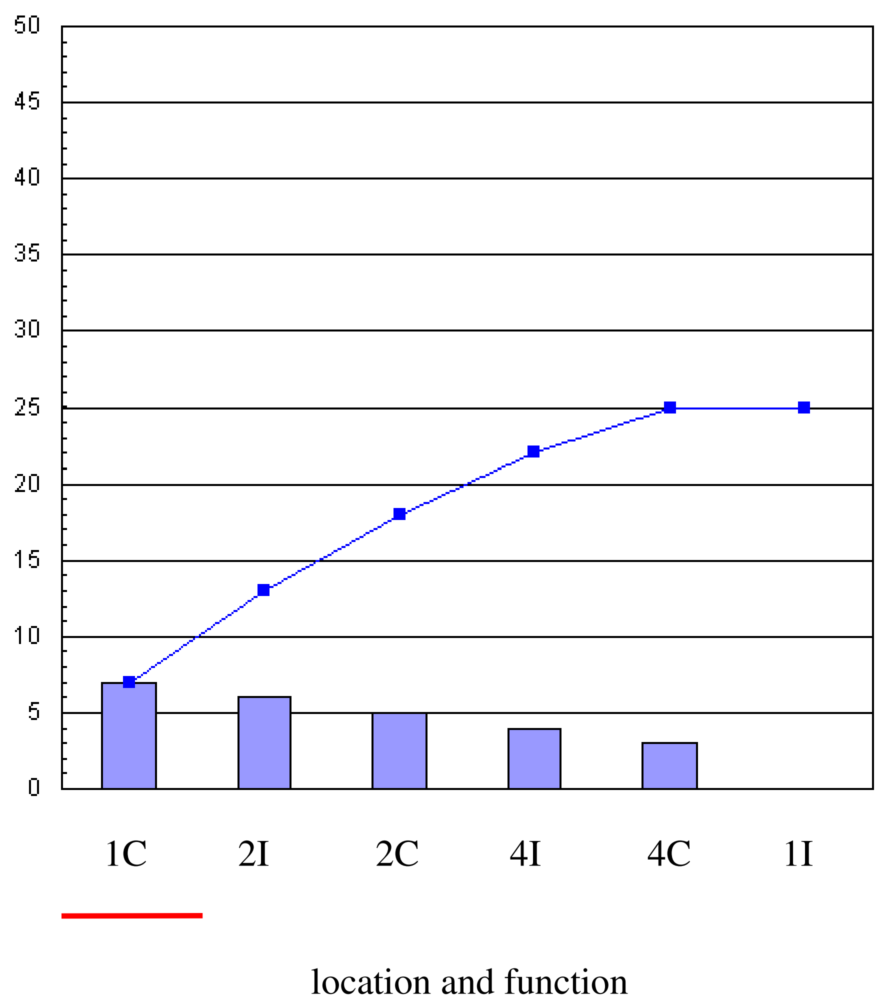


Faults on all machines in one quarter



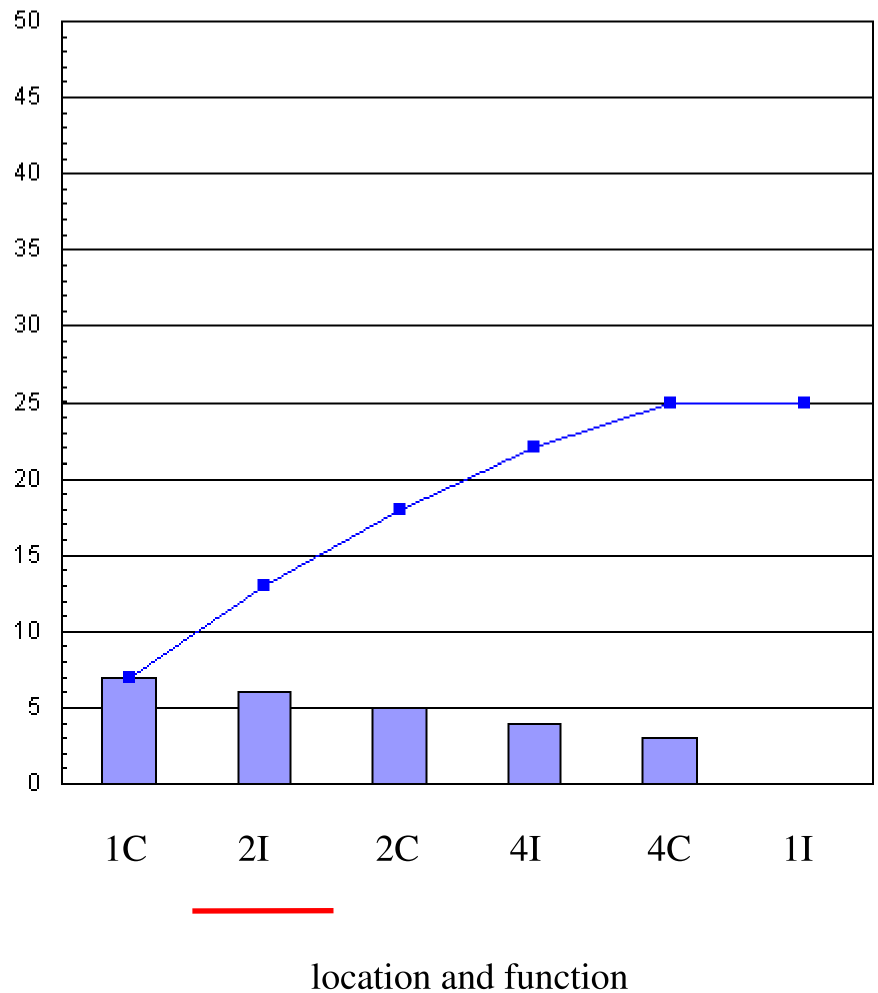
- **Top faults shown by location and function**
  - Allows focusing on the biggest types of issues
  - Few enough issues per category per quarter to investigate each issue
  - Note: A shorter interval, such as monthly,
    - Has the advantage of a faster response if a problem arises
    - Has the disadvantage of “noise” due to smaller sampling (issues shift back and forth)

