How reliable is your car under EMI?

Quantifying the Resiliency of Networked Control Systems to Transient Faults

Arpan Gujarati
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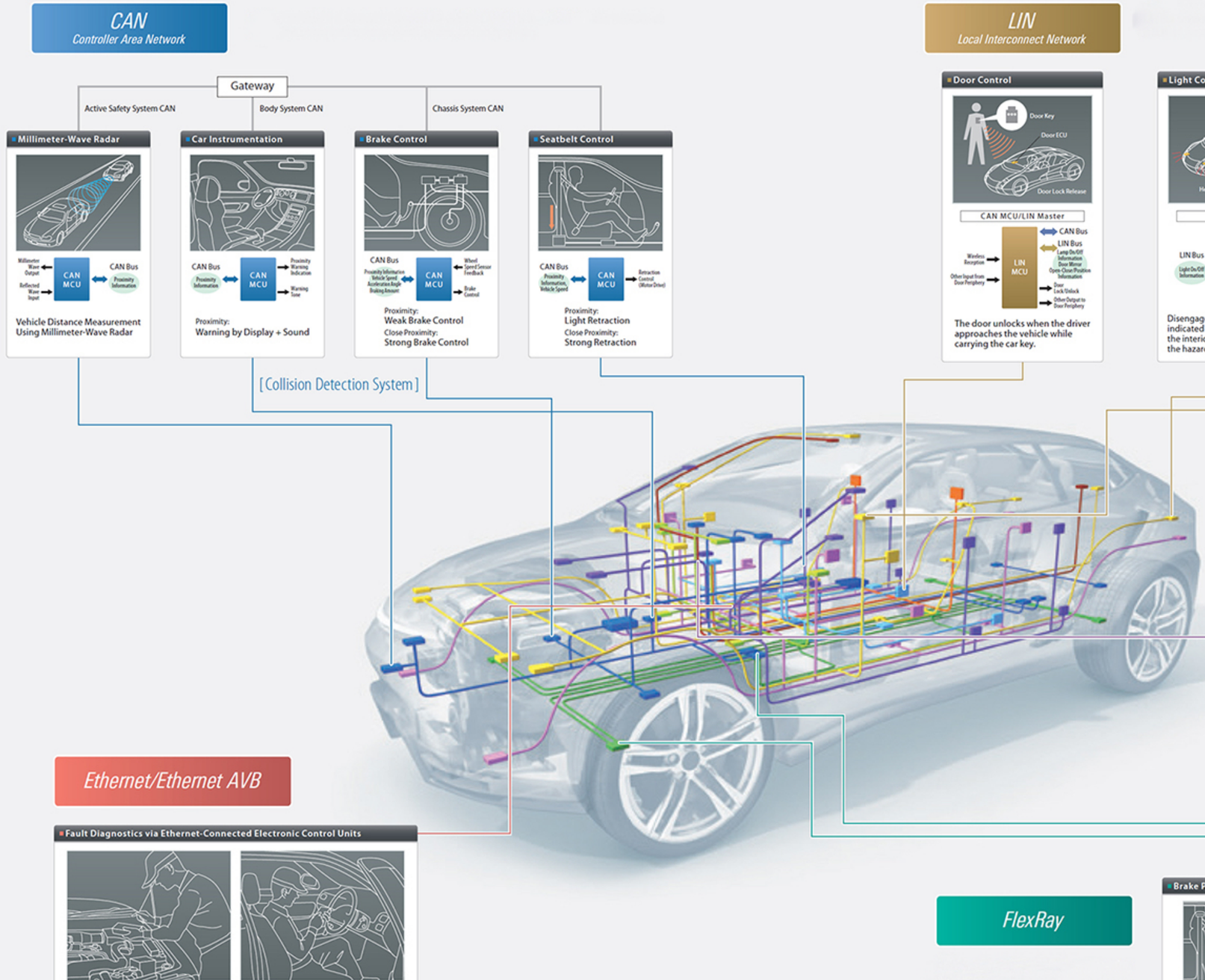
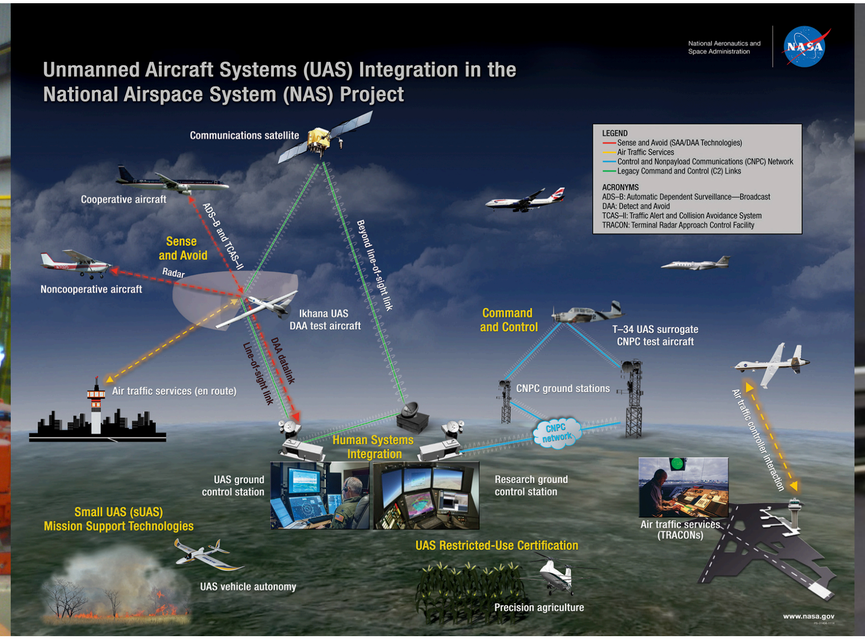


