Electrical & Computer ENGINEERING

18-642:

Embedded Software Safety Overview

These tutorials are a simplified introduction, and are not sufficient on their own to achieve system safety. You are responsible for the safety of your system.

10/25/2018

"Engineering is achieving function while avoiding failure."
– Henry Petroski

Carnegie Mellon University

Is Your System Appropriately Safe?

Edge Case Research

- **Anti-Patterns for Embedded System Safety:**
  - Requirements do not address safety
  - Not using an appropriate safety standard
  - Safety analysis assumes perfect software
  - Redundancy management inadequate
- **Actually *know* system is safe**
  - Correctness is only a starting point
    - Requirements and other aspects matter
  - Fault responses must be safe
    - Hardware faults (permanent; transient)
    - Software faults

General Motors recalls 4 million vehicles after software linked to 1 death

https://goo.gl/EgxHEo

By Associated Press SEPTEMBER 9, 2016, 9:55 AM

The company said Friday that in rare cases, the car's sensing and diagnostic module — a tiny computer that senses what the vehicle is doing and controls air bag deployment — can go into test mode. If that happens, the front air bags won't inflate in a crash and the seat belts may not work either.

https://goo.gl/vnqH7G

Defense-In-Depth For Safety

- **Avoid faults occurring**
  - Careful design of software to avoid software defects
  - Use robust hardware to avoid hardware run-time faults
- **Detect and contain faults**
  - Error correction HW, redundant CPUs
  - Watchdog timers for failed tasks, exception handling
- **Use Fail Safe strategies to mitigate hazards**
  - For example, automatic safety shutdown mechanisms
- **Incidents require operator intervention (or luck)**
  - Operator may be able to react correctly and quickly
  - Incident will be a mishap some fraction of time
- **Want to avoid escalation as much as possible**
  - E.g., fail safe approaches that work to avoid incidents

(For more information, see ***Safeware***, Leveson 1986, pp. 149-150)

Basic Safety Principles

Adapted from MISRA 1994

Edge Case Research

- **Safety must be seen to be present**
  - **System presumed unsafe unless convincing safety argument made**
  - Outsider must be able to determine safety purely from documents
- **The greater the risk, the greater the need for information**
  - Riskier systems require more engineering rigor
- **Safety must be built in, not added on**
  - If code is created without a safety process, throw it away; start over
- **Systematic, random, and malicious faults all matter**
  - Consider design errors and transient faults (e.g., soft errors)
  - If it's not secure, it's not safe
- **Safety must be argued in writing and demonstrated**
  - Failure-free testing isn't enough
- **Safety is a lifecycle concern**
  - "Mission critical failures" can be considered "safety" as well

Safety Culture: Everyone Is Sure It's Safe

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- **Space Shuttle Challenger Mishap**
  - January 1986 launch explosion; 7 fatalities
  - Dual O-rings keep hot gases inside solid booster
    - History of sometimes failing if too cold
    - At launch, joint temperature was below freezing
  - Booster team told: "prove launch is unsafe"
    - Should have been: "no launch *unless* proven safe"
    - Getting lucky is not the same thing as being safe

EXTERNAL FUEL TANK

SOLID ROCKET SEGMENTS

JOINTS

SOLID ROCKET JOINT

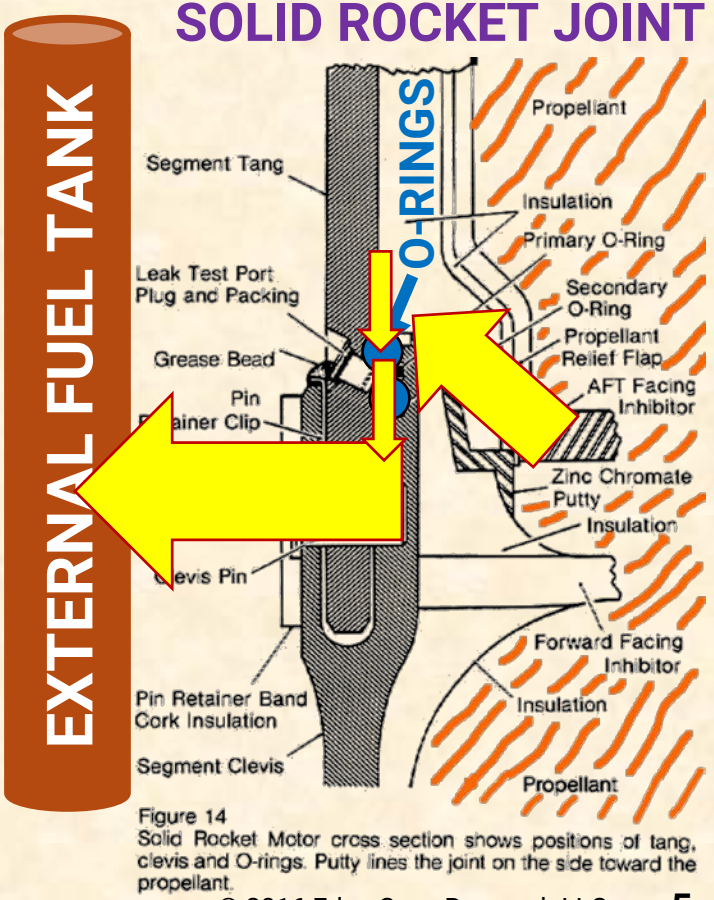
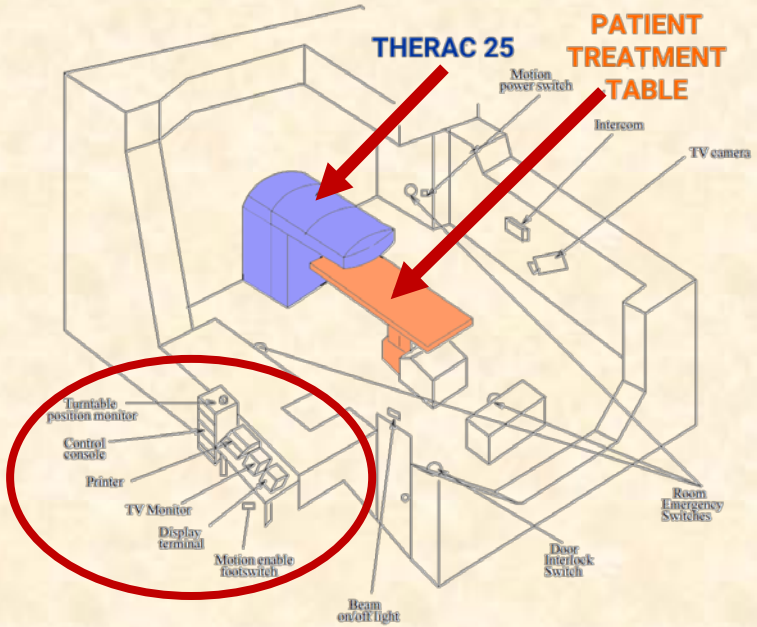


Figure 14
Solid Rocket Motor cross section shows positions of tang, clevis and O-rings. Putty lines the joint on the side toward the propellant.

Overview of Embedded System Safety

Edge Case Research

- **Safety Topics:**
  - Safety Plan & Safety Standards
  - Safety Requirements
  - Critical System Design
  - Dependability
  - Single Points of Failure
  - Redundancy Management
  - Isolation Mechanisms
  - Safety Architectural Patterns



(1985 – 1987) THERAC 25
Software-Controlled Radiation Therapy Mishaps

- **Pitfall:**
  - Safety isn't just about whether you think it's safe …
    … it's about **whether you can prove it is appropriately safe**