

How reliable is your car under EMI?

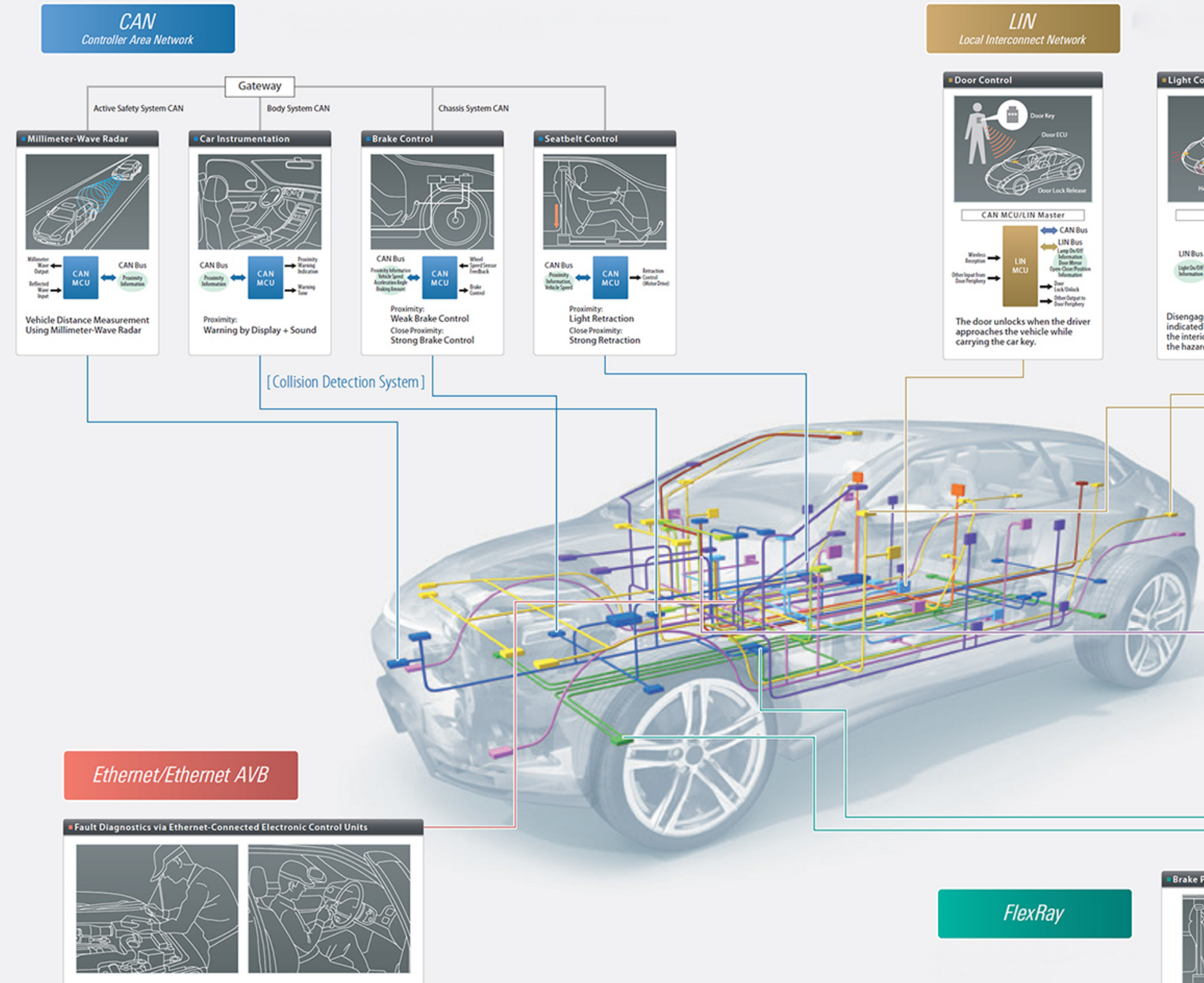
Quantifying the Resiliency of Networked Control Systems to Transient Faults

