FPGAs in radiation-harsh environments

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Application examples

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AFDX

- Used on new commercial aircrafts from Boeing and Airbus
- Main communication interface
- Safety level up to DAL-A

Mission computers

- Used on all aircrafts
- e.g. freight control system for Airbus A400M
- Safety level up to DAL-A

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The old Style: ARINC-429

ARINC-429 commonly found in aircrafts of the 80s

- Mono directional bus → 1 transmitter, n ≤ 20 receivers
- Dedicated wiring for each connection
- 100s km cabling per aircraft
- Transmission rates: 100kbit/s and 14.5kbit/s (low critical)

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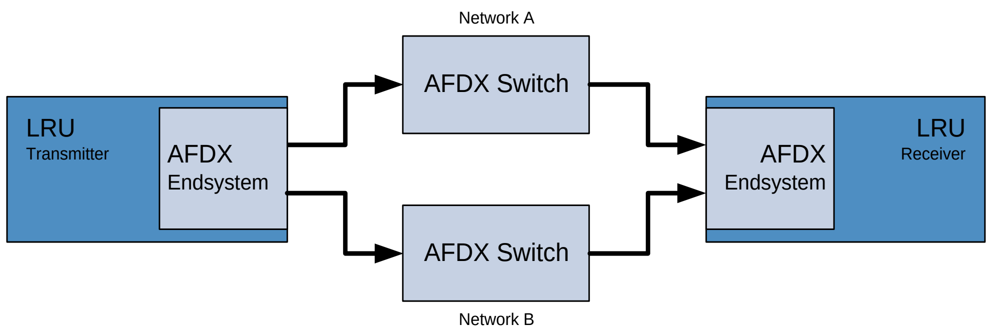
Nowadays: AFDX Technology

Based on IEEE802.3 Ethernet

- 100Mbit/s Ethernet
- Full duplex
- Switched
- Full static configuration, no ARP, no DNS, …

Provides Reliable Data Transport

- Known latency
- High availability through redundancy



Redundant Network Architecture

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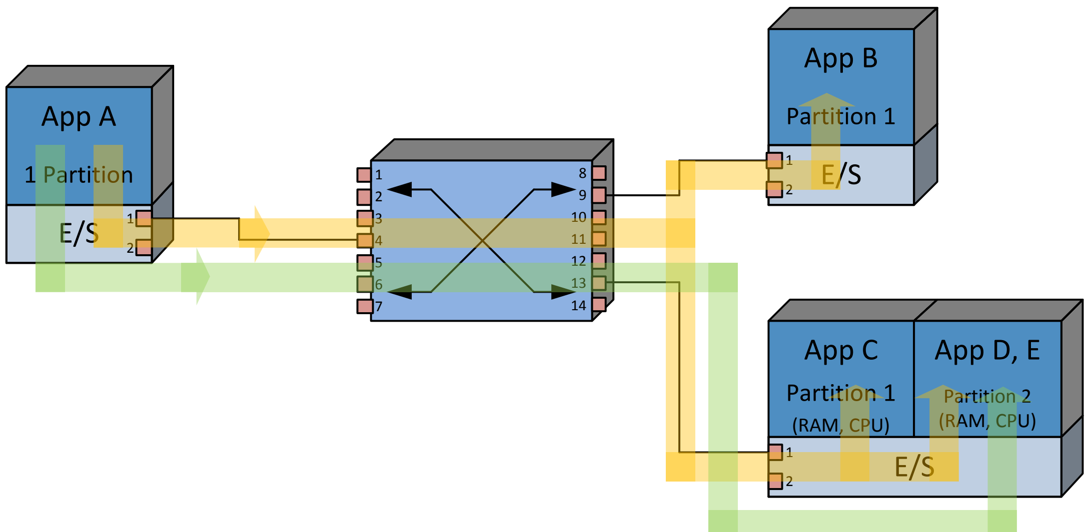
AFDX – Virtual Links replace ARINC-429

