Reconfigurable systems and software radio for space applications (Part 2)

Adelio Salsano

UNIVERSITA' degli STUDI di ROMA
TOR VERGATA

Nanometric technologies

Characteristics

- Minimum features→ < 50 nm
- + High velocity and ULSI integrazione
- - exponential growth of error probability

Areas of interest

- Space
- Autonics
- Biotechnologis

→ SPIN-IN

Design of high dependability systems

- Specs of performances and reliability
- Working environment analysis
- Component choice with the alternative
  - Components not sensitive to faults (fault-avoidance) with higher costs and lower performances
  - or

  –commercial components with redundancy – COTS (fault-tolerance)
- Design for testability
- Testing

Dependability

- Qualitative evaluation of the system capacity of correctly operate, i.e.,
  - Reliability
  - Availability
  - Safety
  - Maintenability
  - Testability
  - …

Definitions

- Reliability → R(t) : probability of correct operation of the system between 0 and t
- Safety → S(t): probability of no catastrophic faults between [0,t] (fail-safe)
- Availability → A(t): probability that the system is correctly working at t
- Maintainability→ M(t) : probability that a faulty system is repaired in a slot time t

Fault - Error - Failure

- Fault →physical fault or bad working (hardware or software) of a component
- Error →not correct external working caused by a fault
- Failure → the component doesn't do its service

Self-checking Circuits/Systems

- Circuits/Systems that automatically detect the presence of errors and, eventually, are able to correct

Coded inputs and outputs

In-code or out-of-code words

Example: Error Detecting And Correcting memories

Other definitions

A circuit/system is

- Self-Testing, if, for each fault of a given set, there is at least one in-code input that gives an out-of-code output
- Fault-Secure, if every in-code input can’t give a wrong in- code output
- Totally Self-Checking if it is Self-Testing and Fault-Secure

The circuit/system reach the Totally Self-Testing Goal if the first erroneous output after a fault is an out-of-code word

Diagnostics, design and repairing

- Fault detection starting from errors
- Design methodologies
  - Test of typical components under possible causes of fault
  - Models for simulation
  - Software techniques as fault injection or repetition of initial tests
  - Software tools
- Correction and/or tolerance methodologies
  - Roll back (software)
  - Reconfiguration

Testing

- Relevance of radiations → Soft errors
- Infrastructures with sources, as ISIS for neutrons
- Italian projects
  - Panarea, (instrumentation)
- Great Britain projects
  - SPAESRANE:

    Solutions for the Preservation of Aerospace Electronic Systems Reliability in the Atmospheric Neutron Environment