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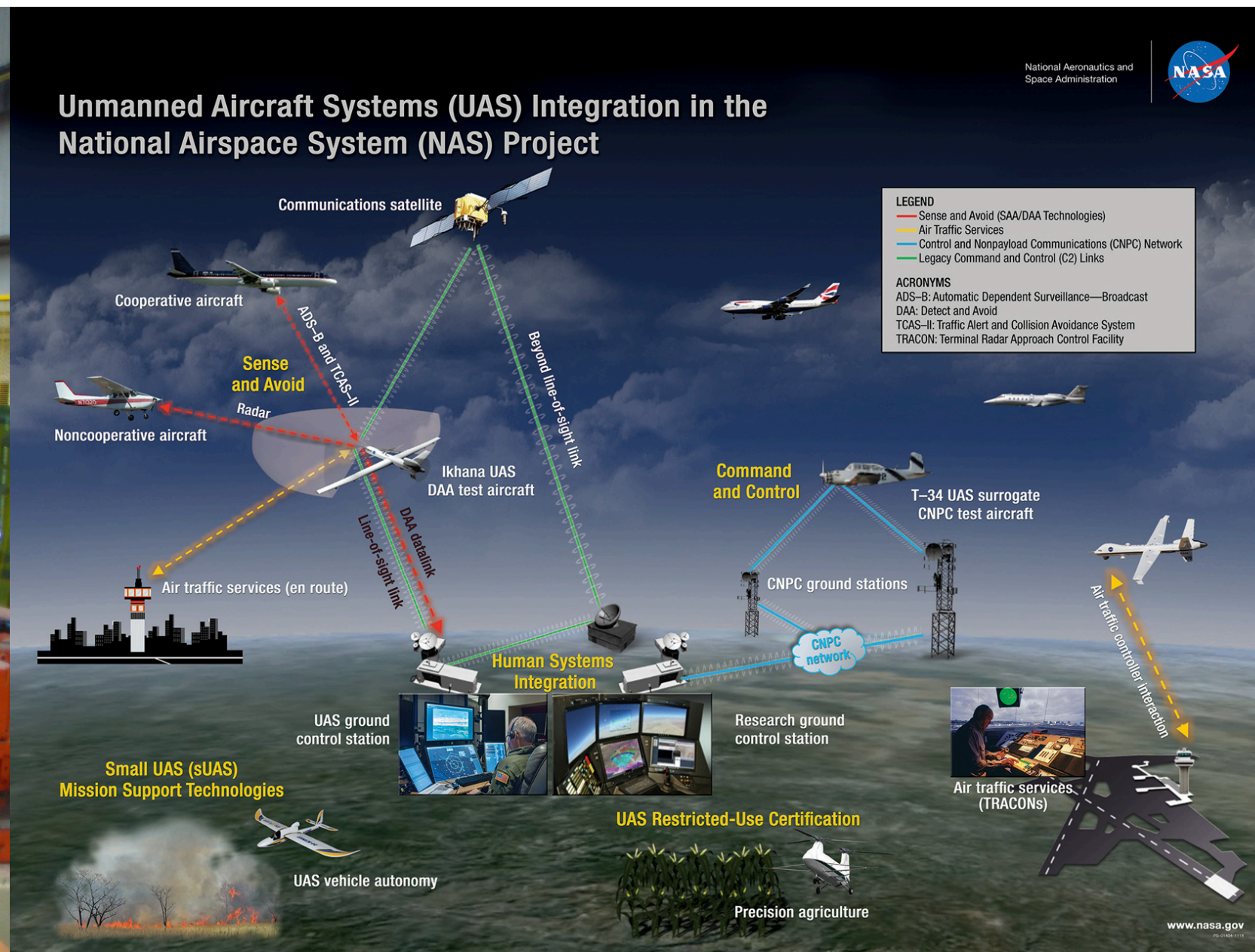


Networked Control Systems (NCS)