Avionics communications are based on multicast

- One transmitter
- One or several receivers



⇨ *Virtual links provide similar properties as ARINC-429*

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Airbus A380: AFDX Network

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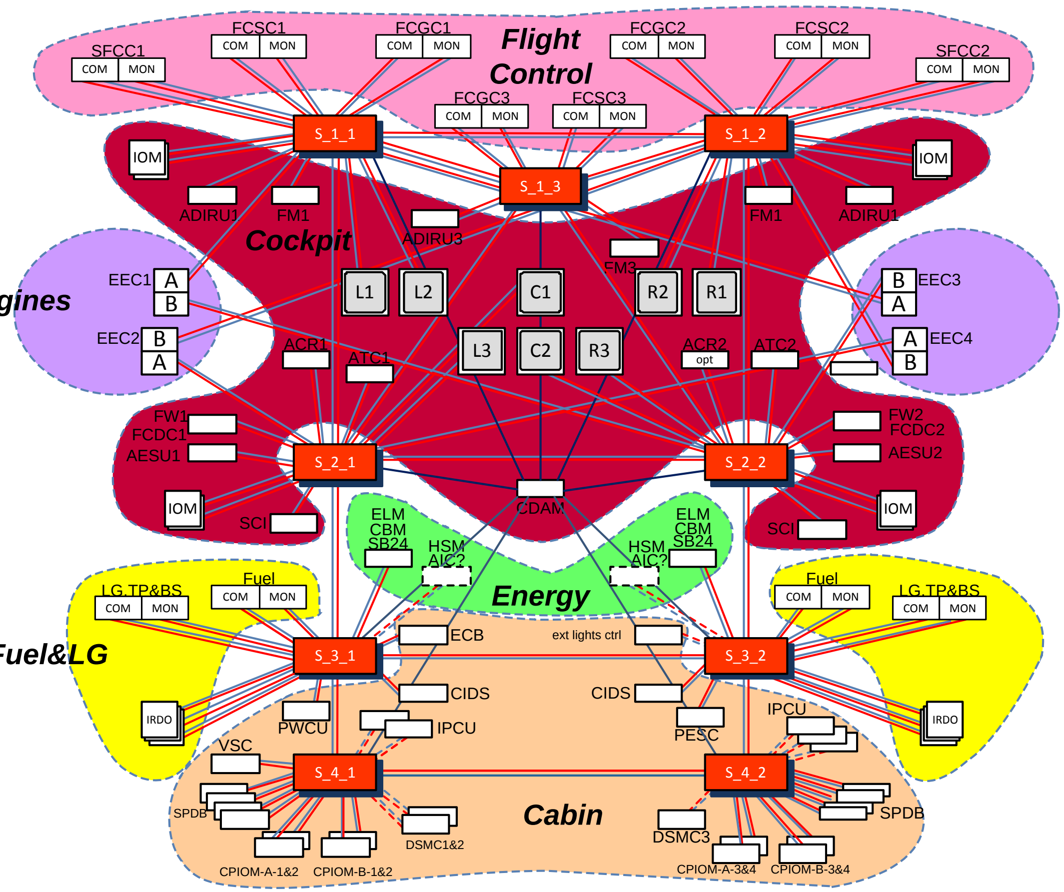
A380 AFDX network

- 100Mbit/s Ethernet
- Redundant networks (A&B)
- AFDX switches (2 x 9)
- #of ports on each switch (20 – 24)
- Up to 80 AFDX end-systems



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AFDX – Ethernet for Mission-Critical Applications

AFDX interface

- Certifiable FPGA implementation
- Available on PMC P520
- Full-featured AFDX protocol engine
- Interoperable with Airbus and Boeing

