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Single Points of Failure



**“Put all your eggs in
one basket, and then
watch that basket!”**

– Mark Twain

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.

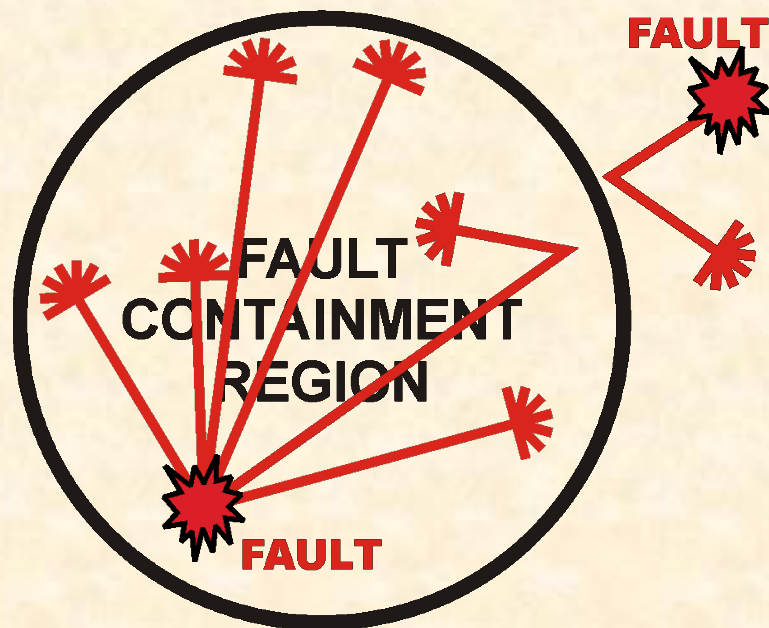
Avoid Single Points of Failure

■ Anti-Patterns for Critical Software:

- Hardware single points of failure
- Correlated, accumulated multi-point failures
- Making assumptions about failures
- Non-diverse, low-SIL software

■ Fault Containment Region (FCR)

- Faults from outside FCR are kept out
 - Faults inside FCR are kept in
- But, **within FCR a single fault has arbitrarily bad effects**
 - It's like a shotgun blast inside the FCR
 - Applies to both SW faults and HW faults (e.g., single event upsets)



Toyota Unintended Acceleration (UA)

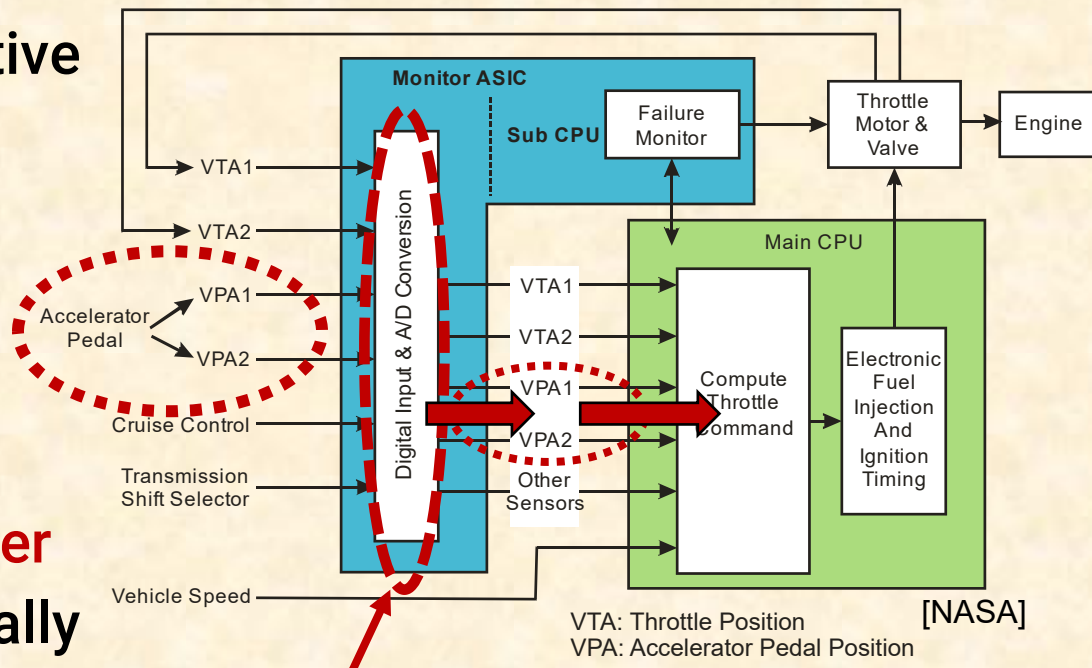
■ Perhaps 89 deaths, hundreds of serious injury lawsuits

- \$1.6B class action settlement
- Jury found system defective
 - Toyota “acted in reckless disregard”
- Many of issues were SW, but also a HW problem:

■ Two accelerator inputs

- But – **shared A/D converter**
- Could result in electronically “stuck” accelerator pedal

