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Redundancy Management

I'm not dead!
'Ere, he says he's not dead.
Yes he is.
I'm not.
He isn't.
Well, he will be soon, he's very ill.
I'm getting better!
– Monty Python

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.

Is Your Redundancy Working?

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- Anti-Patterns for Redundancy:
  - Unsafe because double-spending redundancy
  - No between-mission redundancy diagnostics
  - Low test coverage on redundant components

- Redundant components help reliability
  - But, what happens when a component breaks?
    - Need to gracefully curtail current mission
    - Prohibit additional missions until repaired
  - Reliability assumes perfection at mission start
    - Untested redundancy undermines reliability

https://goo.gl/oBNliw

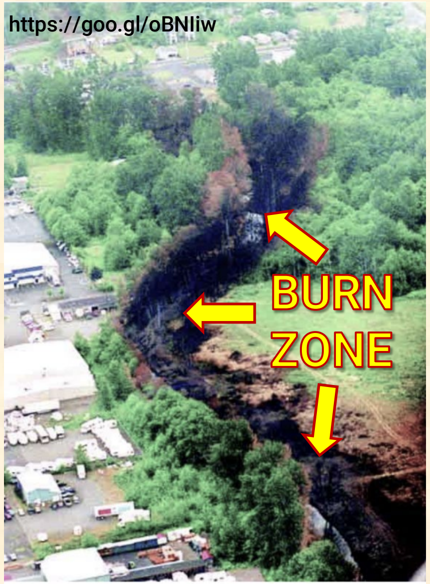

Figure 1. Postaccident aerial view of portion of Whatcom Creek showing fire damage.

Bellingham WA, June 1999: Gasoline spill & fire kills 3 due to improper management of SCADA redundancy

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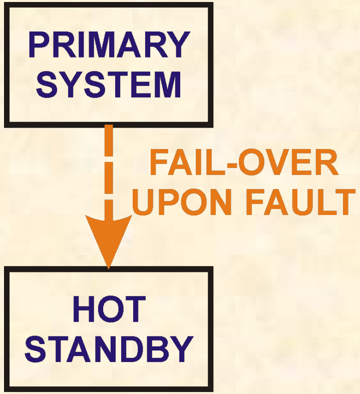
Response To A Component Failure

- **Use of Redundancy: Availability**
  - Hot Standby takes over upon failure
  - Assumes somehow you detect failure
    - For low criticality systems, perhaps it's OK to miss some failures; have human trigger failover

Hot Standby Pattern

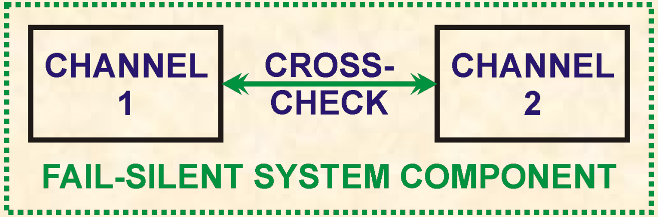


Remember Ariane 5 Flight 501?

- **Even if only one component breaks at a time…**
  - Single computer can fail "active" (dangerous)
  - Self-test cannot find all faults
  - Single component is unsafe for SIL 3,4

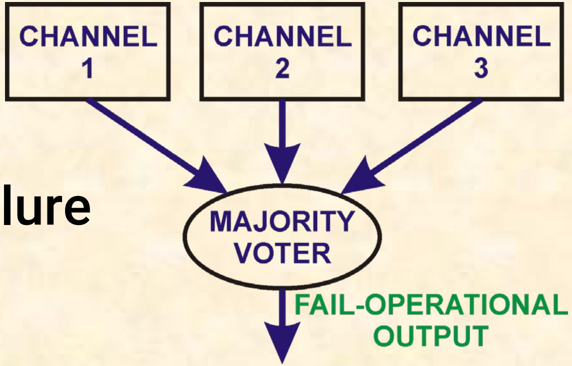
- **Use of Redundancy: Fault Detection**
  - 2-of-2 used for fault detection

2-of-2 Fail Silent Pattern

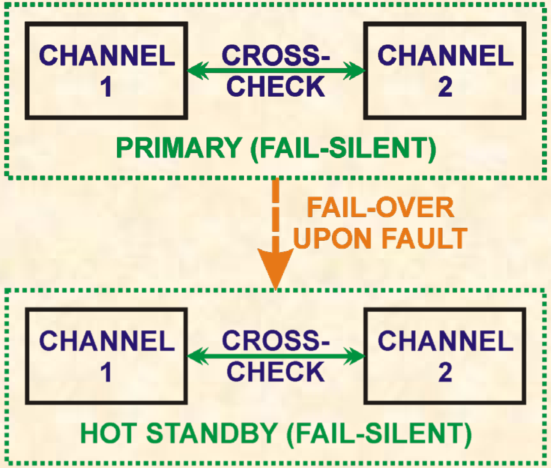


Fail Operational Approaches

- **Can't double-spend redundancy!**
  - Need 2 components to detect a failure
  - PLUS more components to operate after failure
- **Triplex modular redundancy (2-of-3)**
  - Three copies of subsystem and voter
  - But … voter can be single point of failure!
- **Dual 2-of-2**
  - Two copies of subsystem for availability
  - Each subsystem is 2-of-2 to provide fault detection