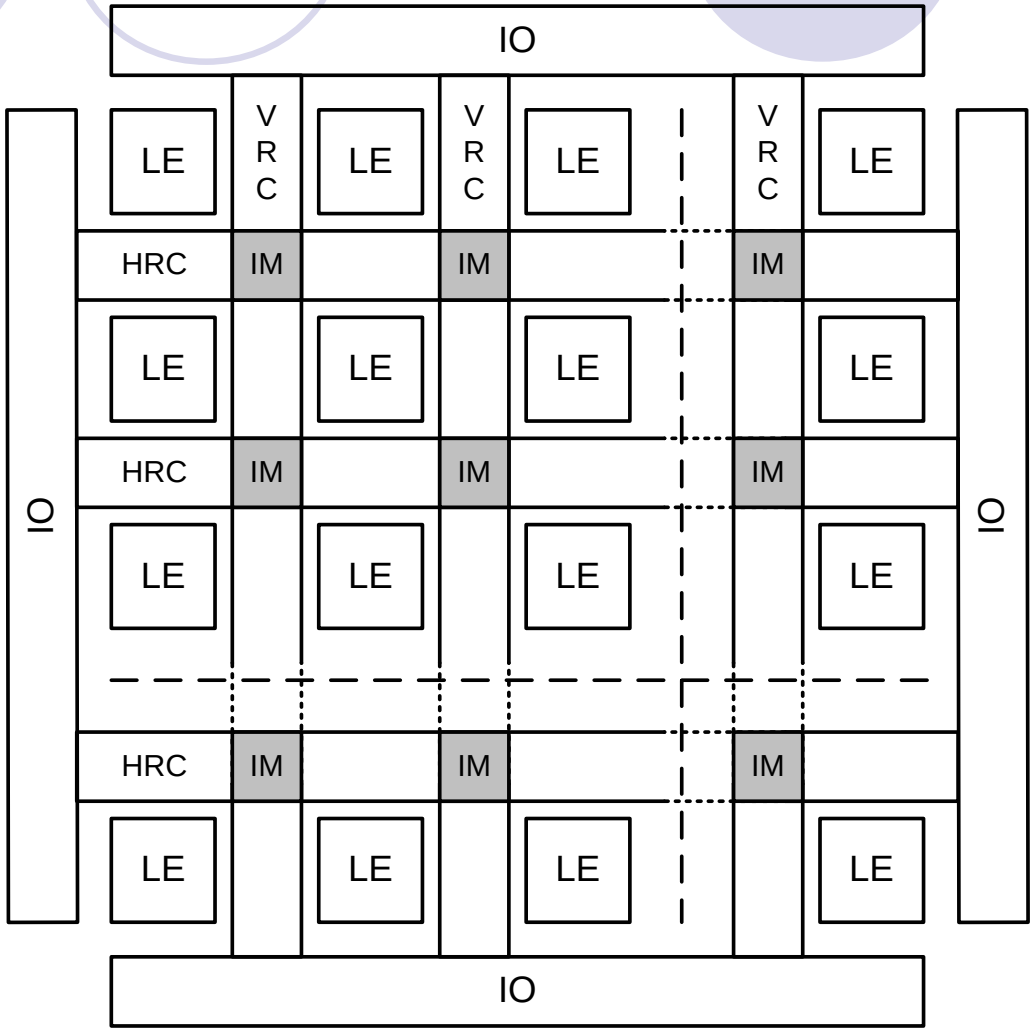
Reconfigurable structures

- FPGA
- Programmable coarser-grain structures → CPU, memories, DSP, interfaces

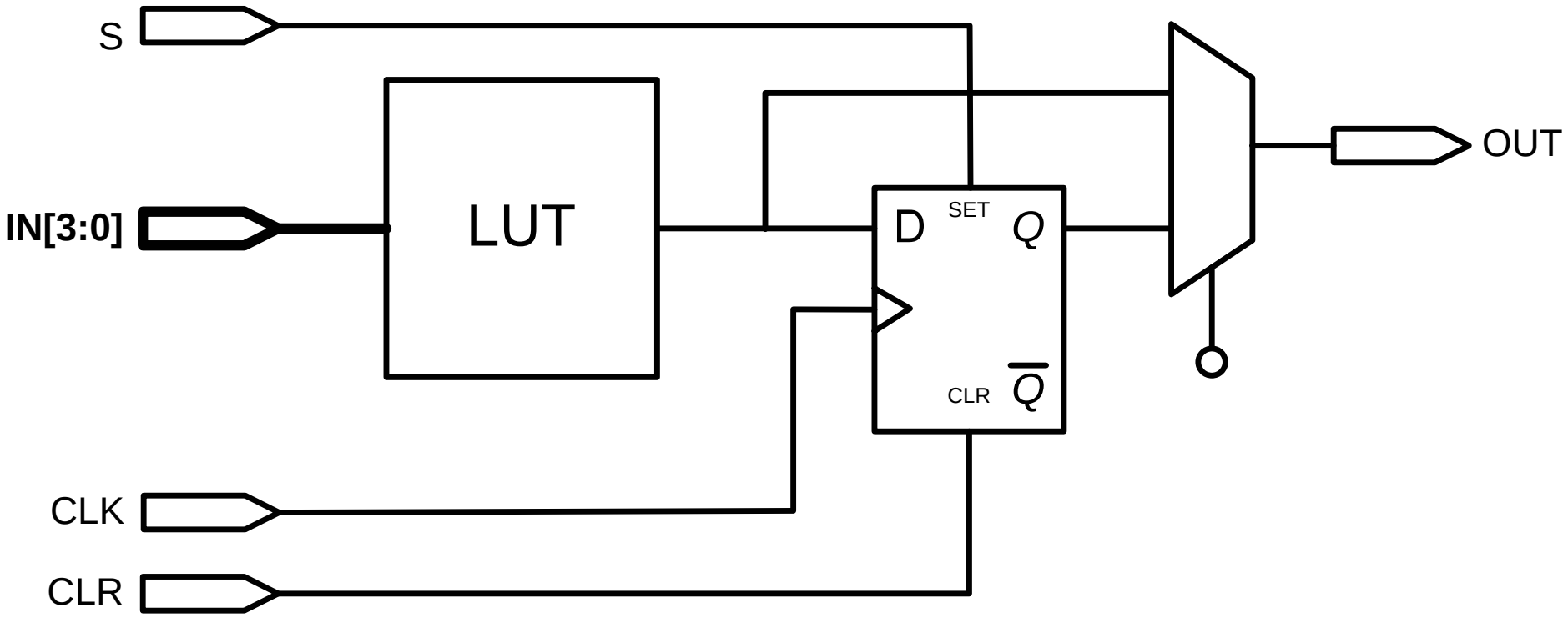
for

- EDAC
- Even on-line change of software

FPGA: Architecture



FPGA: Logic Element (Block)



System on Chip

Includes:

- **Hardware:**
  Field Programmable Gate Array
- **Software:**
  Controller, soft cores, etc.
- **Memory:**
  Program and data storage

Features:

- Single chip integrated system
- Low cost
- Low *time to market*

Reliability of integrated circuits

Problems and solutions

Working environment

- Ground
- High reliability systems are required in many areas: safety applications as biomedicine, avionics, etc.