Faults on all machines in one quarter



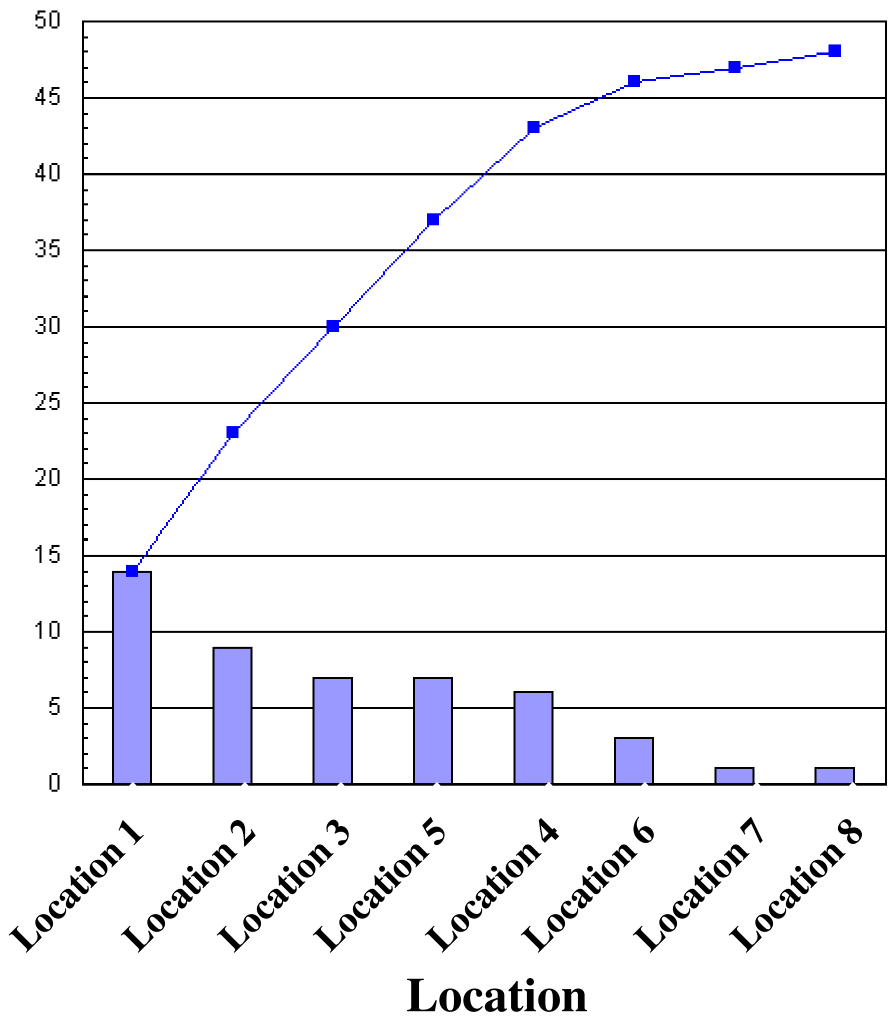
- **Location 1 & Function C**, 7
  - new subsystem
  - new subsystem
  - new dll
  - reboot controller
  - reboot controller
  - component ineffective
  - issue with test wafers
- Most of these faults are not failures: upgrades of subsystem on older machines or rebooting
- No predominant issue

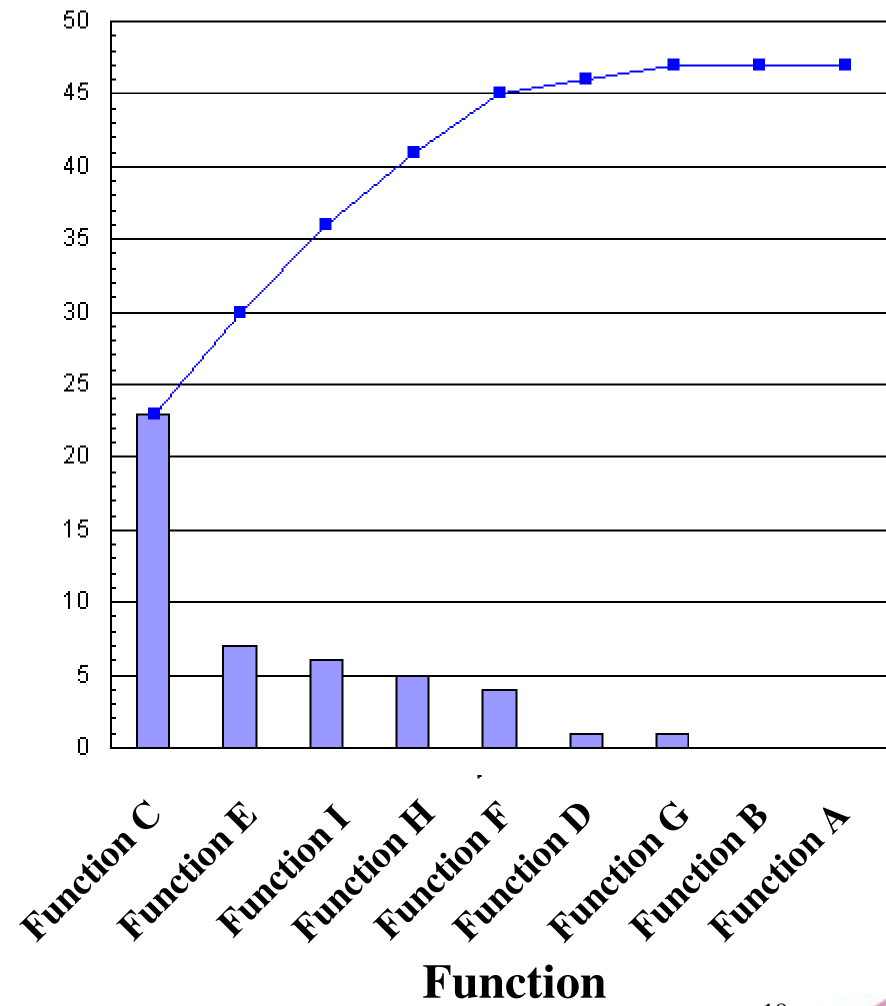
Faults on all machines in one quarter



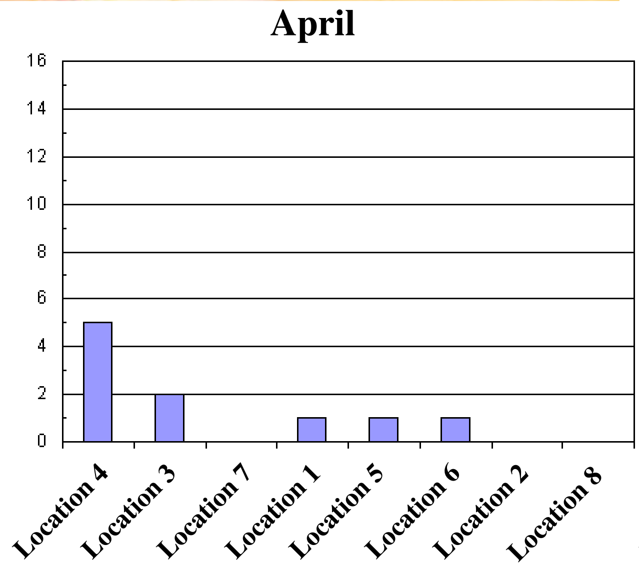
- **Location 2 & Function I**, 6
  - 5 of 6 faults: same component
  - Validated a known issue and two ECO's to address it

