Electronic/Electrical Reliability

18-849b Dependable Embedded Systems

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Required Reading: "Automotive and Aerospace Electronic Systems. Dependability Requirements", P.D. Rose

Best Tutorial: "Reliability Engineering", P. D. T. O'Connor, Chapter 7

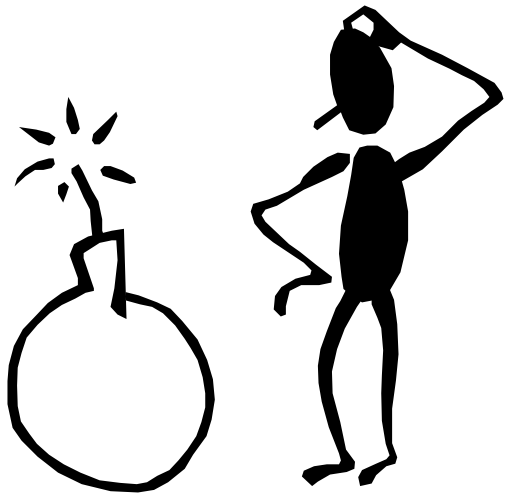
Carnegie Mellon

Overview: Electronic/Electrical Reliability

- Why do electrical systems fail?
- What doesn't fail? (Do they 'wear out'?)
- Long-term non-operating reliability
- How does one design reliable electronic systems?
- The automotive world: Wiring Harnesses
- Conclusions, <u>THE BIG PICTURE</u>

Why do electrical systems fail?

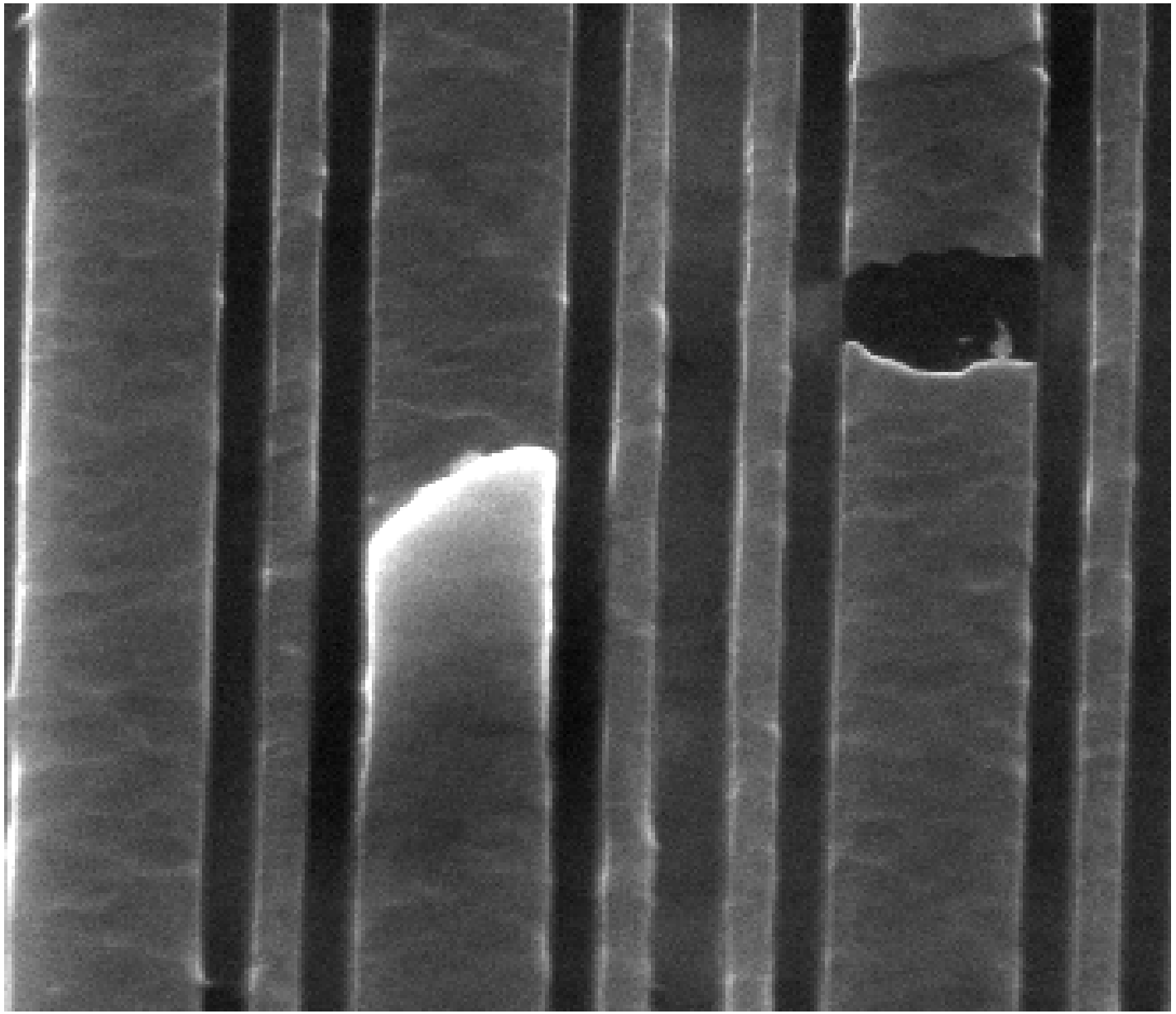
- **Drift of component parameters**
- **Electromagnetic interference**
- **"Mechanical Failures"**
  - Connector breakage
  - Solder joint failures
  - Corrosion
  - Shock/Vibration/Sand/Dust
- **Failure induced by temperature**
- **Transient electrical stresses**
  - Electrostatic Discharge (ESD)
  - Lightning
- **Radiation**