2-of-3 Voter Pattern



Dual 2-of-2 Pattern

Doer/Checker & Redundancy

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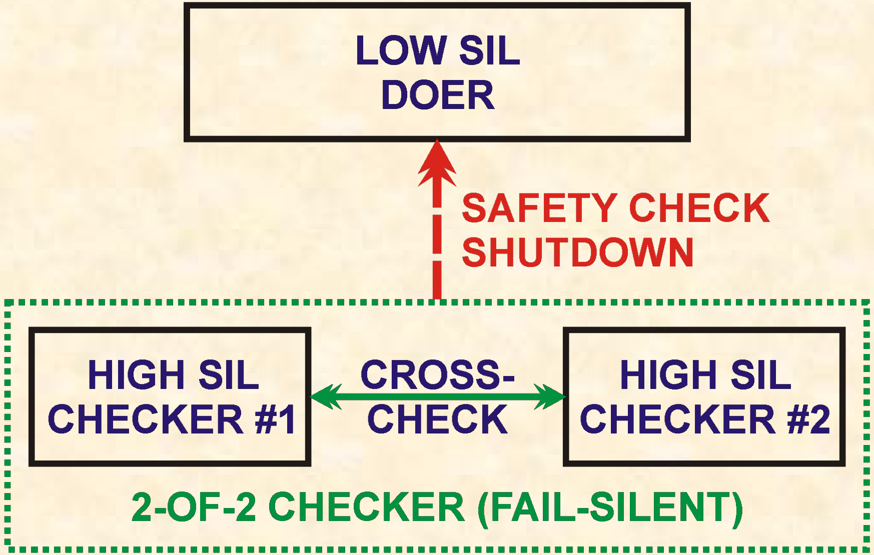
- Hybrid of Low SIL Doer and High SIL 2-of-2 checker
  - Single Low SIL primary
    - Provides normal functionality
  - 2-of-2 High SIL checker
    - Shuts down if primary unsafe
    - Shuts down if cross-check fails

- Common building blocks:
  - 2-of-2 for fault detection
  - Doer/Checker for fault isolation
  - Hot standby for fail operational



Mixed-SIL Doer/Checker Pattern

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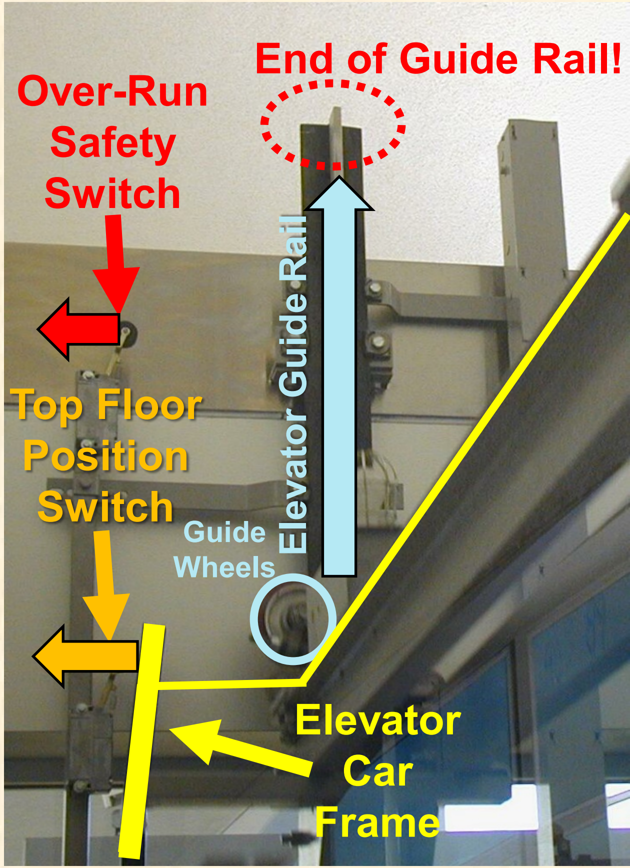
Diagnostic Effectiveness

- Reliability math assumes ***all*** redundancy working
  - On-line diagnostics: self-test at start of mission
    - Example: IEC 60730 self-test library
  - Off-line diagnostics: “Proof test”
    - Example: exercise an elevator safety limit switch
- Latent undetected faults
  - Undetectable faults lead to coincident failures
    - 2-of-2 doesn’t work if both fail the same way!
  - Run-time detection: frequent health cross-checks
    - Scrub state, e.g., compare RAM values
    - Swap active units periodically to self-test
  - Off-line detection: enforce periodic proof tests
    - Self-test or require diagnostic to resume operation