Source: https://www.digikey.com/en/articles/techzone/2014/jul/what-engineers-need-to-know-when-selecting-an-automotive-qualified-mcu-for-vehicle-applications

Networked Control Systems (NCS)

Source: https://commons.wikimedia.org/wiki/File:Float_Glass_Unloading.jpg

Factory Automation



Source: https://www.nasa.gov/sites/default/files/thumbnails/image/uas-nas-integration-lg.jpg

Unmanned Vehicle Navigation

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Domestic Robots

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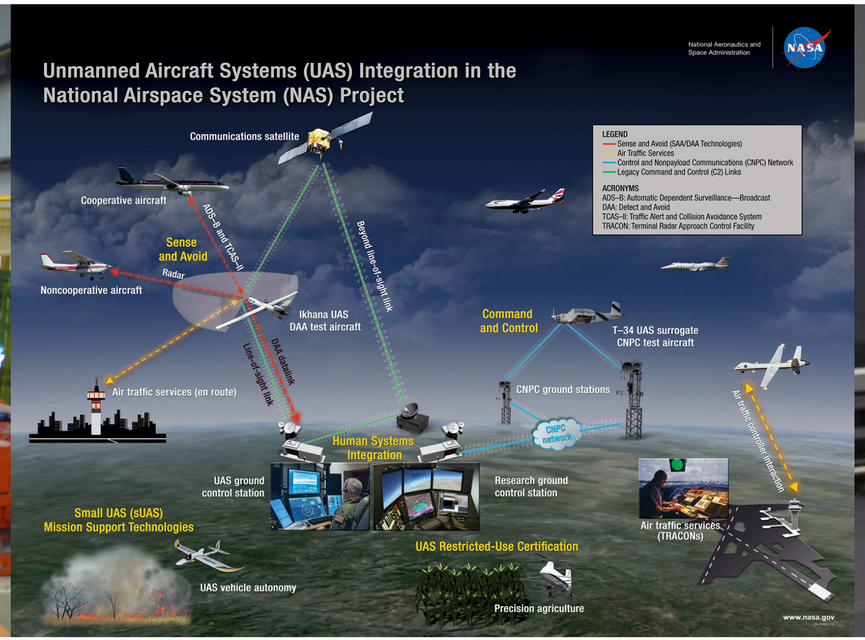