What doesn't fail? (Do they 'wear out'?)

- **Bathtub curve applies to Electrical/Electronic Reliability**
- **One could argue that electrical/electronic systems won't reach the wear-out stage (stage III)**
  - except maybe Electromigration
  - some components do wear out: electrolytic capacitors, electromechanical parts
- **Electromigration - Phenomenon caused by extremely high current densities in on-chip interconnects. Can result in either open or short circuits in extreme cases.**

Electromigration



Long-term non-operating reliability

- **Dormancy can have an effect on electronic devices**
- **Often viewed as negligible, but some say important**

Typical Percentages of Calendar Time for Equipment in Dormancy [Harris, 1980]

Cars (personal use)	93%
Taxis	38%
Safety equipment	98%
Standby power	> 90%
Air conditioning	50% - 80%
Built-in test equipment	99%

- **Looks important to me..**

Long-term non-operating reliability (cont.)

- **During dormancy, the following may occur:**
  - Corrosion
  - Radiation (**accumulation** of alpha particles)
  - Vibration/Extreme Temperatures
    - Loosening of connectors
    - Damage to plastic encapsulated devices
    - Depolymerization of printed circuit boards
    - Loss of Hermeticity
      - » Moisture
      - » Other contaminants
  - Electrostatic Discharge (ESD)
  - Contamination induced parameter degradation

  - In general: Environmental factors!

Long-term non-operating reliability (cont.)

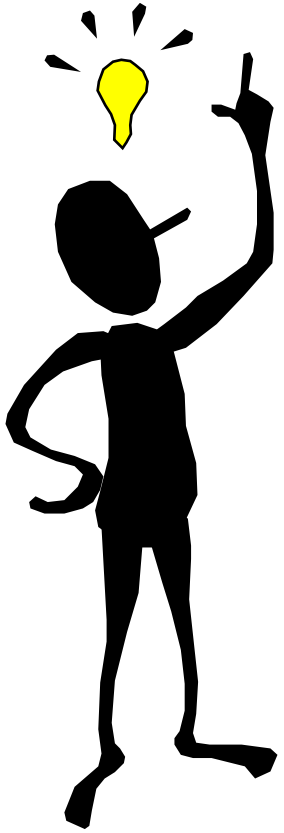
(the bottom line)

- **LOTS OF BAD THINGS CAN HAPPEN. Know the environment that your device is going to be:**
  - used in.
  - stored in.
  - lay dormant in.

6 Design Principles to follow...

- **On the road to achieving reliable electronic systems, the automotive handbook says "Do the following:"**

- ☑ Part Selection, Control, and Derating
- ☑ Reliable Circuit Design
- ☑ Redundancy
- ☑ Environmental Design
- ☑ Human factors Design
- ☑ Design Reviews



6 Design Principles to follow… (cont.)

Part Selection, Control, and Derating

- Reliability of end item is dependent upon the electronic building blocks that make it up. Part selection cannot be overemphasized!

- To name a few, you must consider:
  - Power dissipation
  - Thermal resistance (heat dissipation)
  - Device parameter drift.
  - Etc…….