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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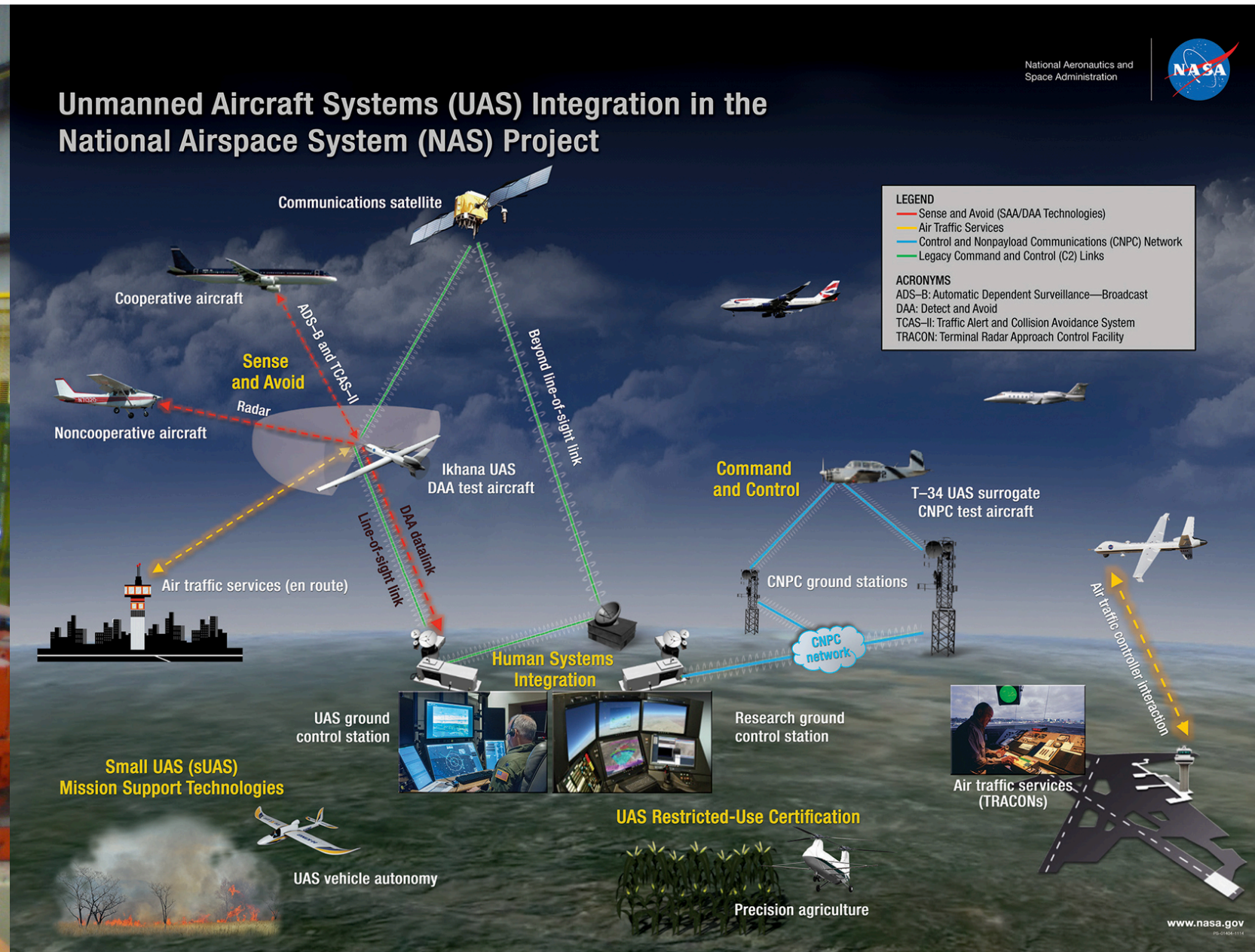
Domestic Robots