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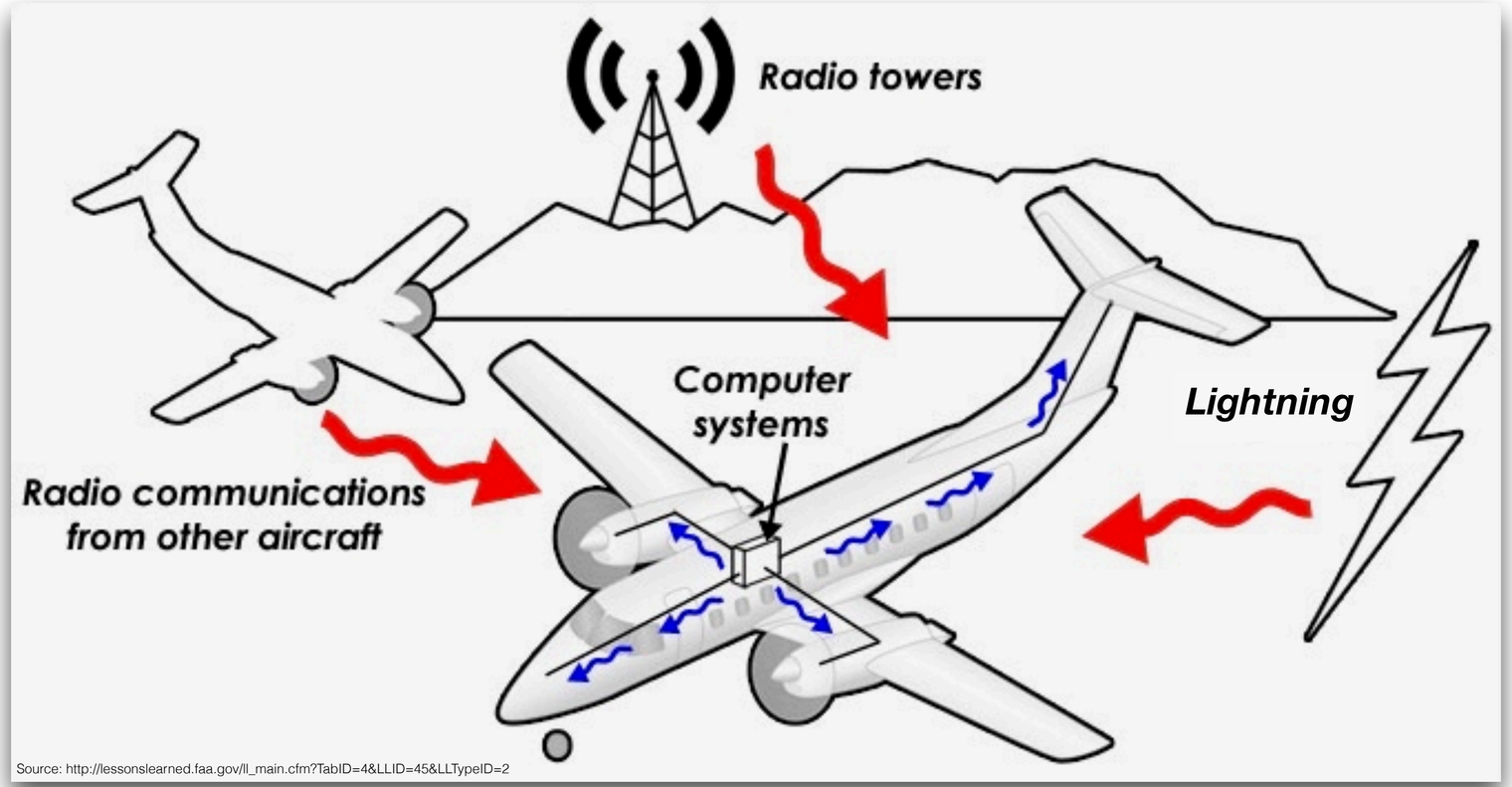
Domestic Robots