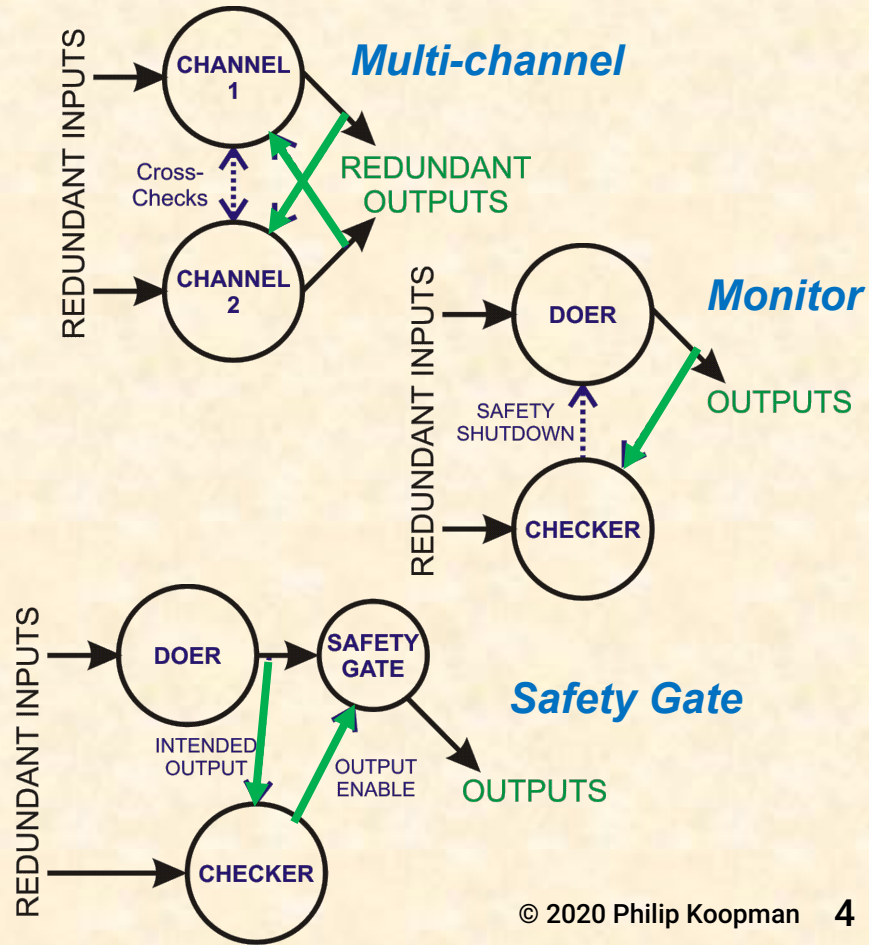
Toyota Electronic Throttle Control



Single Point of Failure

Eliminating Single Points of Failure

- Multiple FCRs required for life-critical and highly mission-critical systems
 - This isolates faults in redundant components – no single point of failure
 - Avoid an Achilles' Heel in your system
 - All software on CPU can be a “single point”
- Multi-channel (e.g., 2 of 2)
 - Compare identical component outputs
- Doer/Checker (monitor/actuator pair)
 - “Checker” makes sure “Doer” is safe
- Safety gate
 - Only permits safe outputs to issue



Correlated & Accumulated Faults

■ Correlated faults if multiple FCRs are likely to fail together

- Common design faults (including software)
- Common manufacturing faults
- Shared infrastructure (e.g., power, clock)
- Physical coupling
 - Shared wiring harness, connectors
 - Shared location (e.g., hot spot)



USAF: <https://goo.gl/df5pdg>

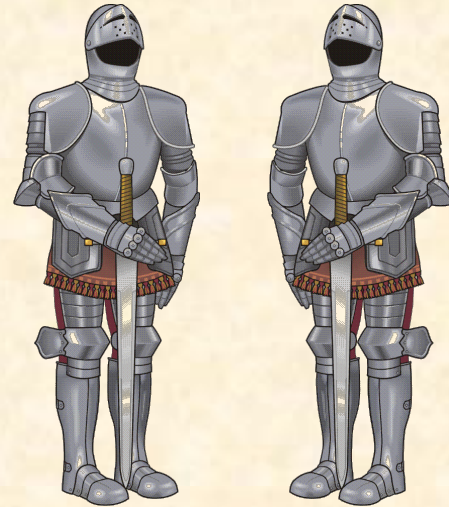
■ Accumulated faults

- Fault not detected
- Fault not repaired before next mission

Best Practices To Avoid Single Points of Failure

■ Safety is improved by using multiple FCRs

- Hardware redundancy / HW isolation
 - Typically each FCR should be an independent chip
- Software must be practically “perfect”
- Common patterns: multi-channel, checker, safety gate



■ Pitfalls are numerous and sometimes subtle

- Two copies of same SW fail the same way
- Ensure multi-channel doesn't fail as “always trust one channel”
- Ensure the checker doesn't fail as “always checks OK”
- Look for hidden correlation (HW design defects, shared libraries, shared requirement defects, physical connection, shared clock, shared power, ...)

⚠ ERROR

IF YOU'RE SEEING THIS, THE CODE IS IN WHAT I THOUGHT WAS AN UNREACHABLE STATE.

I COULD GIVE YOU ADVICE FOR WHAT TO DO. BUT HONESTLY, WHY SHOULD YOU TRUST ME? I CLEARLY SCREWED THIS UP. I'M WRITING A MESSAGE THAT SHOULD NEVER APPEAR, YET I KNOW IT WILL PROBABLY APPEAR SOMEDAY.

ON A DEEP LEVEL, I KNOW I'M NOT UP TO THIS TASK. I'M SO SORRY.



NEVER WRITE ERROR MESSAGES TIRED.

<https://xkcd.com/2200/>