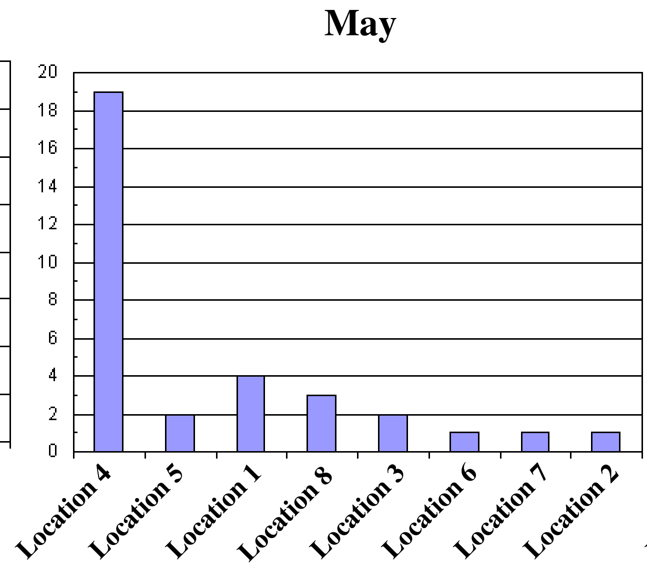
Faults on all machines in one quarter

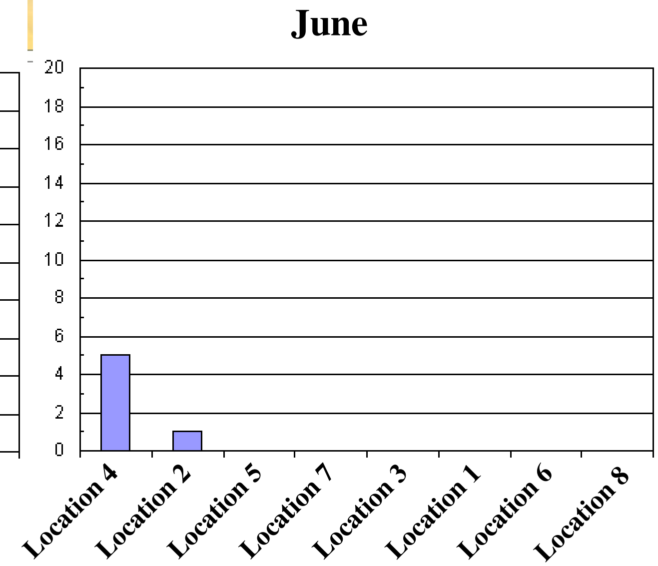


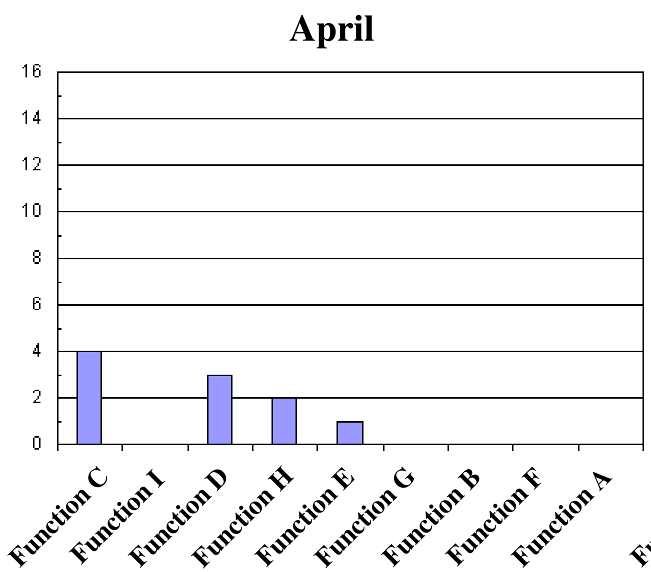


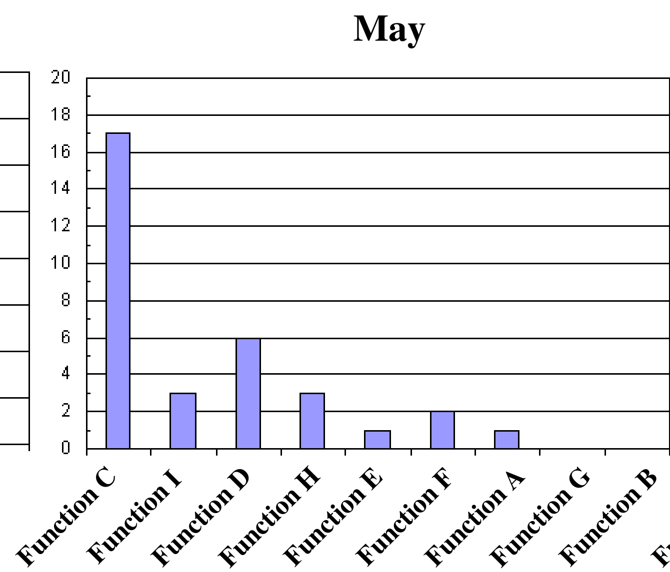
Sample size & machine failures by month

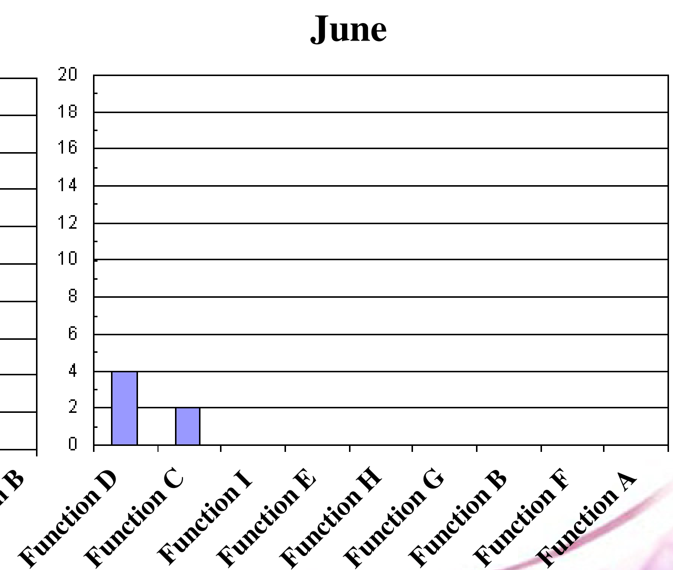












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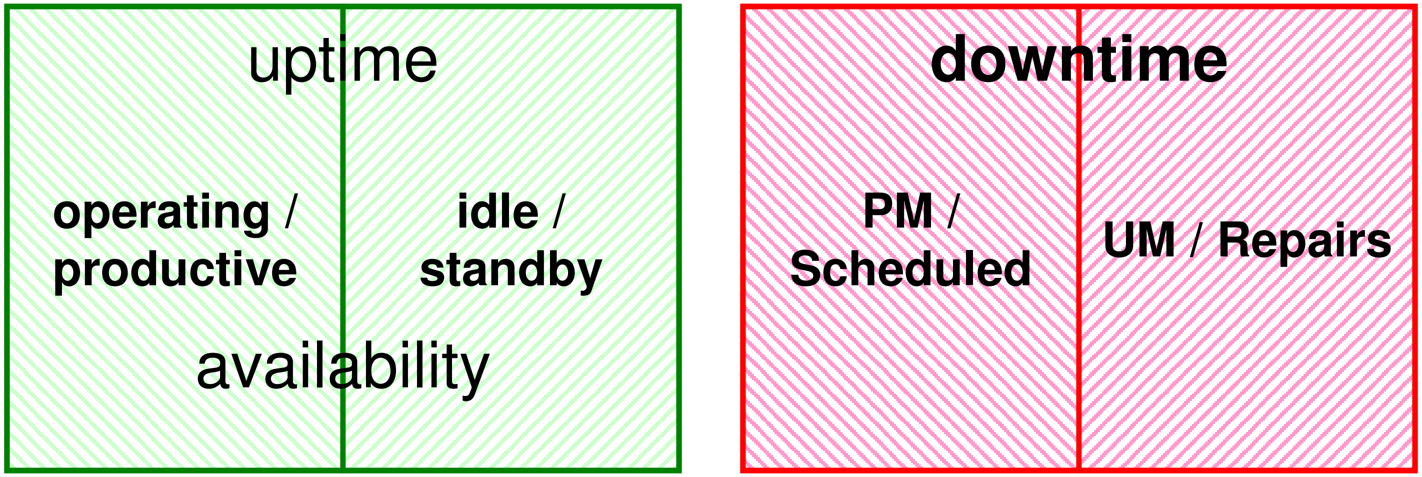
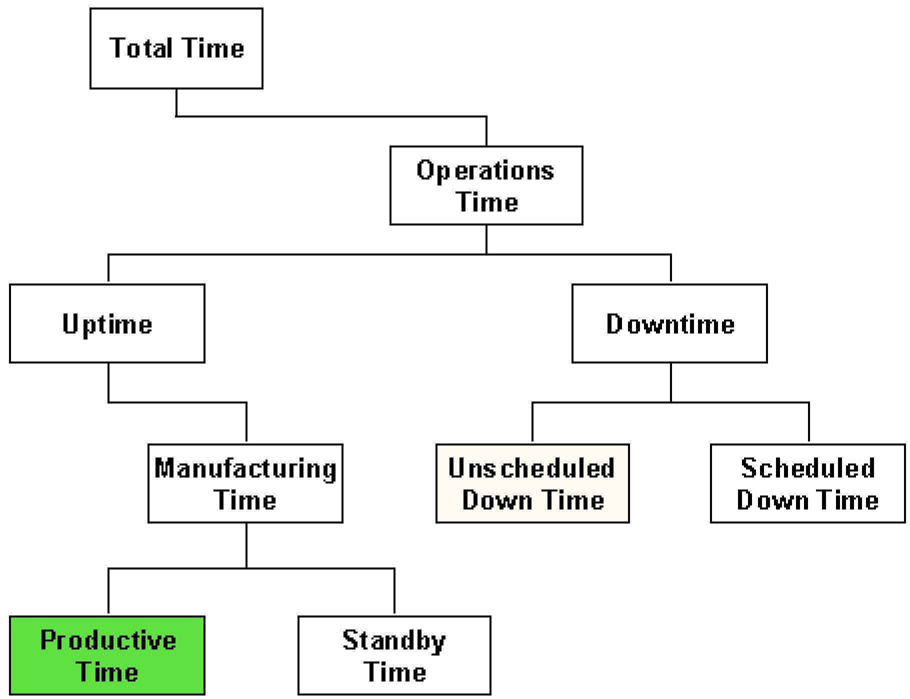
Reliability definitions: uptime, etc.



- All time: either “uptime” or “downtime”