NCS = Multiple control loops + Distributed nodes
+ Shared communication network

NCSs are susceptible to **electromagnetic interference (EMI)**



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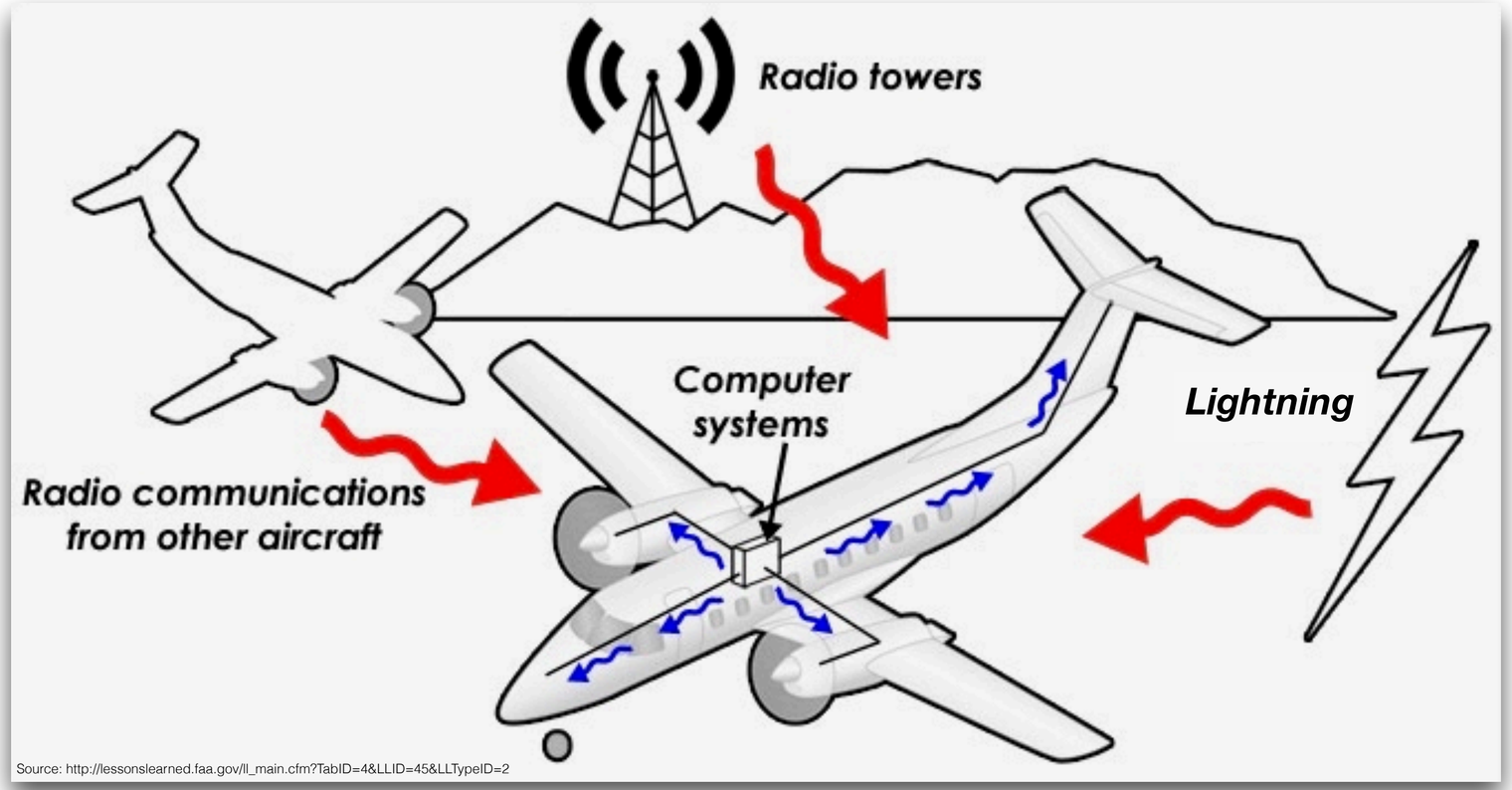

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Program-visible failures

Transmission failures

Message corruptions

Hangs and crashes

Safety-critical NCSs must be **fail-operational**

Continue functioning despite EMI-induced failures

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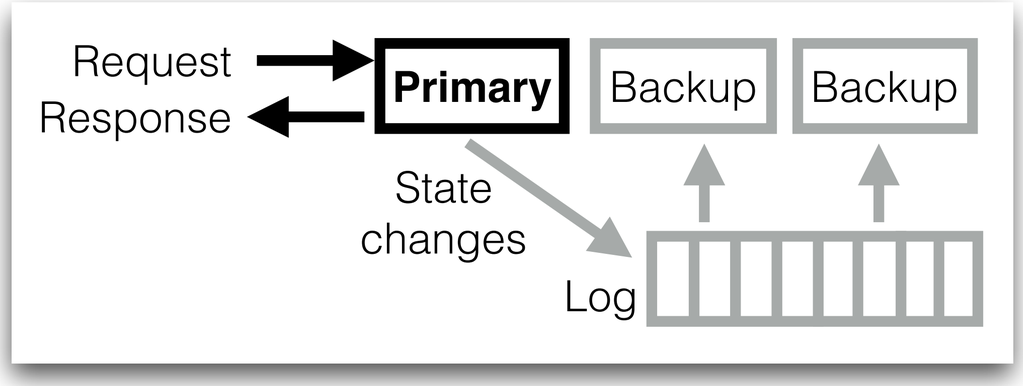
Passive replication



