Reliability

Advanced Topics in Computer Architecture

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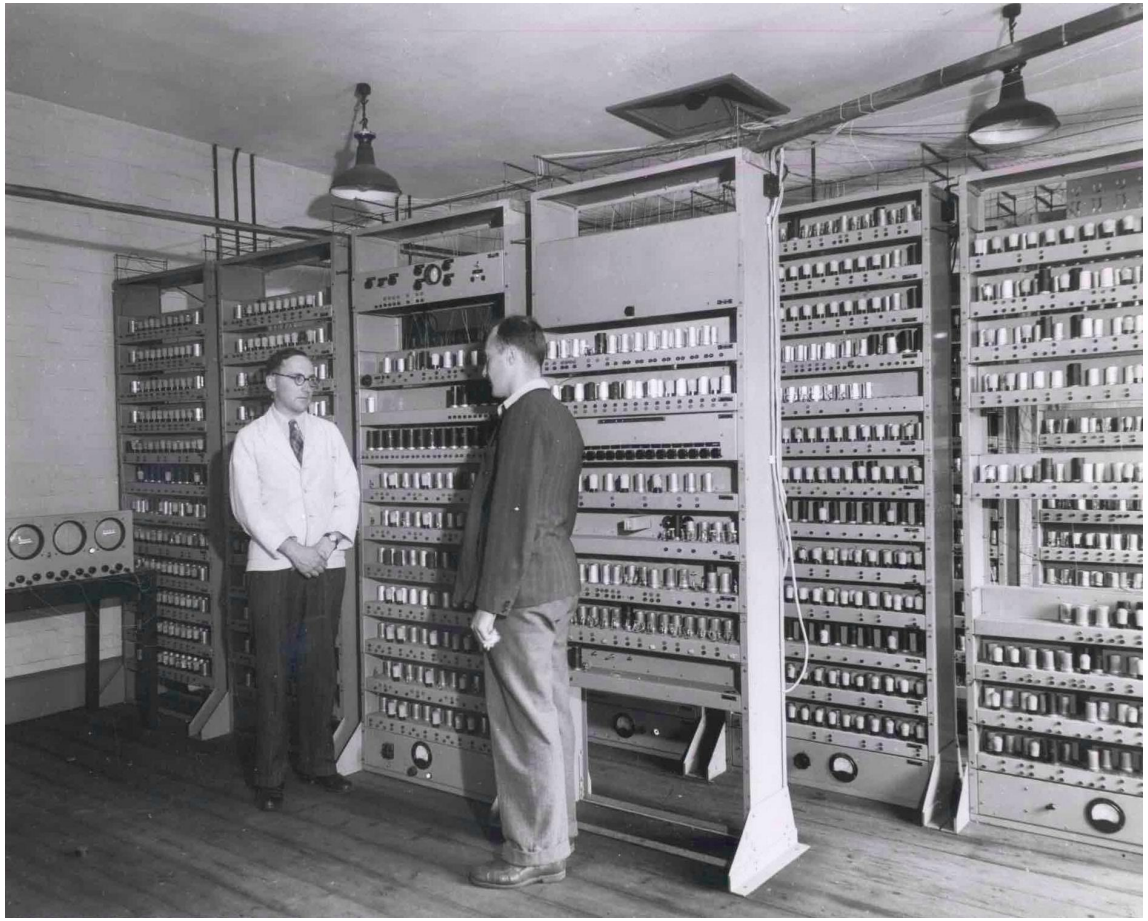
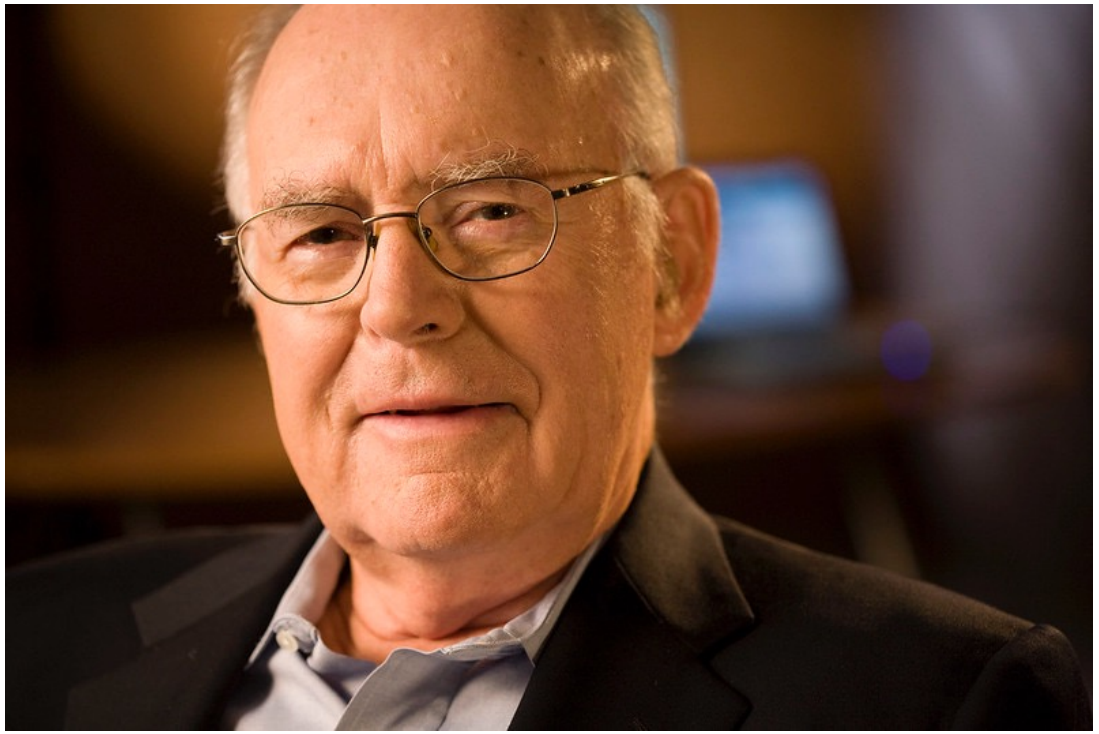
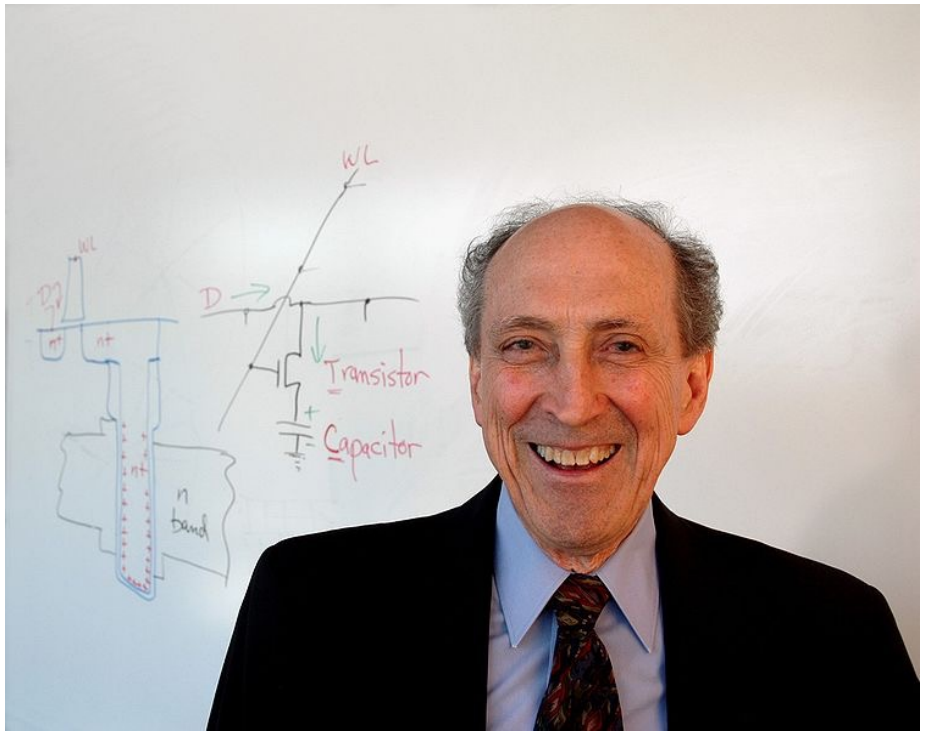
Historic reliability