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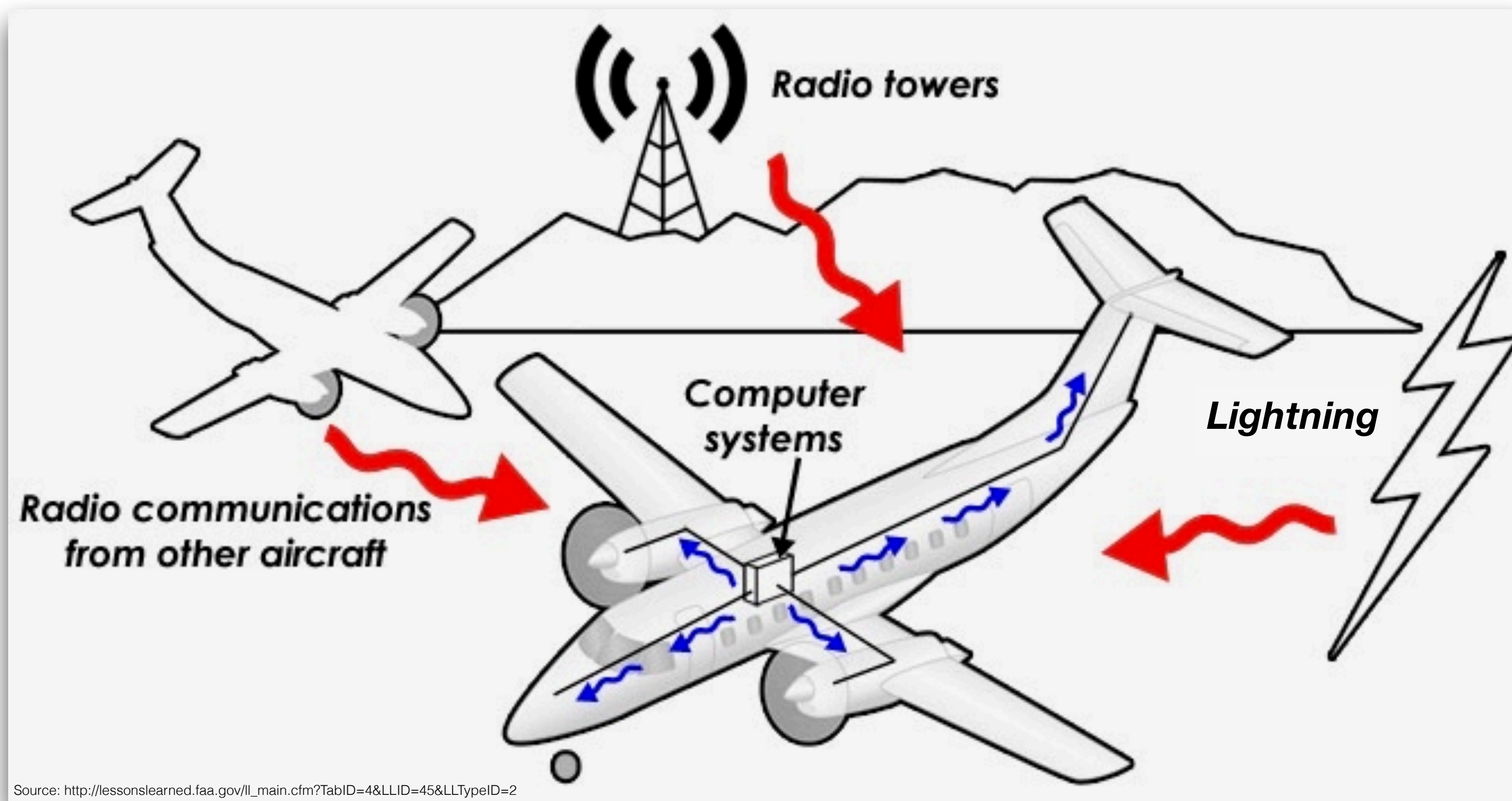