- “Uptime”: either operating or idle time
- “Uptime” (hours) $\leftrightarrow$ availability (%)
- “Downtime”: either PM, or Unscheduled Maintenance (Repairs)
- MTTR (mean time to repair) applies to PM and to UM

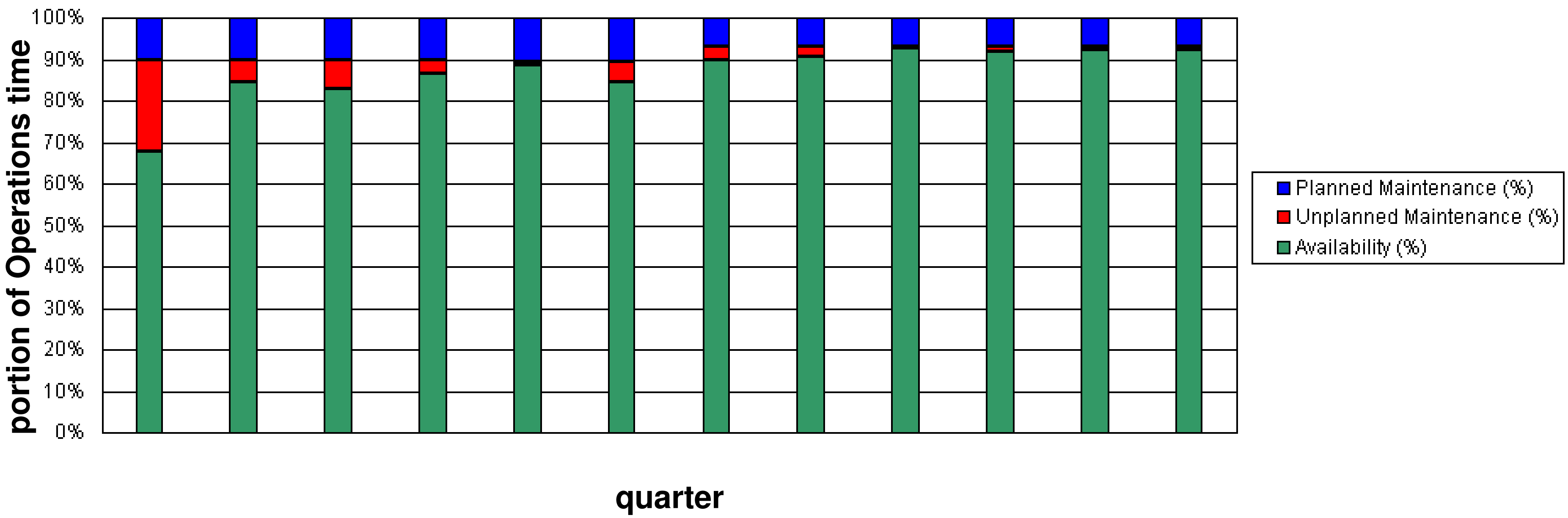
Reliability definitions: SEMI



- Above plot is from SEMI E10
- We assume that Total Time is "Operations Time"

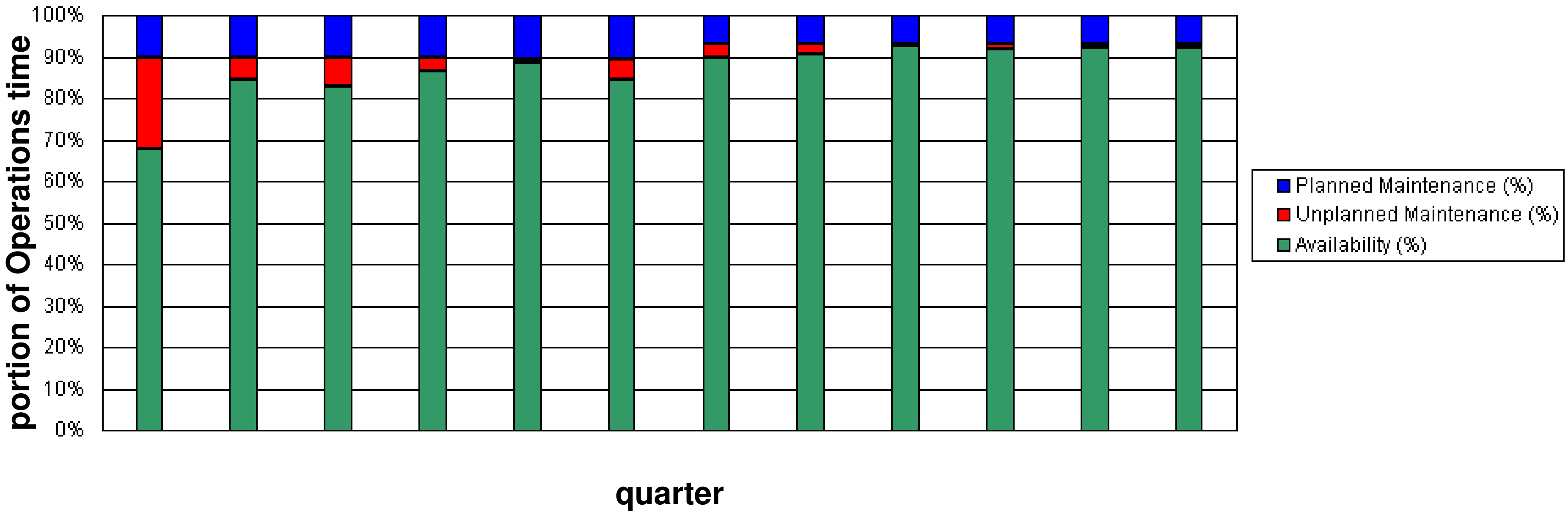
6.3 *EQUIPMENT AVAILABILITY* — The probability that the equipment will be in a condition to perform its intended function when required.