Silicon trends





Why we care now

- Microprocessors are increasingly used in situations where we want to be sure of their correctness
  - Self-driving cars, nuclear power stations, medical devices, etc
- Many industrial sectors mandate the use of error-detection strategies
  - For example, ASIL standards in automotive
- With increased susceptibility to faults, even non-safety-critical computing starts to require fault tolerance

  https://perspectives.mvdirona.com/2009/10/you-really-do-need-ecc-memory/

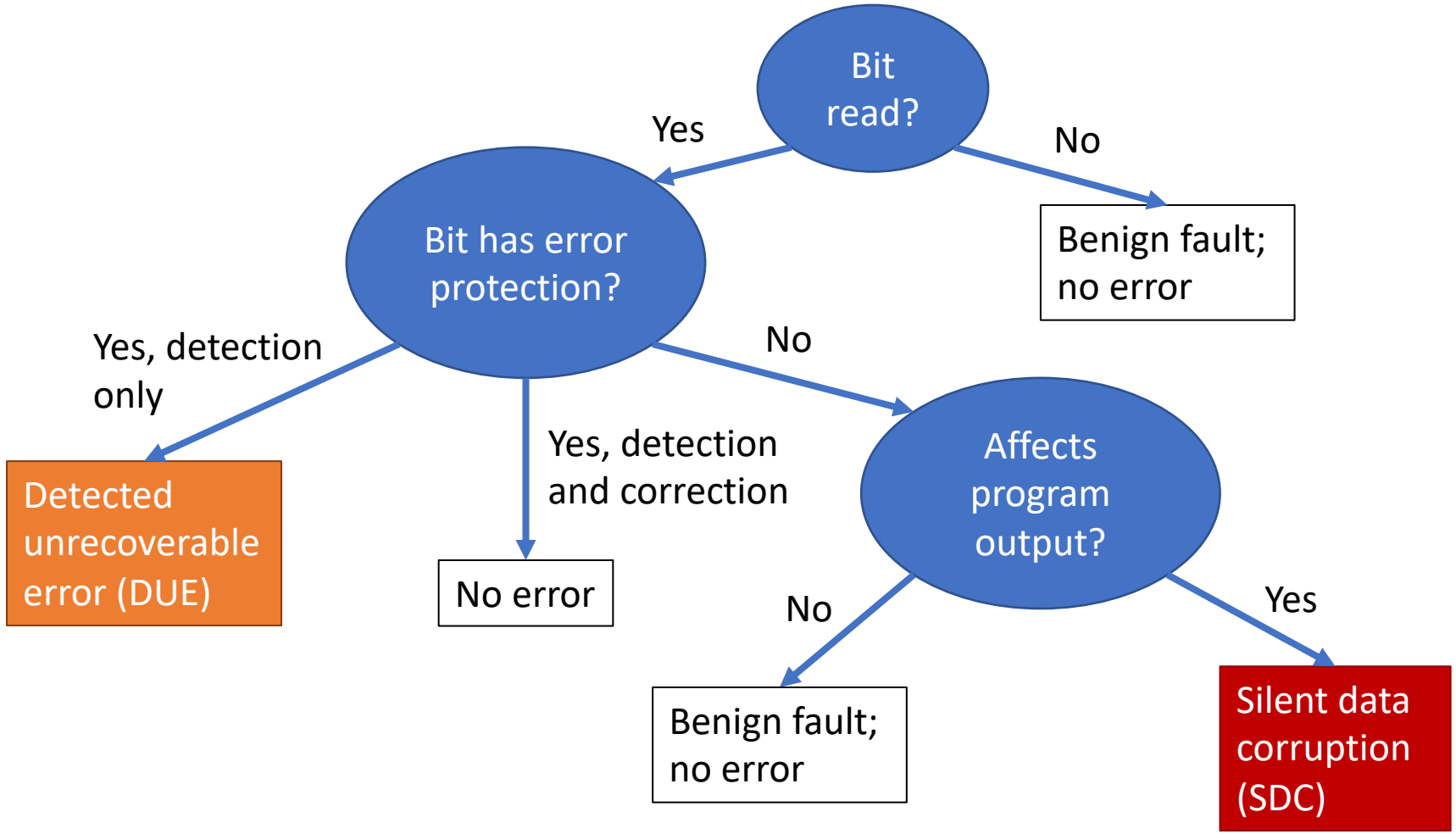
Hard errors

- Permanent errors that affect operation
- Caused by device wearout in-the-field
- Also can occur from manufacturing variabilities

Soft errors

- Transient errors that can affect operation
  - They are transient because their effects don’t last
  - They are not repeatable
- Caused by
  - Alpha particle strikes
  - Cosmic rays!