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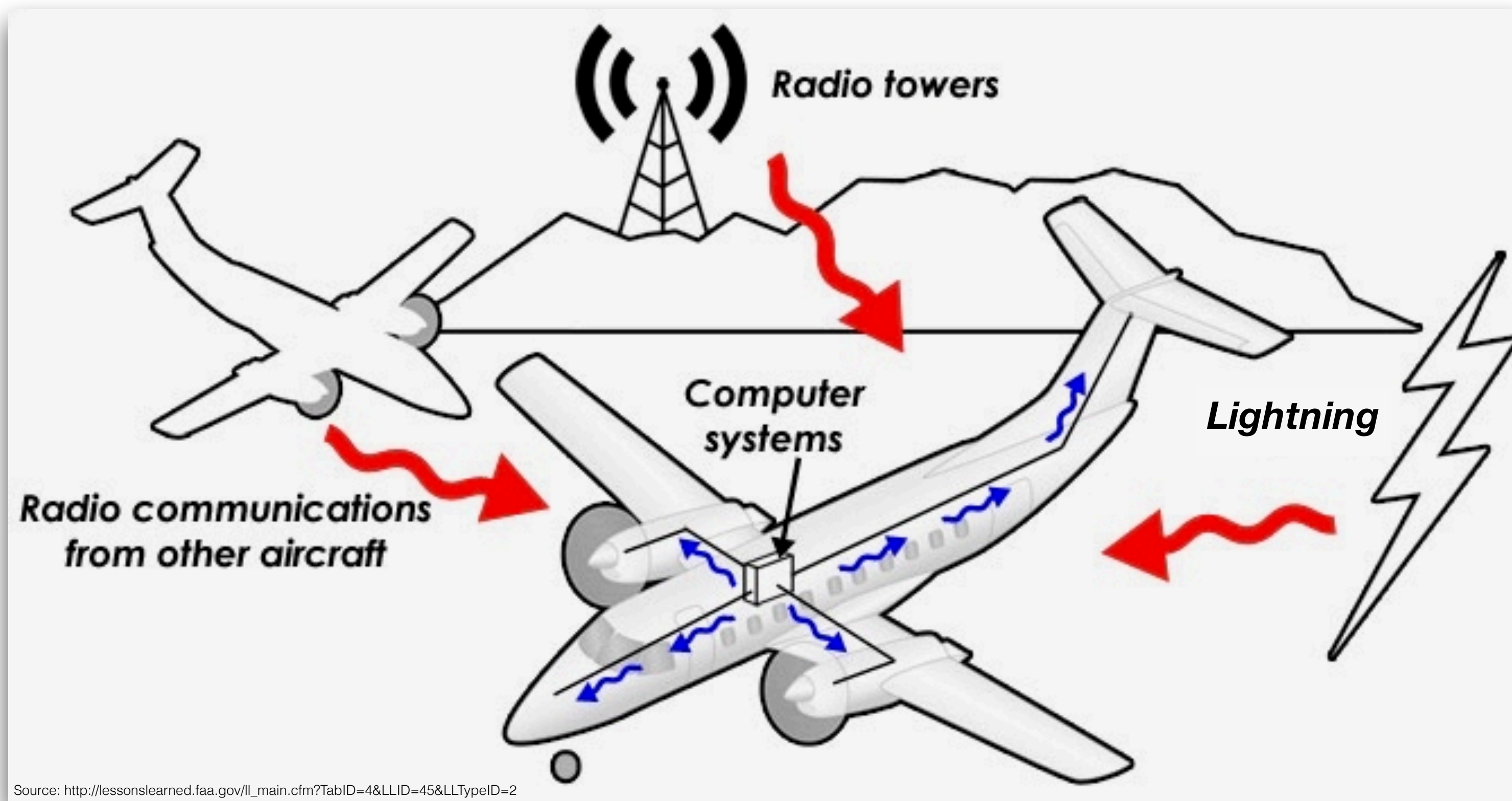
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NCS = Multiple control loops + Distributed nodes
+ Shared communication network

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



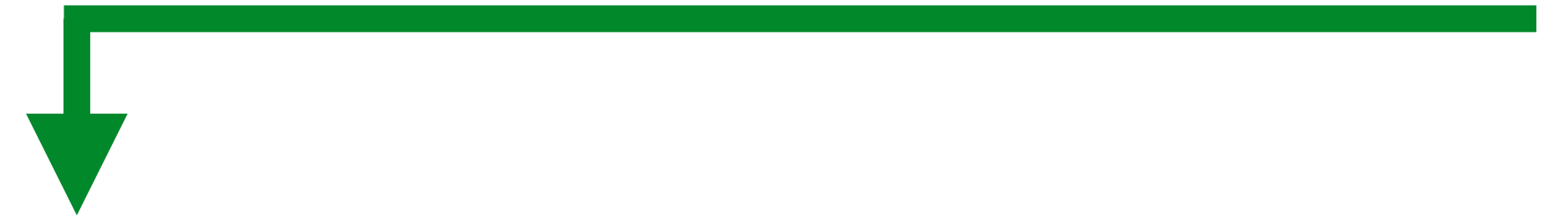
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Program-visible failures