Machine availability, on average



- Machine Availability
  - Specification: availability > 85%
  - Typical performance: 90%
- Measured from Field Service Reports

Machine availability, on average



- Machine Availability
  - Specification: availability > 85%
  - Typical performance: 90%
- Measured from Field Service Reports
- Machine PM time approximately 7%. Customers report
  - At beta Customer, one machine: 94.3% avail. ⇒ better than 6% PM
  - At another customer: 6% PM reported

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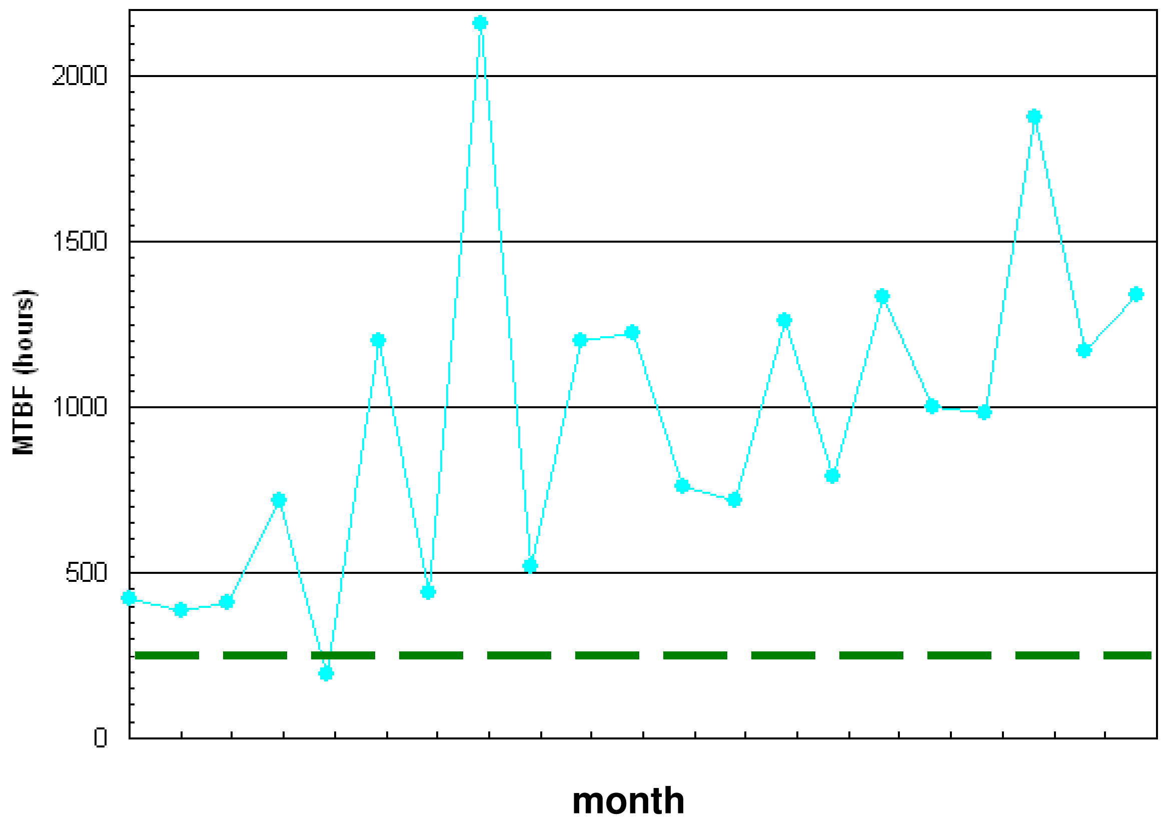
SEMI E10 definitions

- **Assist**: an unplanned interruption where
  - Externally resumed (human operator or host computer), and
  - No replacement of parts, other than specified consumables, and
  - No further variation from specifications of equipment operation
- **Failure**: unplanned interruption that is not an assist
- # of **interrupts** = # of assists + # of failures

SEMI E10 definitions

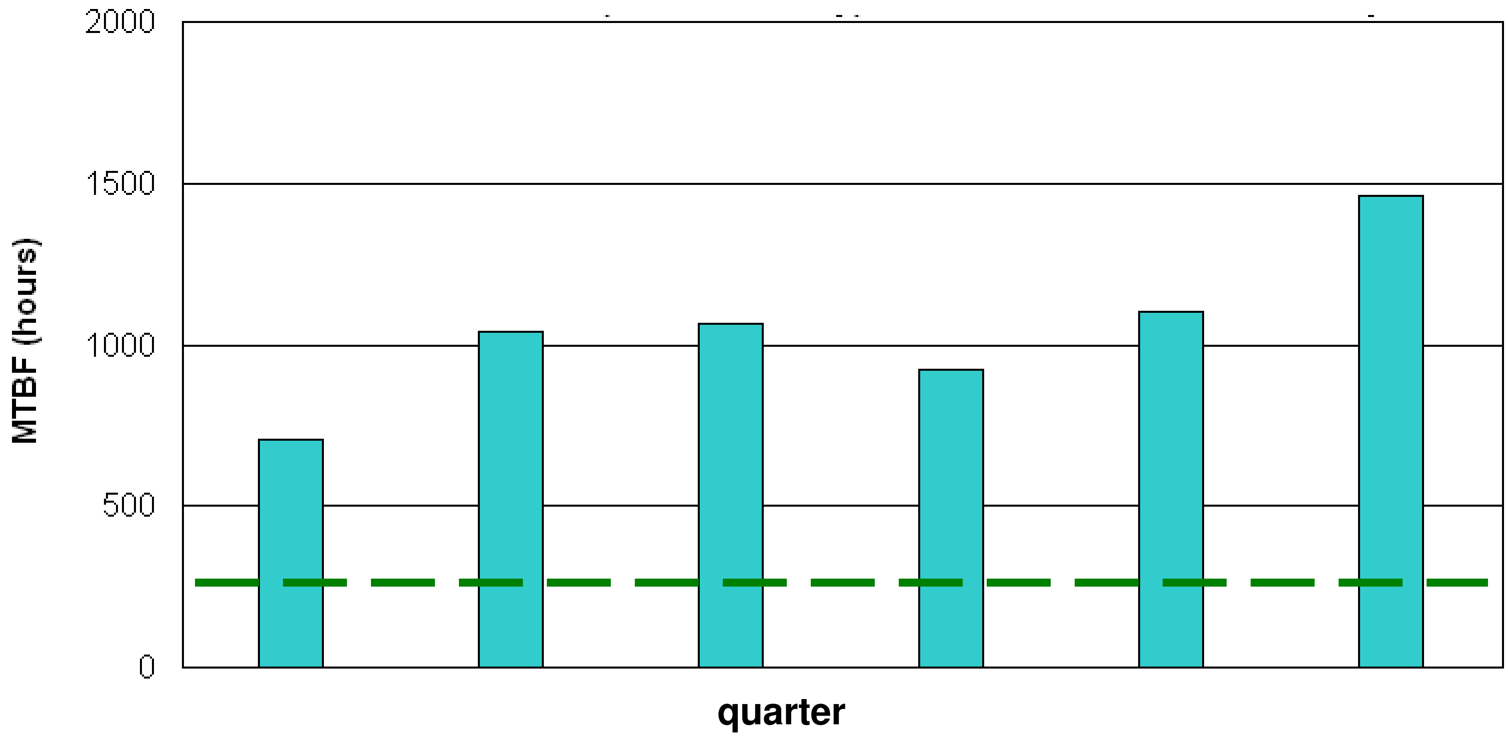
- MTBF, MTBA, MTBI
  - MTBF = Interval / (number of failures)
  - MTBA = Interval / (number of assists)
  - MTBI = Interval / (number of interrupts)