Airbus A400M Freight System

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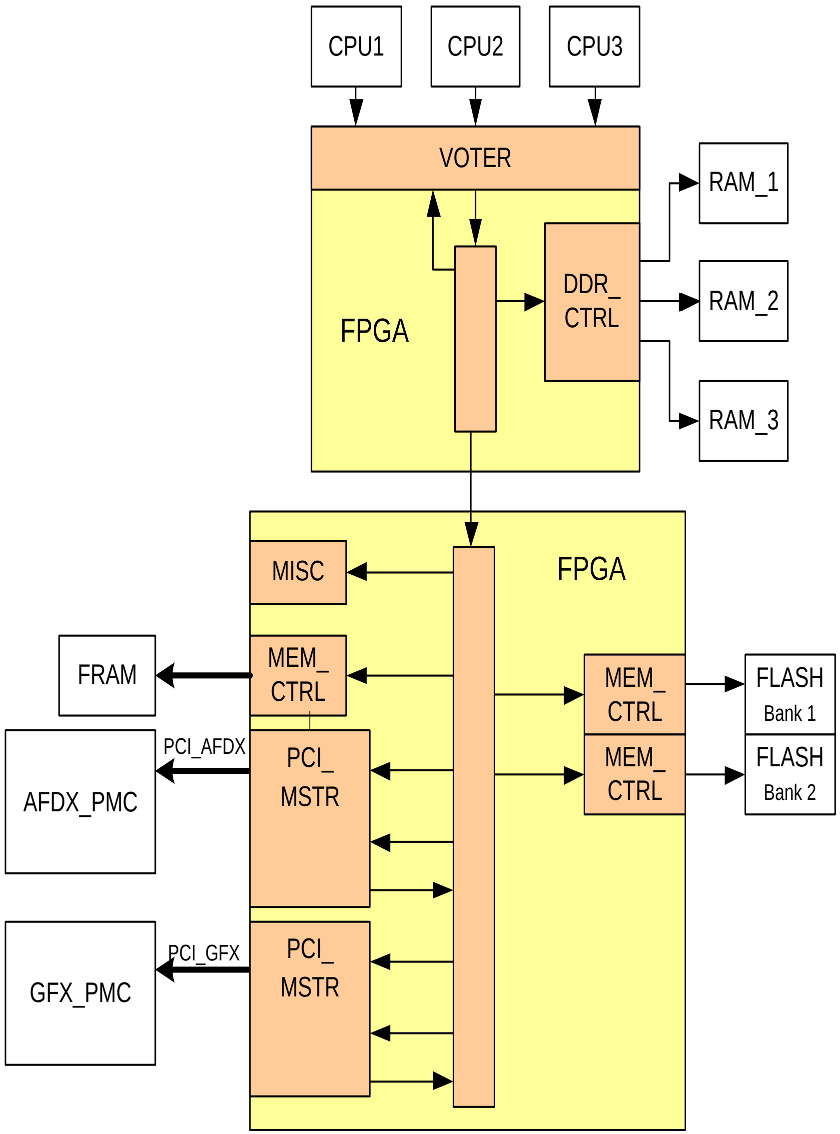
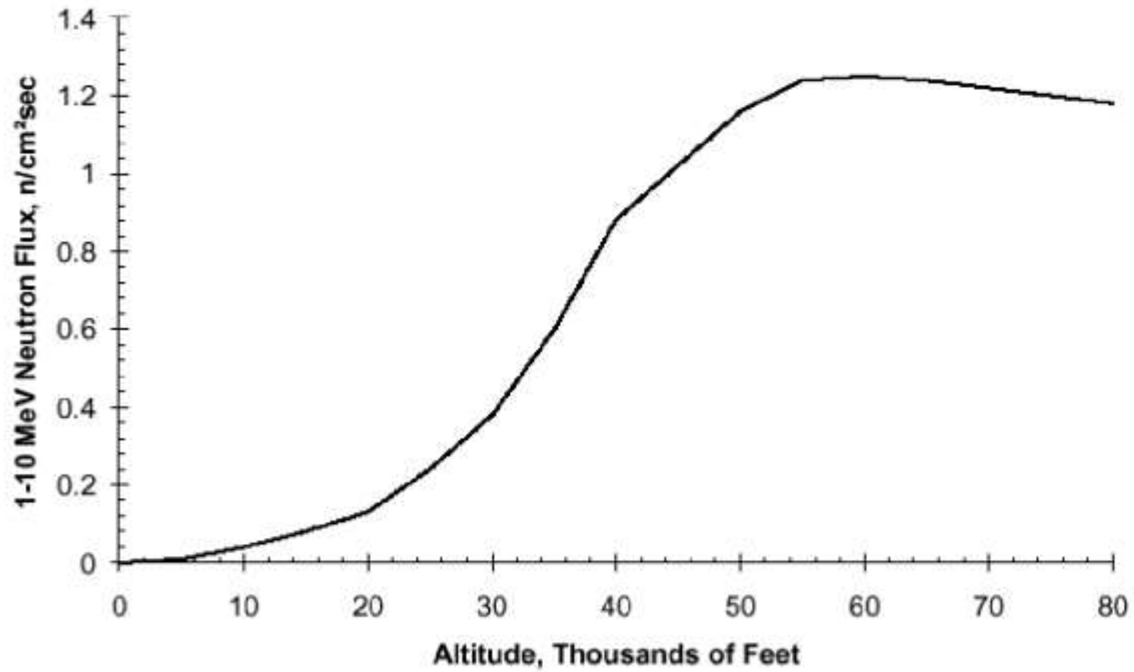
Mission Computer with FPGA Architecture