Transmission failures
Message corruptions
Hangs and crashes

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

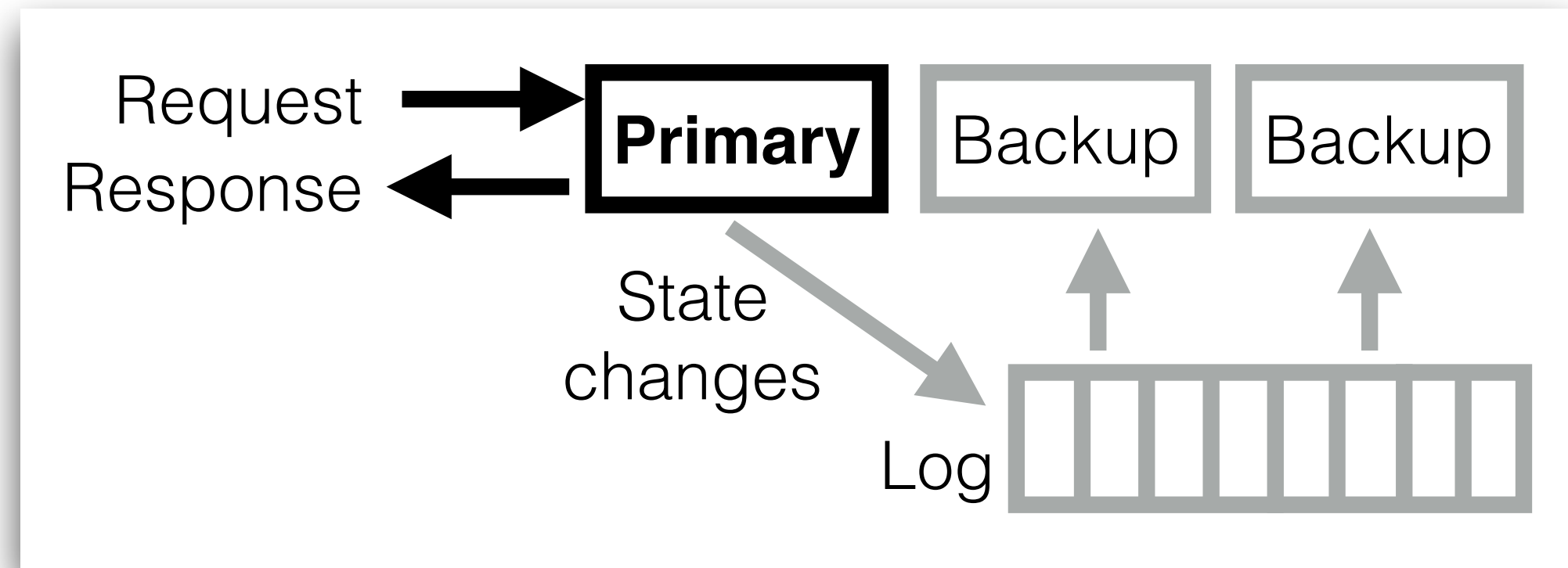


Continue functioning despite EMI-induced failures

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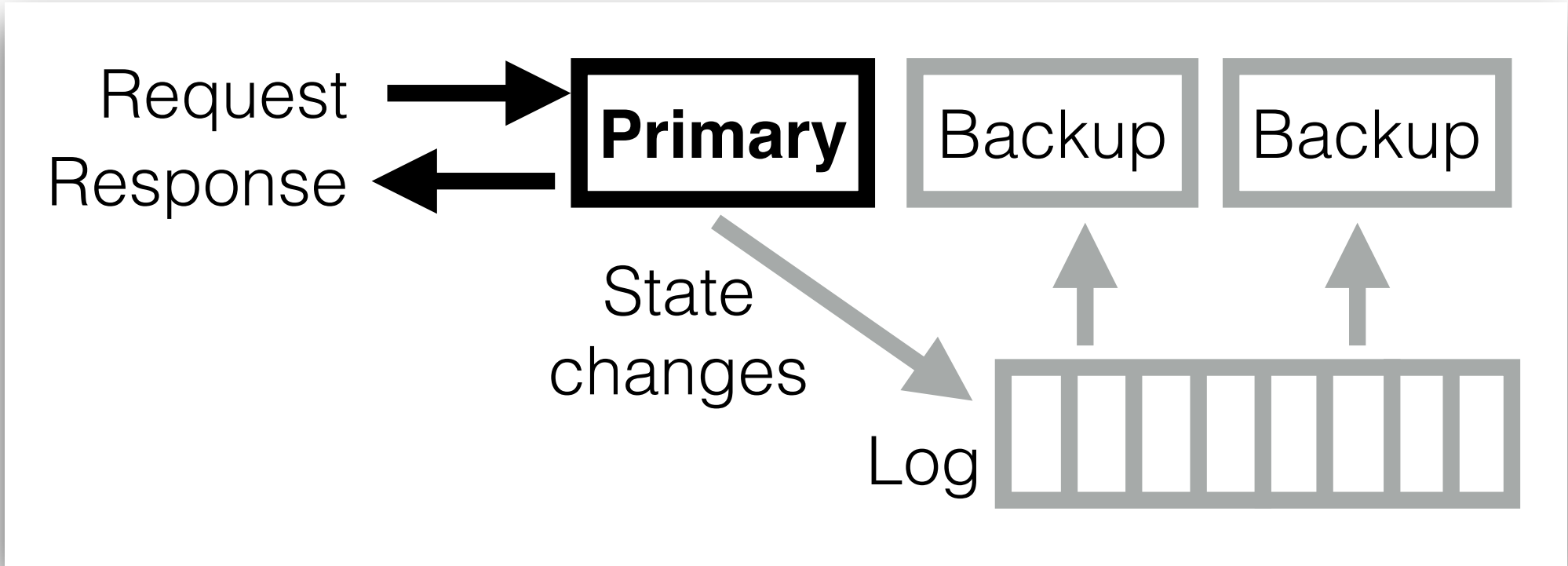
Passive replication