MTBF (Mean Time Between Failure) in hrs
per machine each month



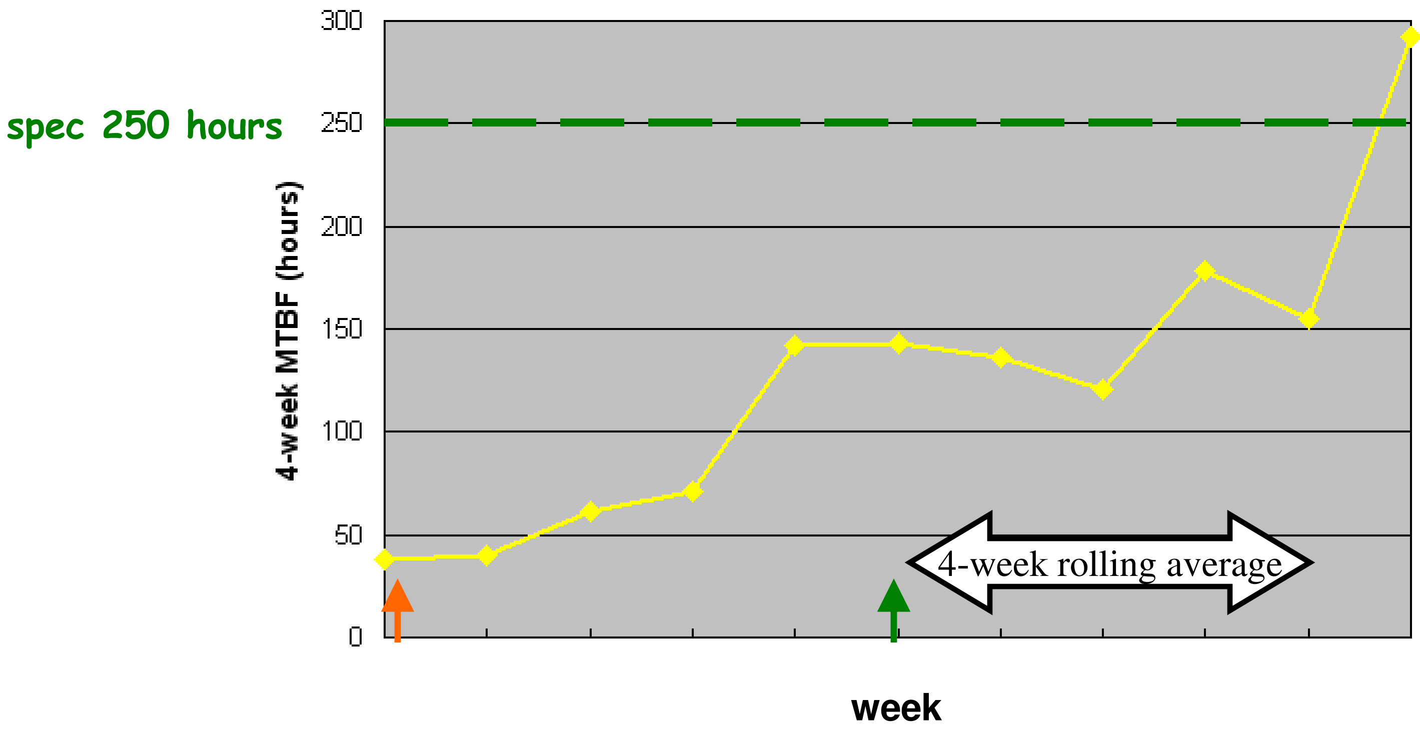
- 250 hours is specified
- Based on Field Service Reports

MTBF (Mean Time Between Failure) in hrs
per machine each *quarter*



- **250 hours is specified**
- Field Service Reports indicate we exceed this
- Quarterly less "noisy" than monthly

Customer-measured MTBF due to our improvements



- Per machine, averaged over two machines
- 1: Adjusted one of the subsystems
- 2: Installed an upgraded version of the subsystem in one machine

MTTR (Mean Time To Repair) and MTR

- MTTR is Mean Time to Repair (SEMI E10 definition): the average elapsed time (not person hours) to correct a failure and return the equipment to a condition where it can perform its intended function, including equipment test time and process test time (but not maintenance delay).
- MTR is Mean Time to Restore: includes maintenance delays.

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      - Uptime and Availability: time is up or down
      - MTBF, MTBA, MTBI: I = F + A
      - MTTR, MTR: working time vs. clock time

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      - ⇨ Additional metrics specific to industry
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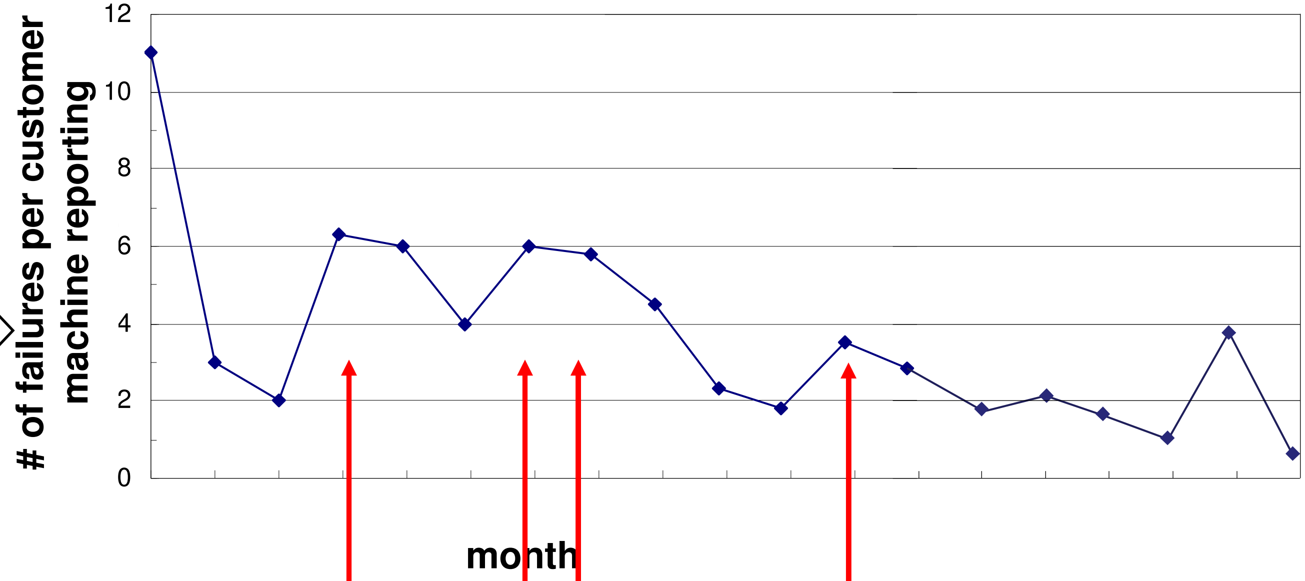
Broken wafers