- Advanced technologies imply a growing probability of faults (atmospheric neutrons, for instance)

- Space
- High dependability circuits and systems needed
- Mechanical and thermal stresses
- Faults and soft errors caused by space radiations

Faults

- Temporary
  - Space:

    Single Event Effects caused by ionizing radiations
  - Ground:
  - Stuck-at, bridging faults, etc.
  - EMC
    Single Event Effect caused by atmospheric neutrons
- Permanent
  - Space:

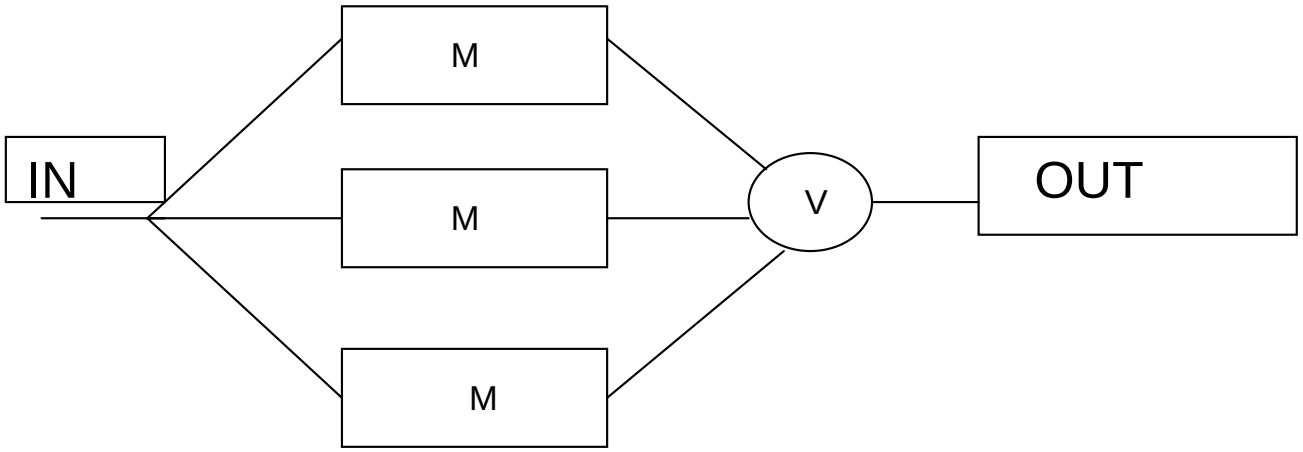
    Total Ionization Dose (TID) can harm device characteristics
  - Ground:
    Devices ageing can be faster for last generation technologies