- Derating - making sure operating environments of components never exceed their specified maximum stress levels.

6 Design Principles to follow… (cont.)

Reliable Circuit Design

- Simplify designs as much as possible!
  - Since reliability is a function of complexity, anything that can be done to reduce complexity will, as a rule, increase reliability
- Use standard components and circuits when possible
- Transient and overstress protection
  - Consider the effects of EMI, ESD, capacitance, inductance
- Parameter degradation analysis
  - Parts are known to change with time; must ensure that different tolerances can not combine in such a way that interferes with intended function.

6 Design Principles to follow… (cont.)

Redundancy

- Incorporate when needed.

- Active Redundancy - elements not required to perform function of detection, decision and switching when element fails.

- Standby Redundancy - elements are required to detect, make a decision and switch as replacement for failed element.

6 Design Principles to follow… (cont.)

Environment Design

- Temperature protection
  - Heat sinks, fans, thermal conduction plane on printed circuit boards, liquid cooling if severe!
- Shock and vibration protection
  - Heavy components should be supported mechanically rather than completely relying on solder connections
  - Solder has poor fatigue properties
- Moisture and chemical protection
- Sand and dust protection
- Variable electric supply
  - Spikes, ESD
  - Operator misuse: improper powering of automobile batteries
- Transient noise and electrostatic protection

6 Design Principles to follow… (cont.)

Human Factors Design

- People use systems, people cause problems!
  - People operate systems, people fix systems
  - Design so fixable, usable, etc..

Design Reviews

- Critical audits aimed at assuring that the most satisfactory design has been selected.

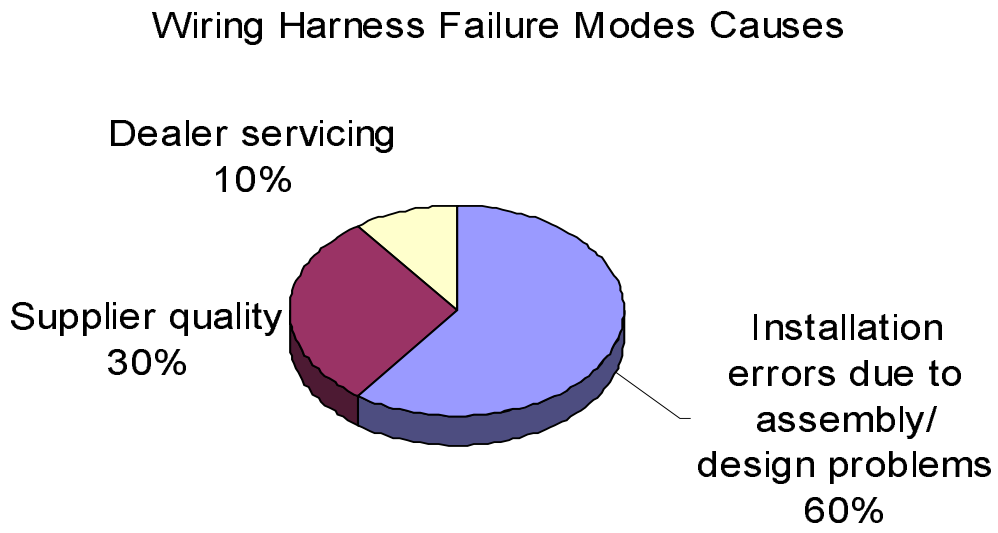
The automotive world: Wiring Harnesses

- **Automobiles pretty good with dealing with the majority of electrical problems**
- **Wiring harnesses mainly susceptible to failure for "mechanical reasons"**
  - Opens or shorts due to physical interruptions
  - Damage during wiring installation (piercing with screws)

- Entrapment by an adjacent component during torque down
- Chafing due to omission of retaining clips

The automotive world: Wiring Harnesses

- **Largest portions of failures due to:**
  - Supplier quality
  - Routing
  - Installation
  - Service



Conclusions: the big picture.

- **At first glance, electronics is a safe medium to build safety critical systems.**
- **Like most aspects of engineering, there are a bunch of things that can go wrong!**
  - Some electronic components can wear over time
  - Others "wear" by having their component parameters drift
- **Subsystems tend to wear by corrosion, fracture of connectors, etc.**
- **Non-operating failures can be a significant problem**

- **Experience, methodology and forethought are the keys to designing reliable Electronic systems!**