- Goals
  - Ideally zero
  - In practice, need fewer than 1 in 10k (or 1 in 100k)
- Broken wafers reported on four different machines
  - Qty 1, Dec, "Year 1"
  - Qty 4, Feb, "Year 2"
  - Qty 4, March, "Year 2"
  - Qty 1, May, "Year 2"
- Total broken wafers reported
  - 1 in "Year 1"
  - 9 in "Year 2" Q1 and Q2
- >7,000k wafers/year on all machines $\Rightarrow$ within 1 in 300k
- Total reported on "newer-style" machines: zero

Failures vs. time

per customer machine each month

dropped from >5 to <4 per month



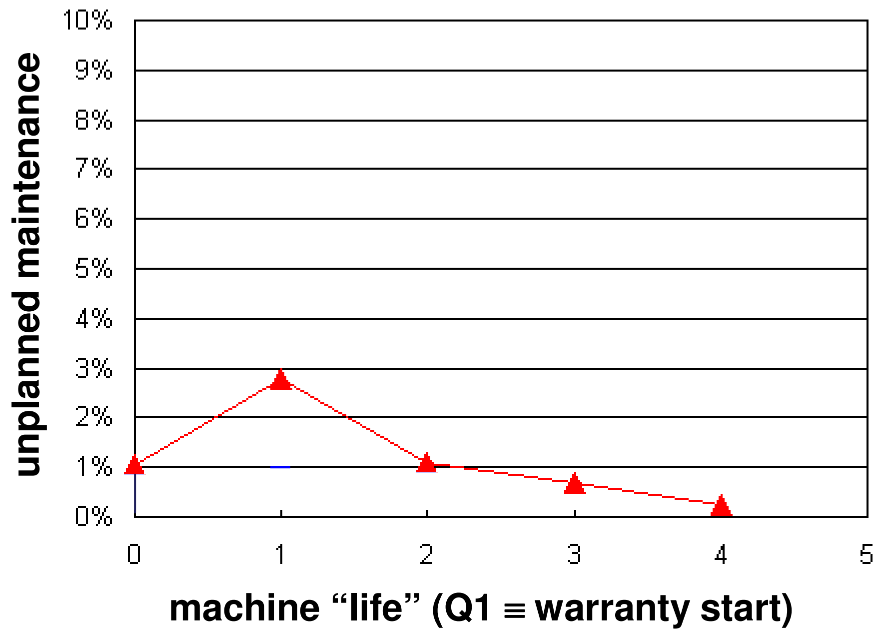
First two “new-series” machines being used 24/7.

Another machine arrived at customer

2 more machines both arrived at customer

First machine with two new major features shipped.

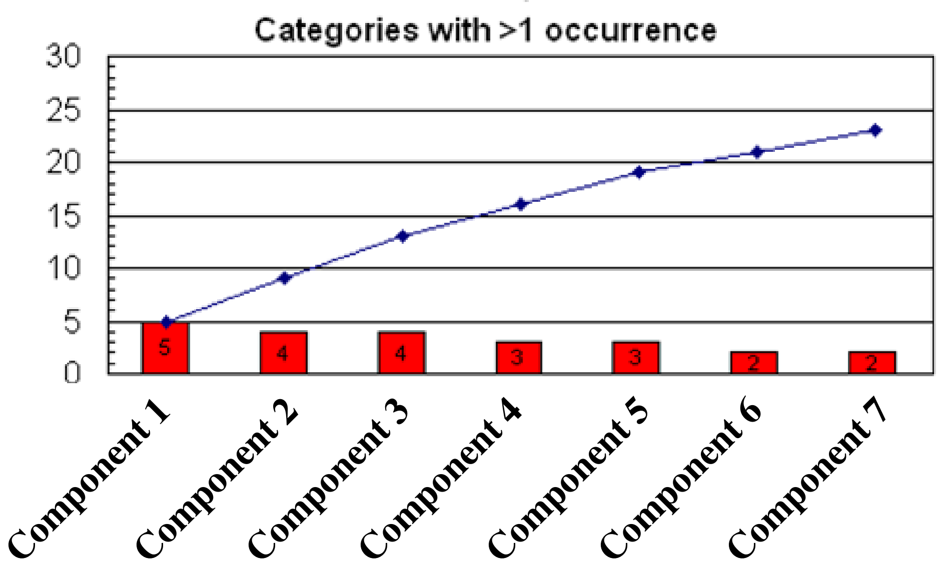
Unplanned downtime by machine "life"



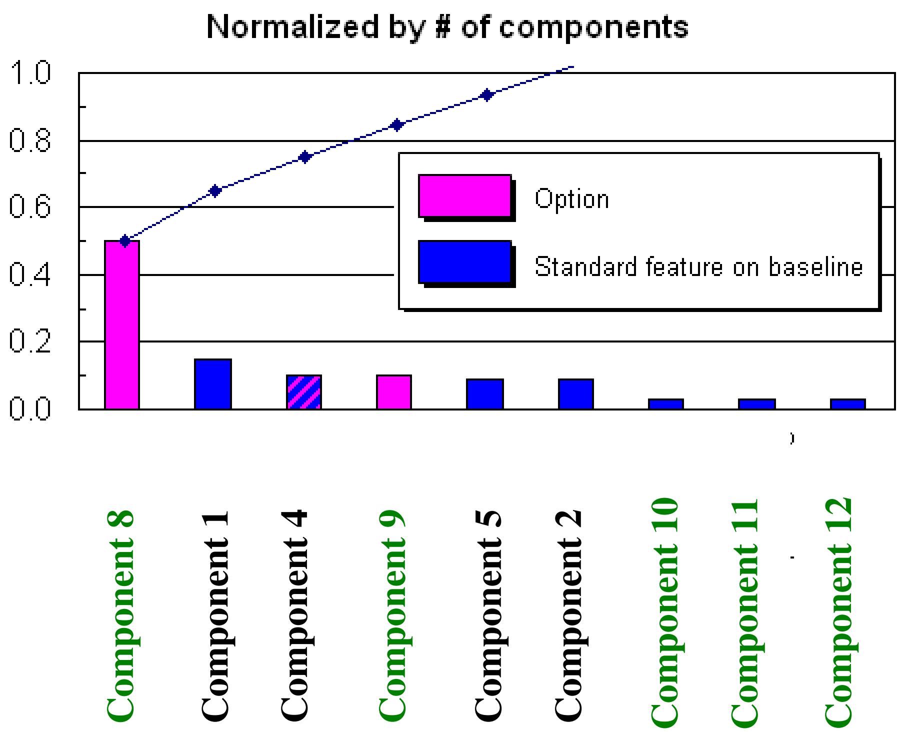
- **Not customer dependent**
- **PM > UM**