Best Practices For Redundancy Management

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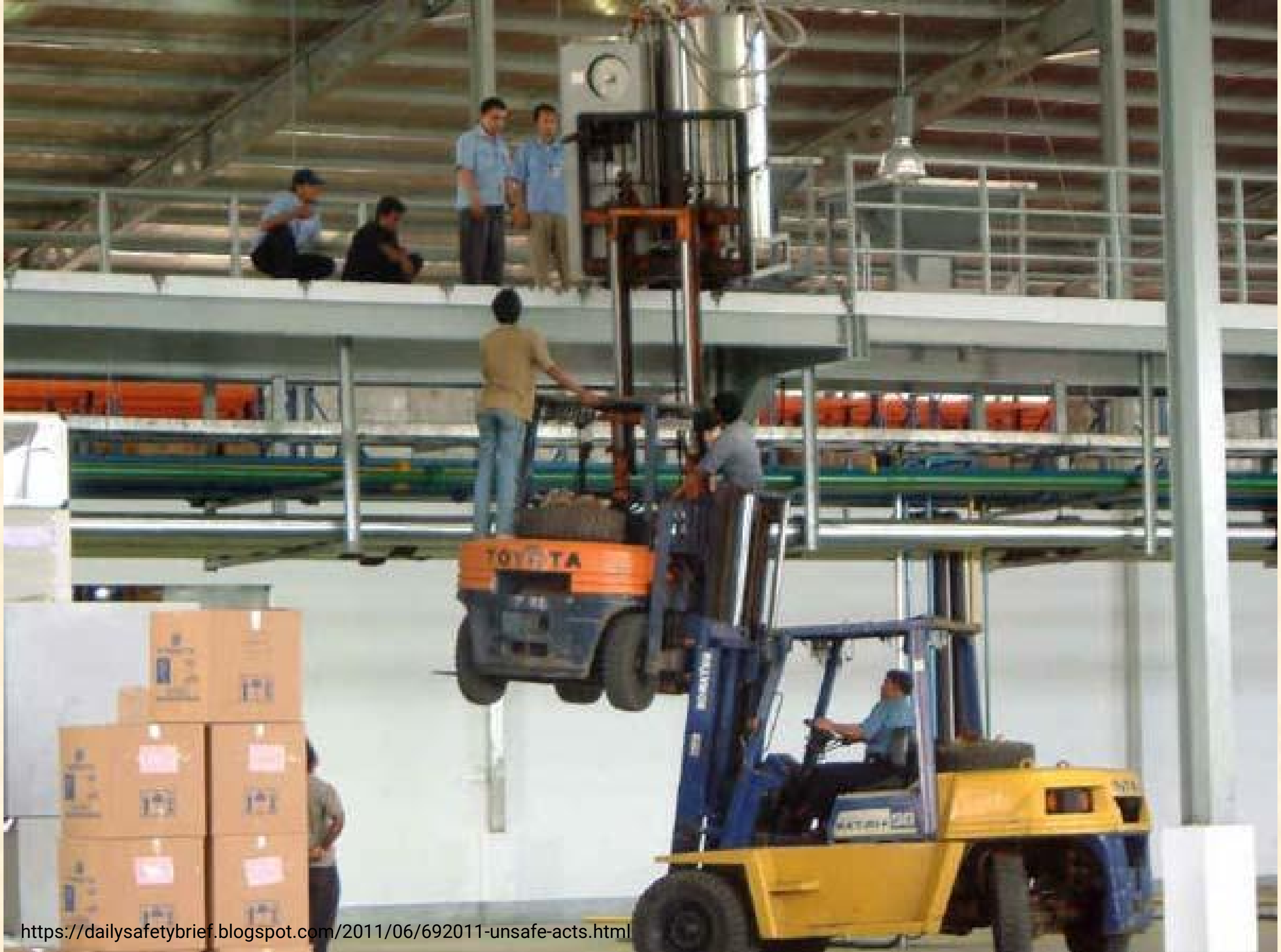
- What happens when component fails?
  - Some redundancy is for fault detection
  - Other redundancy is for availability
  - Plan how to detect & survive failures
- Diagnostic coverage matters
  - Pre-mission test; cross-checks; proof tests
  - Minimize potential for latent faults
- Pitfalls:
  - Don’t double-spend your redundancy (detect & failover are different)
  - Look for common-mode failures (e.g., software updates)

https://goo.gl/iT4QLx

Figure 1. Accident Caused by SIF Failure

Safety Instrumented Function (SIF)
Failure at an Undisclosed Plant



https://dailysafetybrief.blogspot.com/2011/06/692011-unsafe-acts.html