Error manifestation



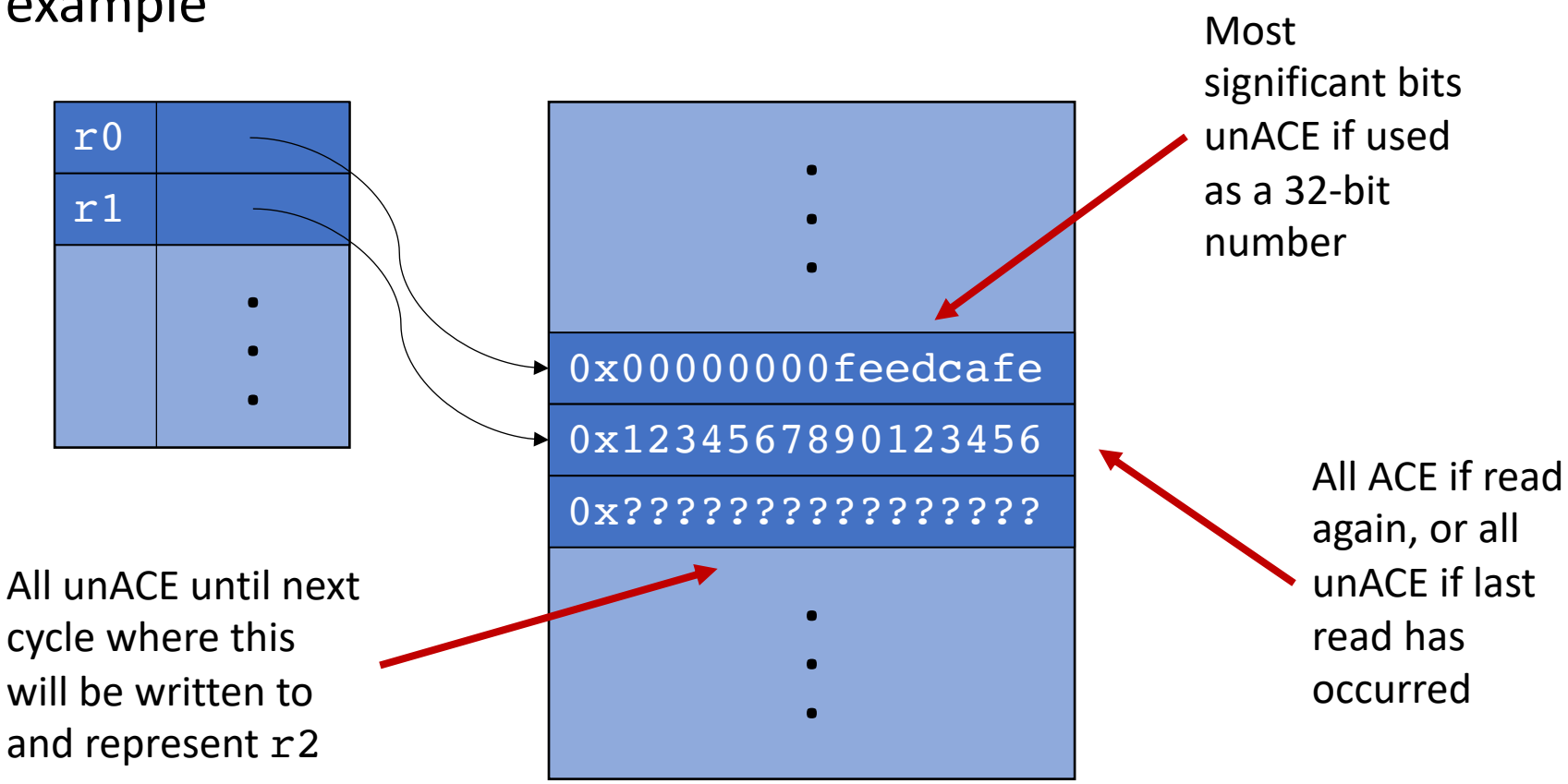
Identifying vulnerabilities

- We can perform an analysis of processor structures to identify vulnerable state
- We identify the bits that are required for architecturally correct execution (ACE)
- These bits *could* result in incorrect output if they were flipped
- The architectural vulnerability factor (AVF) is a useful metric