- Triple redundancy on board
- 3x redundant PowerPC 750 CPU with up to 800 MHz (Lockstep)
- Redundant memory
- Onboard data transfers paths realized with FPGAs
- Voting done inside FPGA
- Compliant with DO-254 up to DAL-A

Challenge: Single Event Upsets/Multi Bit Upsets

- Aircrafts are exposed to radiation environment
- Neutrons (Secondary Cosmic Ray Particles) may cause SEUs and MBUs in electronics equipment
- Particle flux varies with altitude - max. flux at 60.000 ft.



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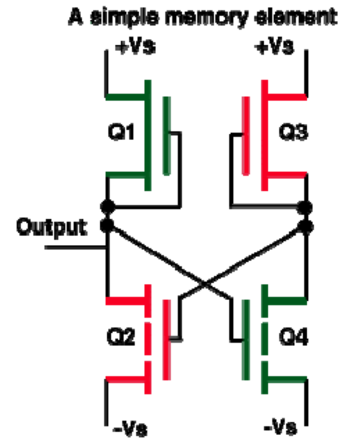
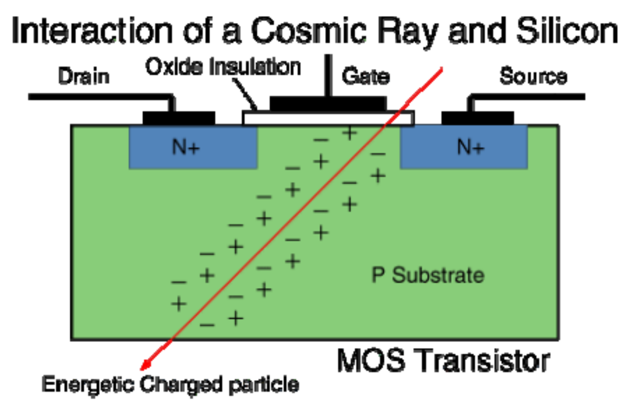
SEU/MBU Effects

Components susceptible to SEU/MBU bit flips

- SRAMs
- SDRAMs
- Microprocessors
  - Register
  - Caches
  - Internal buffers/FIFOs
- FPGAs
  - Cell configuration
  - Logic cell state
- ...





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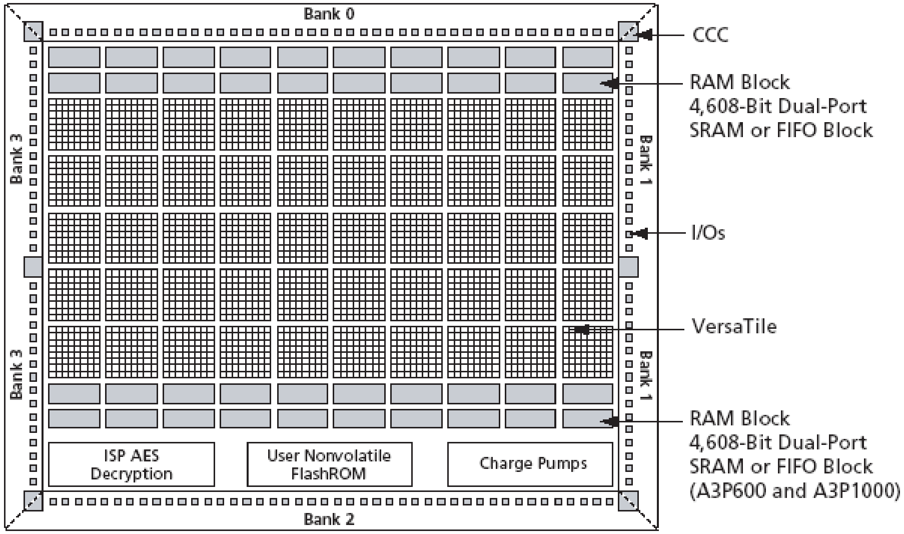
FPGA Issues

FPGA configuration must be SEU hardened

- FPGAs with RAM based configuration need mitigation strategy
- FPGAs with FLASH based configuration are SEU/MBU immune

But

- Registers and RAM within FPGAs still not SEU immune!
- Other mitigation techniques required



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SEU/MBU RAM Sensitivity

Failure probability 10^{-7} / flight-hour (DAL B)

- Only one safety relevant failure in 10 Mio. flight hours!