- Unplanned maintenance (UM) based on FSR's only
- Actual UM is higher
- Data scattered: 1 std dev ~ values themselves
- All machines have reported in time shown (6 quarters)

Failures by component

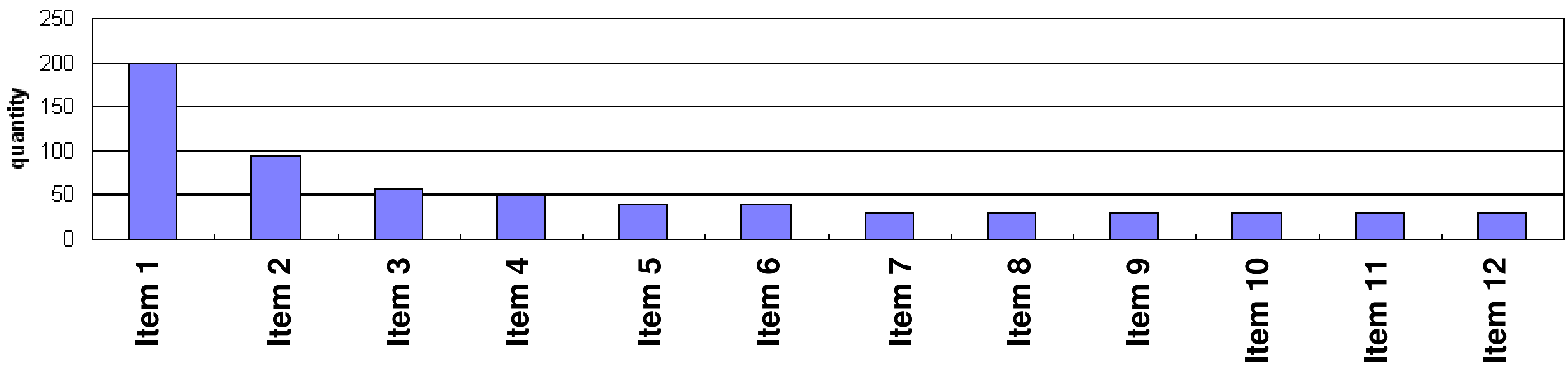


Component failure rate normalized



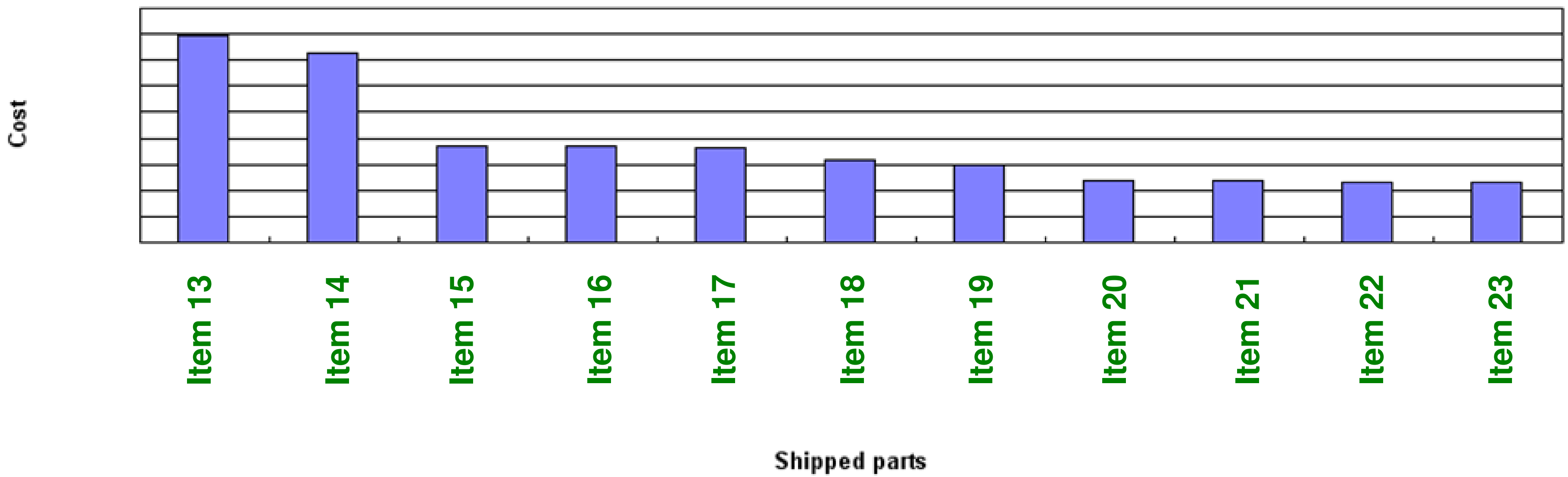
- Component 8 failure rate is 3 to 5 times the rate of other failures
- Component 1 failures addressed by ECOs
- Component 4 to be moved from baseline
- Component 9: Eng project

Database dump of parts shipped



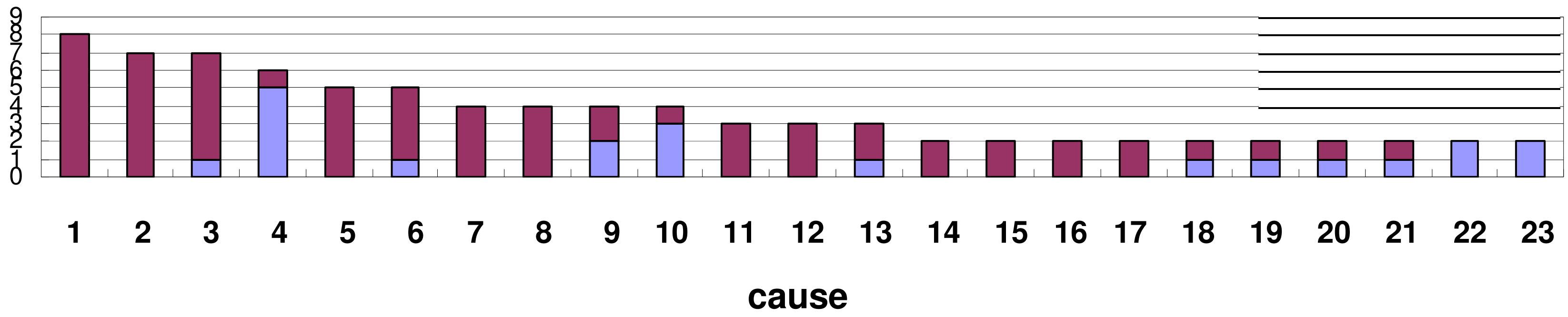
- Qty 30 or more
- Excludes bolts, screws, washers, and nuts

Most expensive shipments



- Includes all shipments
  - replacements
  - upgrades
- 5 quarters

All failures



- Two quarters
- 123 reported failures, which fell into 65 categories
- One series and another series
- Categories are named by cause not by symptom
- Other faults were not included. If PM was required, then the fault was not counted as a failure.
- Failures occurring twice or more are plotted, which are in 23 categories.
- Failures occurring three times or more were analyzed—13 categories. Next slides…

Failures from previous slide: analysis

Failures occurring three times or more

1. 8
2. 7
3. 7
4. 6+2
5. 5
6. 5
7. 3 (not 4)
8. 4+1
9. 4-1
10. 4
11. 3
12. 3
13. 3

Status of design improvement

- completed, 24
- in progress, 7
- not started, 33

- Acknowledgements

Thank you

Thank you

End of presentation