$$AVF = \frac{\sum_{i=0}^{ncycles} ACEbits}{ncycles \ * nbits}$$

Identifying vulnerabilities

- Bits can be ACE in some cycles, not ACE in others
  - Registers, for example



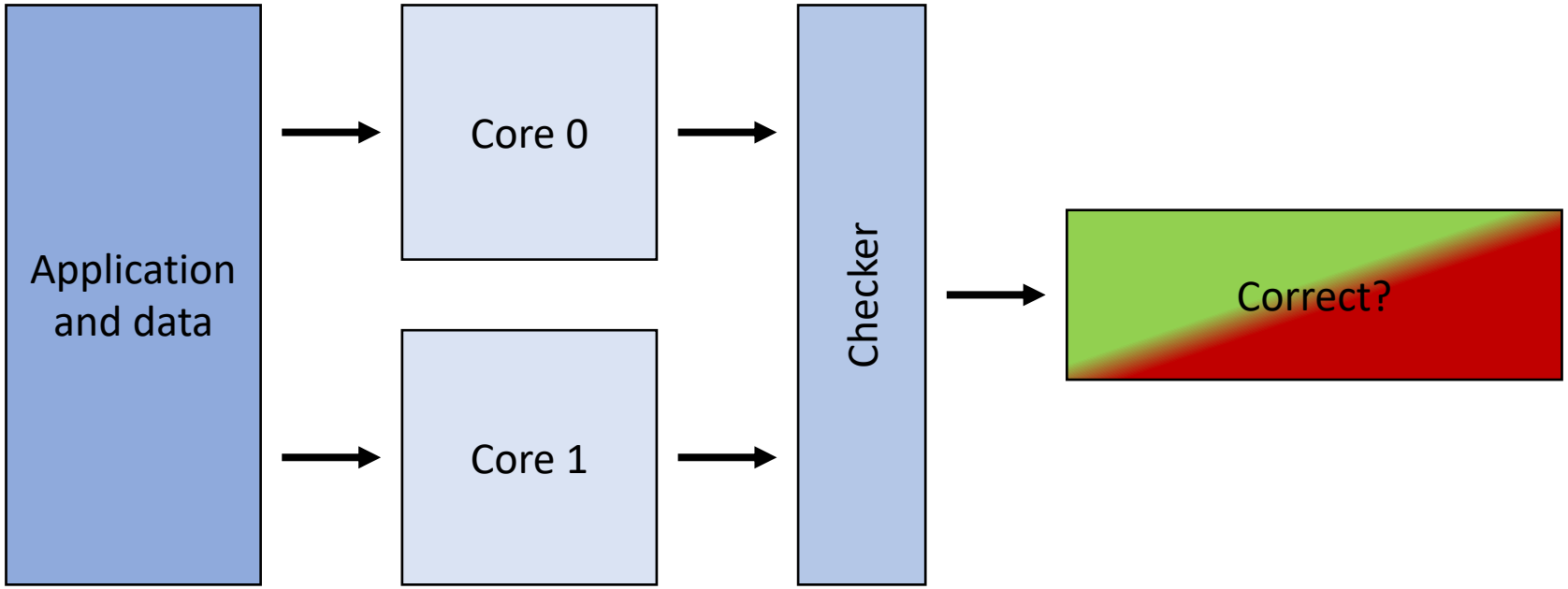
Metrics

- Two related metrics are often used to define reliability
- The FIT rate (failures in time)
  - Defined as the total number of errors per billion device hours
- MTTF (mean time to failure)
  - Represents the time between two errors