UNIVERSITA' degli STUDI di ROMA TOR VERGATA

Static redundancy

- Reliability of a system can be improved with redundant modules: general model implies the use of three identical modules and final voter

Triple modular Redundancy (TMR)



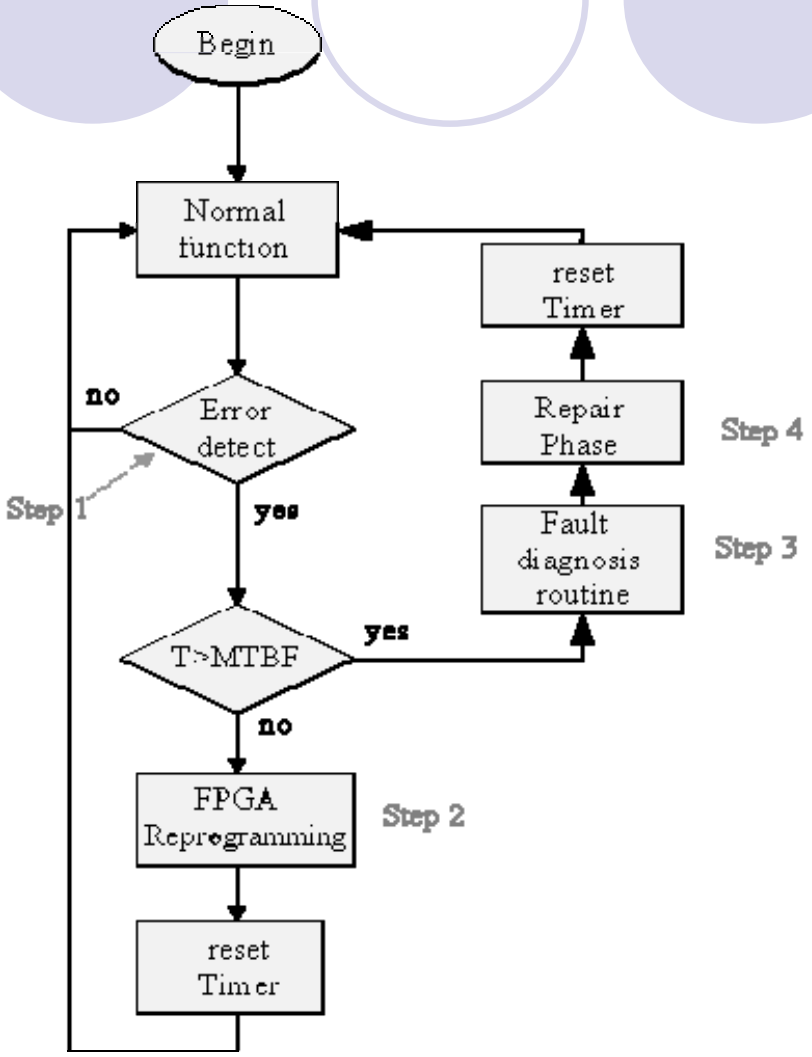
Static redundancy

- Less redundancy :
  - ECC codes for memory blocks
  - Arithmetic Codes for DSP applications
  - Instruction flow analysis for microprocessors

Dinamic Redundancy

- Better redundancy schemes can be used for reconfigurable systems (FPGA)