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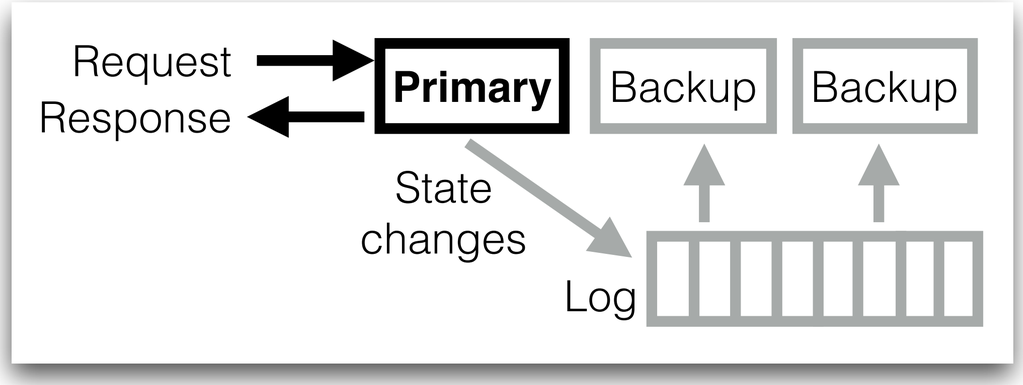
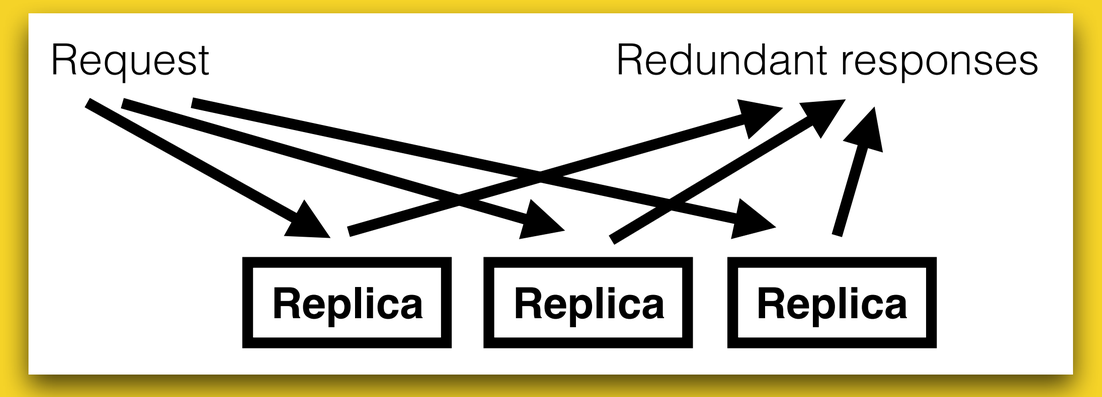


Active replication



... often used for time-sensitive NCSs

What is a **good** **active replication scheme**?

- Which tasks should be replicated?
- What should be their replication factors?
- What should be the replica to node mapping?

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This work

Quantifying the resiliency of NCSs under EMI-induced transient faults

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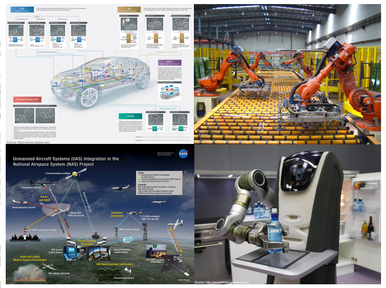
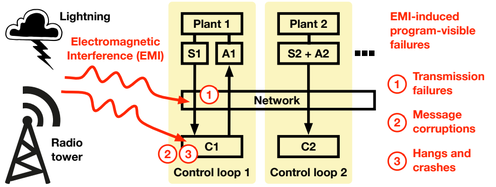


Networked Control Systems (NCS)

= multiple control loops + distributed hosts + shared communication network



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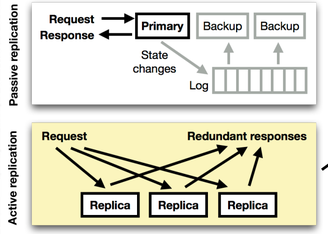
i.e., continue functioning despite EMI-induced failures



Active replication is often used because

- NCSs are time-sensitive
- they may contain high-frequency control loops

Problem

What is a good active replication scheme?

Objective: meet the dependability requirements

Constraints: size, weight, power, and cost

Opportunity: controller inherently robust to occasional disturbances

Solution: Quantifying NCS resiliency to EMI-induced transient faults

… to help engineers design reliable systems under resource budgets or without over-provisioning

Step 1: **P (** single control loop iteration **"fails")**

- CAN-based NCS model
- Probabilistic failure model
- Fault tree analysis
- Simple majority voter for redundancy suppression

Actuation in the iteration deviates from the expected actuation in a failure-free iteration

But the control system may remain stable despite a few failed iterations!

Step 2: **P (** control loop **"fails beyond recovery")**

- Using Step 1
- (m,k)-firm model to characterize controller robustness i.e., at least m out of k consecutive iterations must not fail
- Failures-in-time analysis, i.e., expected failures in one billion operating hours

The control system cannot be stabilized again, e.g., an inverted pendulum crashes on the ground