$$MTTF \sim \frac{1}{FIT}$$

Dual-core lockstep

- In a system with dual-core lockstep, a program is run twice on different cores
  - Results compared at each cycle
  - Introduces temporal and spatial redundancy into the system



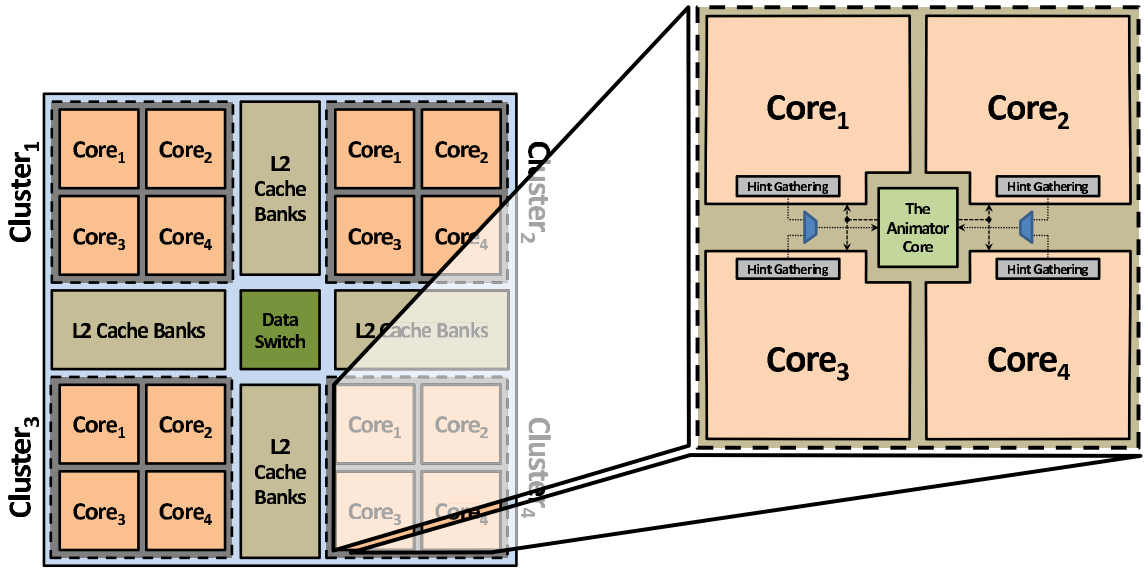
Redundant multithreading

- Run two versions of code and compare results
  - Can be a software scheme, perhaps with some hardware support
  - Or a purely hardware approach