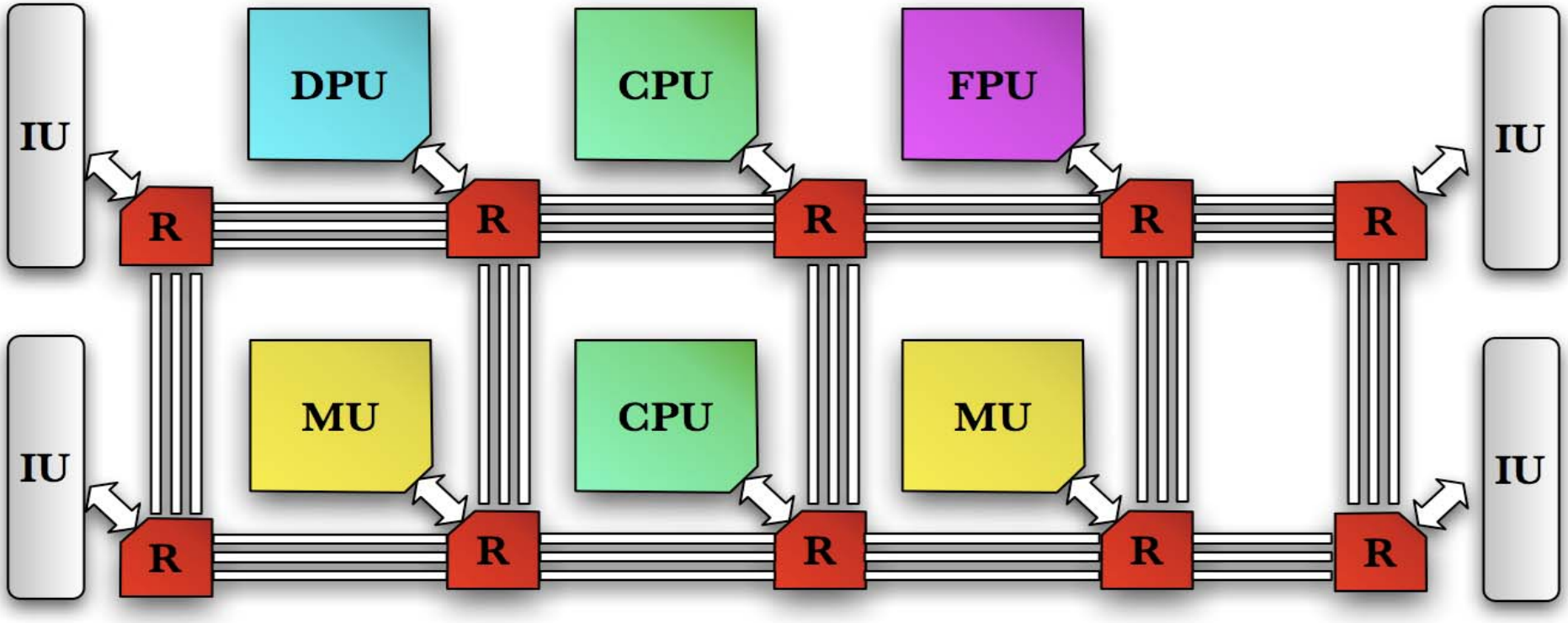
Error Detection and Repair



Space computing systems

- Modularity: soft cores by IP
- Performances
- Reliability
- Availability
- Working time
- Software updating

Computing module



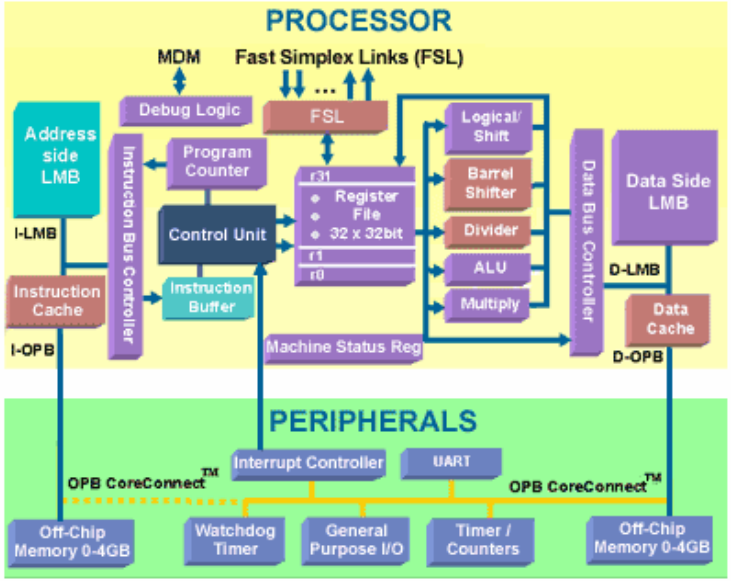
An Architecture for Reconfigurable Computing in Space