Error probability increases with number of bits

Examples

- 512MByte SDRAM at 60.000 ft. (no ECC)

  → Fails after 10 hours!

- 32kByte cache

  → Fails after 3.5 month

⇨ *Safe airplanes would not be possible*

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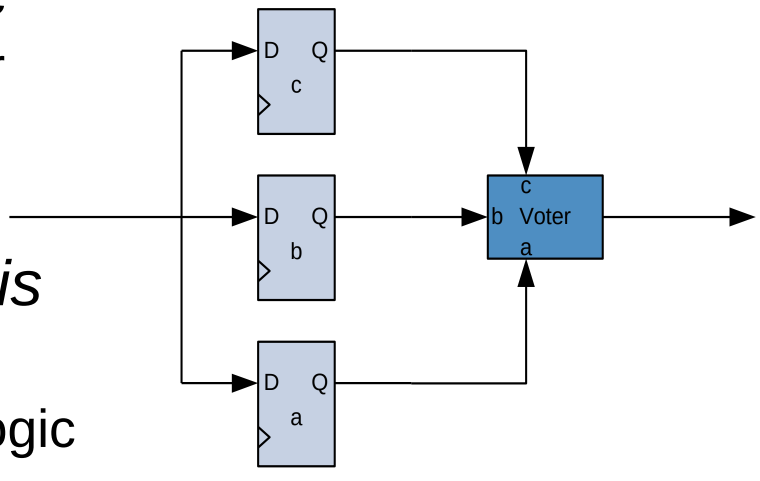
Architectural Solutions

Register and logic protection strategies

- All FPGA registers subject to SEUs
- Critical sections use 2oo3 voting logic
- Majority voter overrules faulty register value



Triple modular redundancy (TMR) is expensive

- Requires more than 3 times regular logic
- Slows down timing up to 20%

TMR significantly lowers the probability of SEU induced failures in the FPGA logic

⇨ *Safe airplanes are possible*

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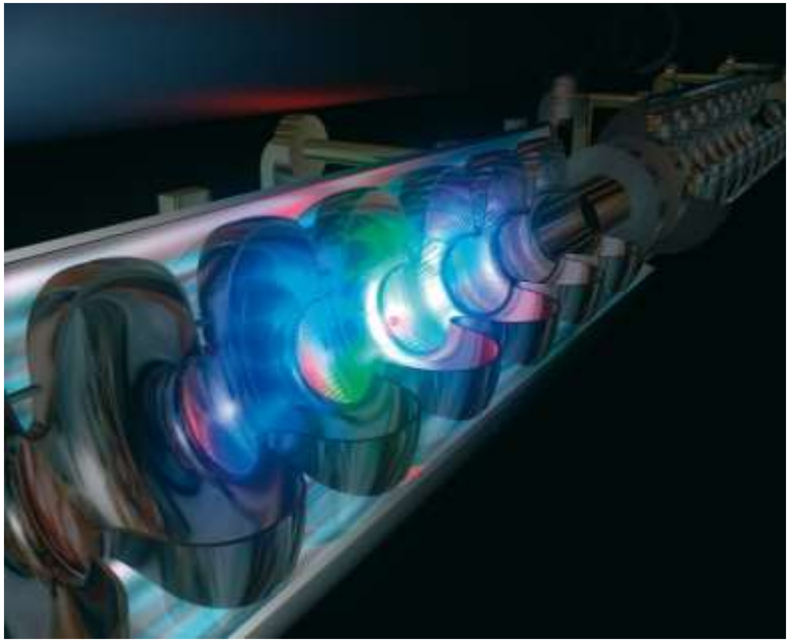
Verification of TMR Technology

Architectural mitigation strategy can be verified by proton beam experiments

- DUT is exposed to particle beam with density equivalent to high altitude radiation
- DUT is running in test to demonstrate operability



Source: http://xfel-development.4pi-communications.net/media/assets/XFEL_Beschleuniger02-jpg

Thank you for your attention!

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