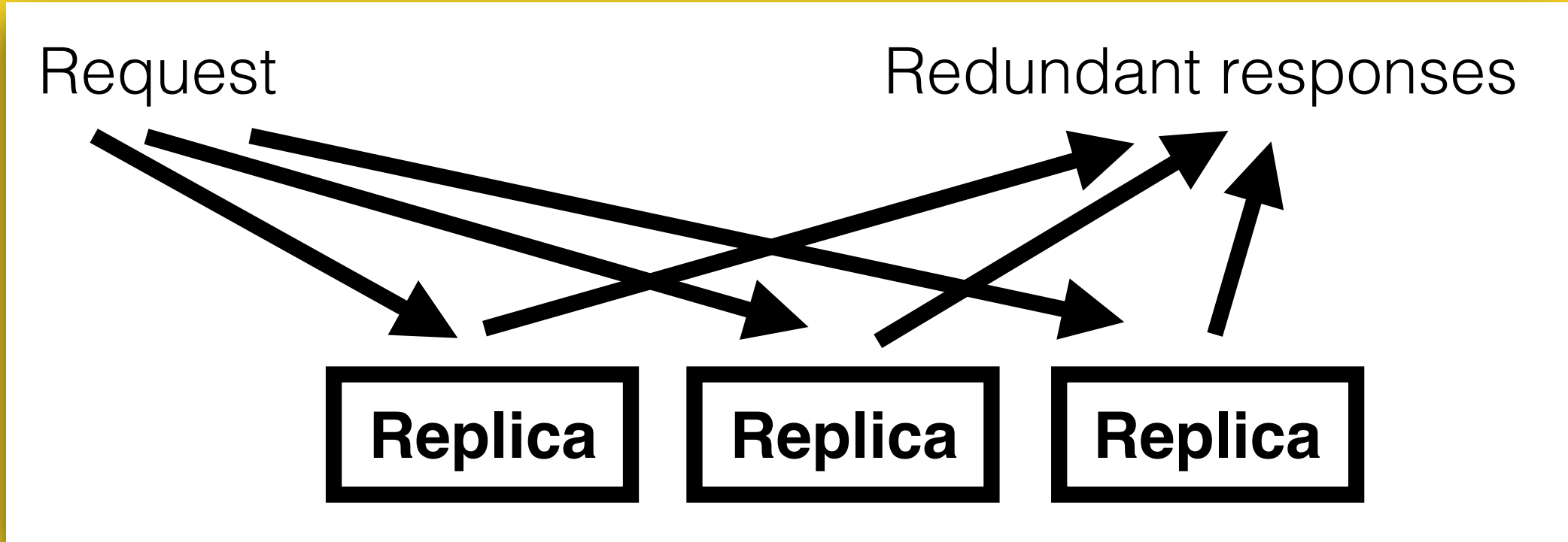
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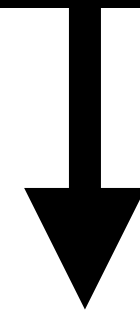


Active replication



... often used for time-sensitive NCSs

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



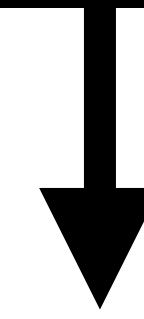
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- ◆ What should be their replication factors?
- ◆ What should be the replica to node mapping?

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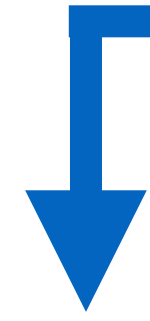
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Meet the dependability requirements



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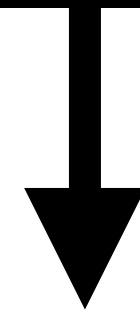


Objective

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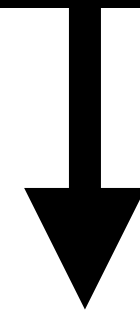
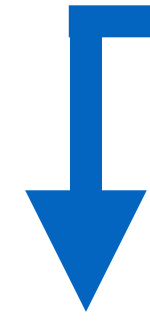
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Size, weight, power, and cost