- Can run on different cores with one passing the other data
- Or the same core, within a different SMT context

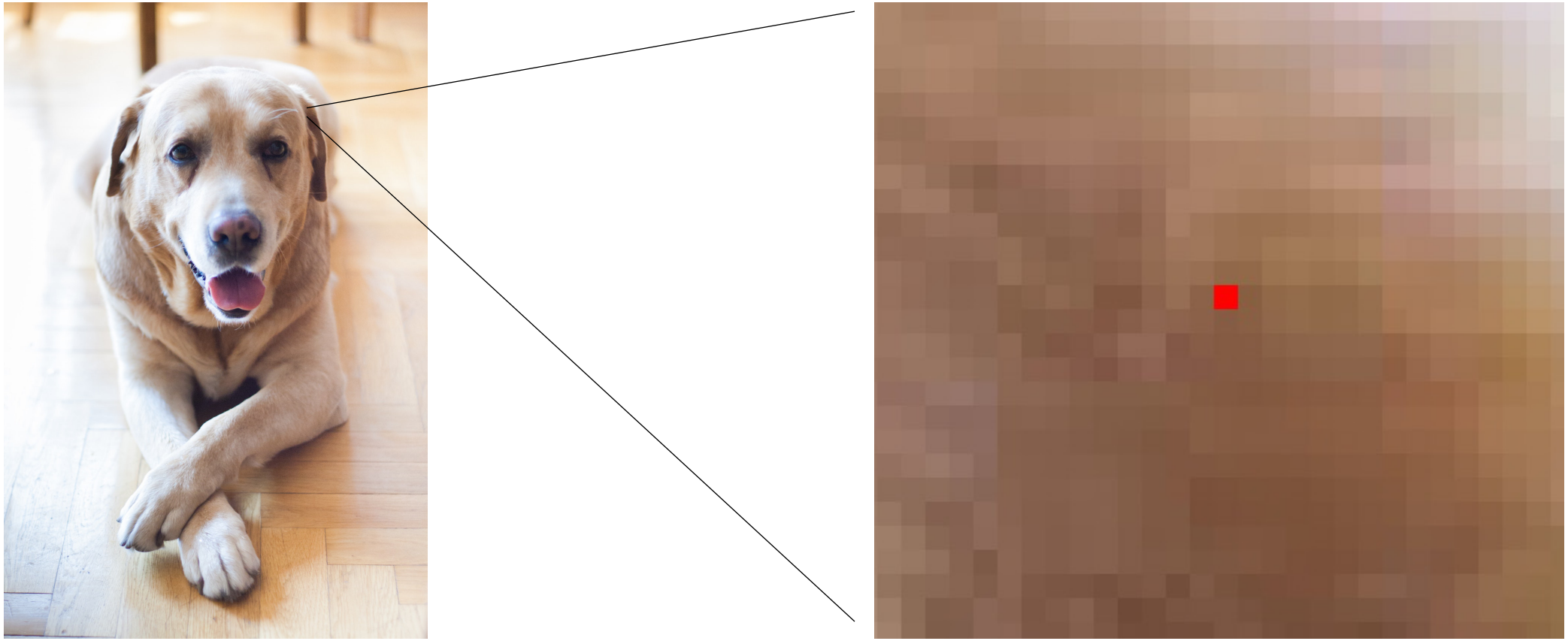
Taking advantage of faulty hardware

- Some systems use the faulty core to provide hints to others
- For example, *Necromancer: Enhancing System Throughput by Animating Dead Cores*
  Ansari, Feng, Gupta and Mahlke
  ISCA 2010



Approximate computing

- In certain situations we can embrace errors



Summary

- Reliability is a problem that has come back to haunt us
- Required for safety-critical systems
  - Increasing needed / desired in others too
- A variety of techniques developed to
  - Identify which parts of the core are vulnerable
  - Reduce vulnerability to errors by re-executing parts of the code
  - Embrace the unreliability for performance