- *Robert F. Hodson[1], Kevin Somervill[1], John Williams[2], Neil Bergman[2], Rob Jones[3]*

- *[1]NASA LaRC, [2]University of Queensland, [3]ASRC Aerospace*

RSC Goals & Objectives

- To develop the next generation high performance space-qualified computing system leveraging…
  - Field Programmable Gate Arrays FPGAs
  - Intellectual Property (IP)
    - Soft cores, processors
  - COTS software architectures
    - Multi-processor
    - Specialized
- Meet Strategic Challenges
  - Reconfigurability
  - Modularity
- First step towards the next generation avionics suite

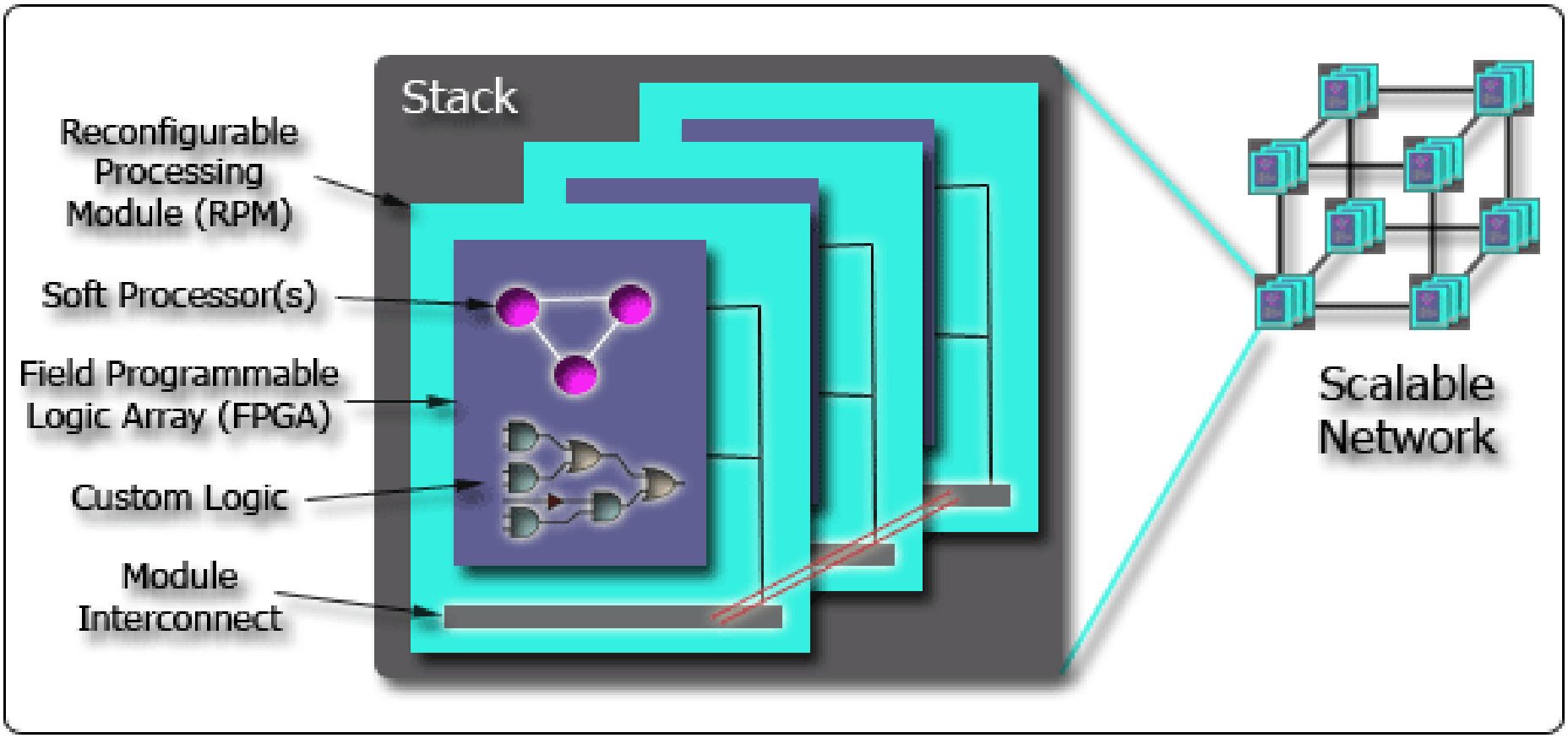


Why Reconfigurable Computing with Soft Cores & Custom Logic

- Soft cores readily available for rad-tolerant FPGAs
- Custom co-processors can improve performance on average by 5.8X
- Power consumption can also be reduced on average by 57%
- Reconfiguration allows many designs without hardware redesign – reducing cost