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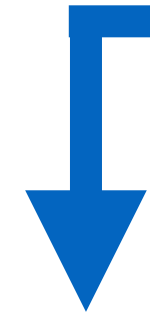
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Opportunity

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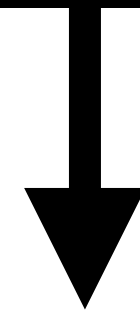
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This work

Quantifying the resiliency of NCSs under EMI-induced transient faults

Features

NCSs connected using the widely used
Controller Area Network (CAN bus)

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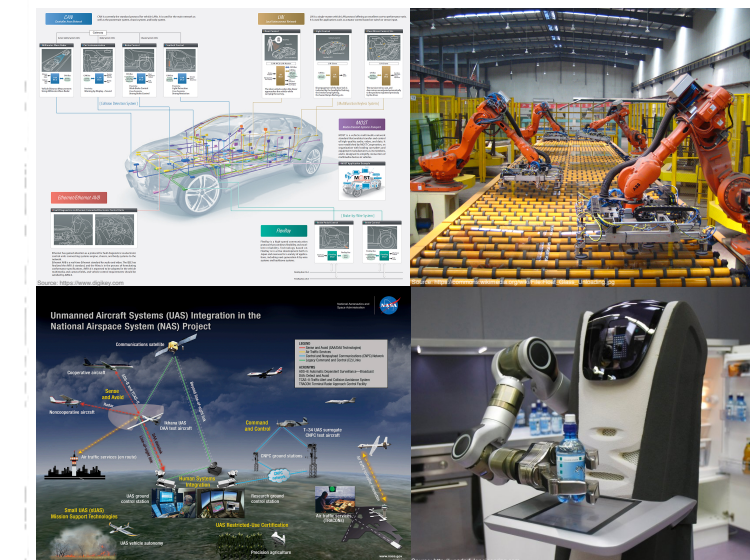
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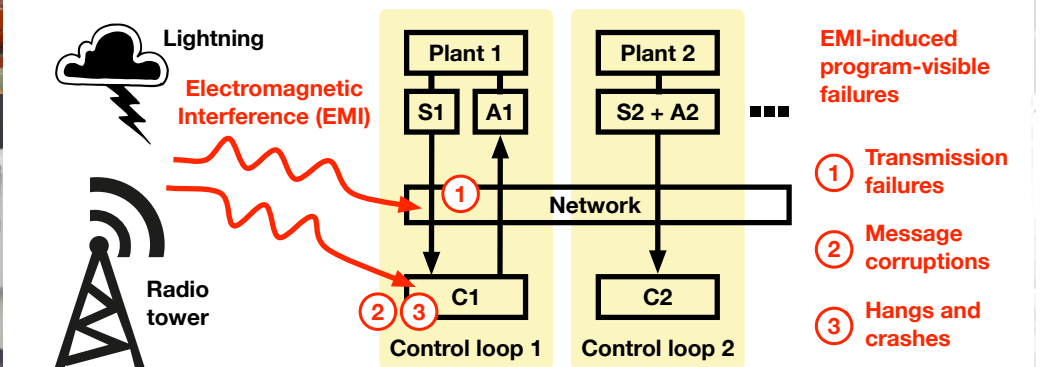
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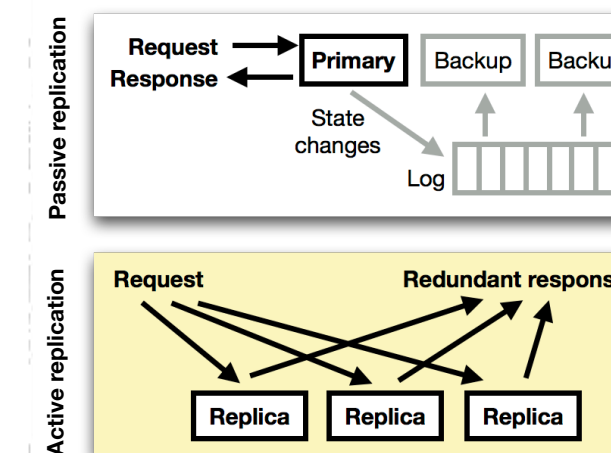
Networked Control Systems (NCS)

= multiple control loops + distributed hosts
+ shared communication network



Safety-critical NCS must be fail-operational

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