- Making this approach competitive with current space computing systems

UNIVERSITA' degli STUDI di ROMA TOR VERGATA

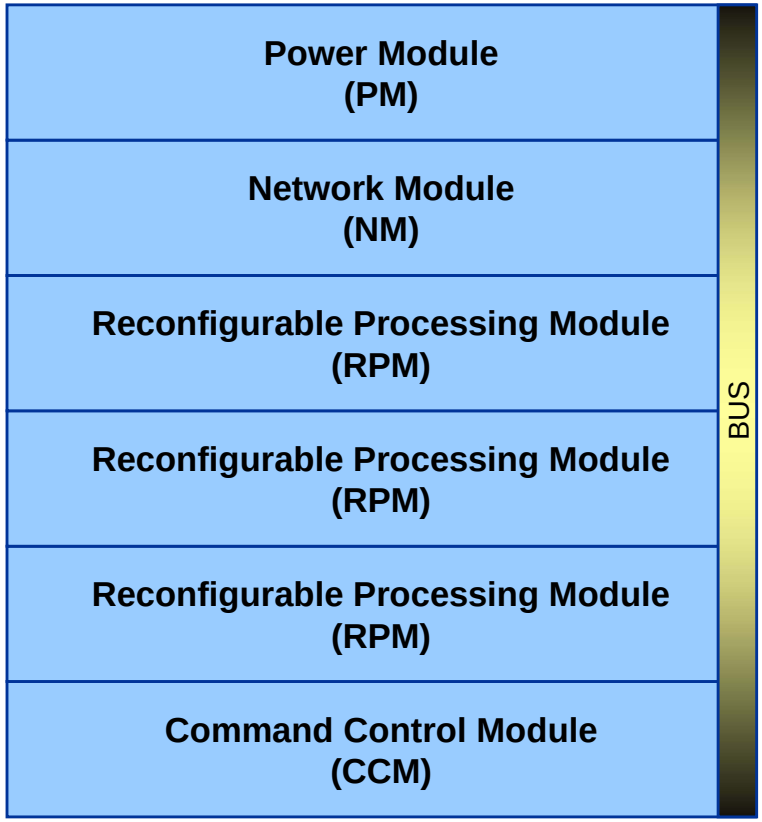
Scalable Architecture



Multiple interconnected general purpose processing nodes with optimized custom logic attached for special purpose processing.

Modular Technology

- Modules will be combined to build RSC systems
- Designs will be based on rugged small form factor modular stackable technology
  - Allows mixing and matching of appropriate modules to meet mission requirements
- Planned modules
  - Reconfigurable Processing Module (RPM)
  - Command/Control Module (CCM)
  - Network Module (NM)
  - Power Module (PM)



Conclusions

Modular computing system COTS based (long time availability, costs and performances)

Development of parallel operating systems for module interconnession

Possible reuse on different hardware → IP availability