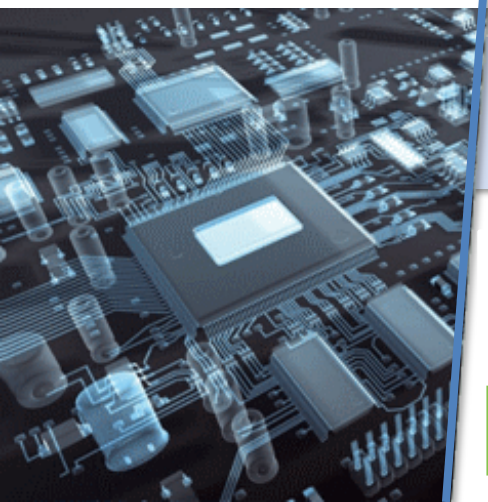

A Fault-Tolerant On-Board Computer For CubeSat Based-On Hybrid Architecture

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Friday, April 26, 2013 – Jérémy Delaporte

Outline

1. Institut Supérieur Des Sciences Et Techniques (INSSET - UPJV)

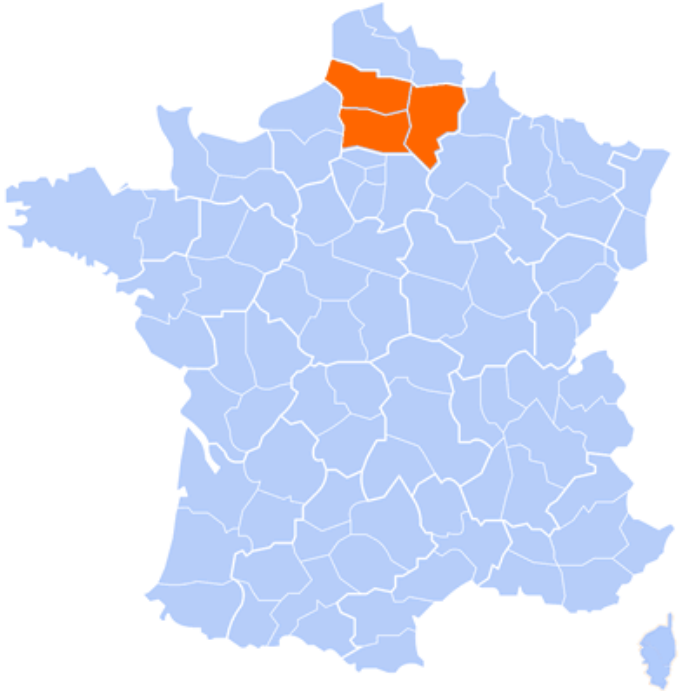
2. Space Environment – Effects On Electronic And Consequences

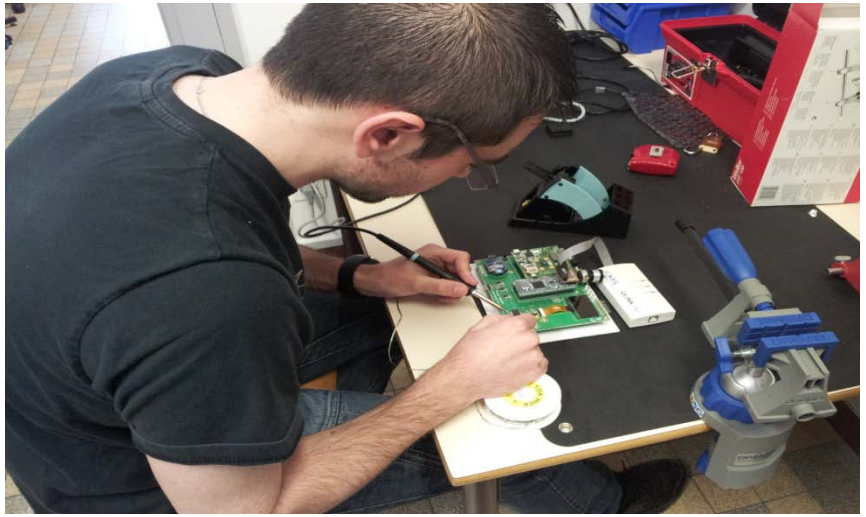
3. On-Board Computer For CubeSat
    1. Architecture And Mitigation Techniques
    2. Our Approach : Secure_ODB Project

4. Functional And Validation Tests
    1. Test Facilities
    2. Injection Faults Based-On JTAG Interface
    3. QB50 Project

5. Conclusion And Perspectives

Institut Supérieur Des Sciences Et Techniques (INSSET – UPJV)





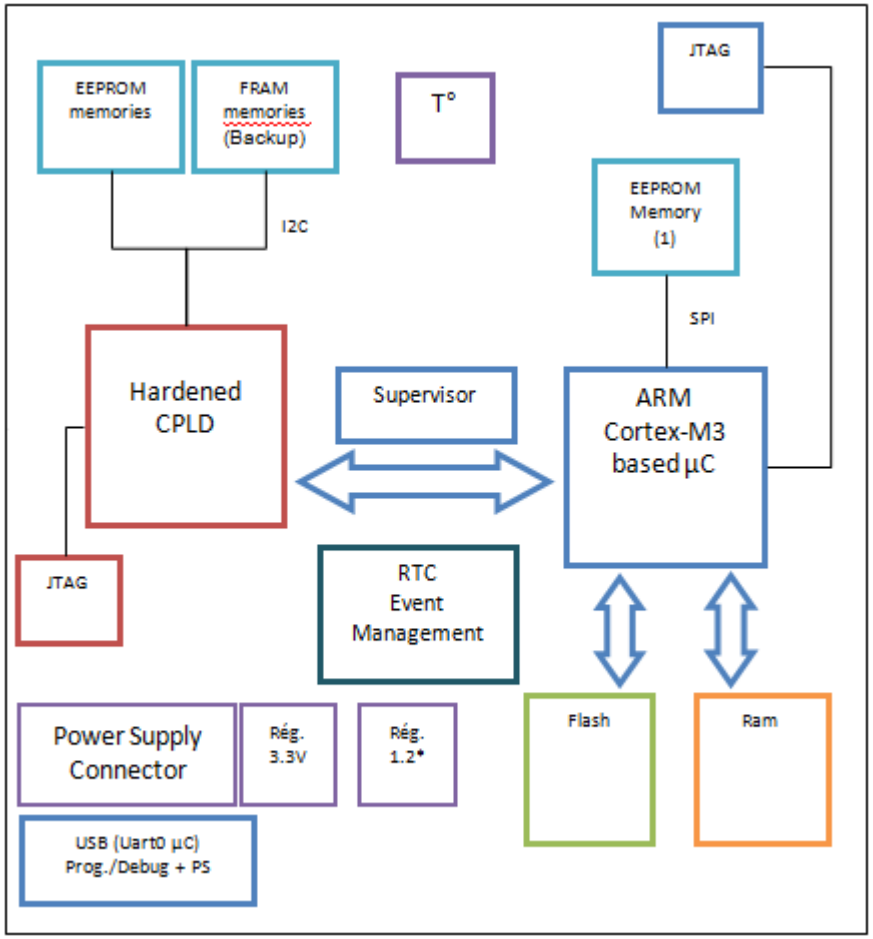
Embedded Systems

Embedded System

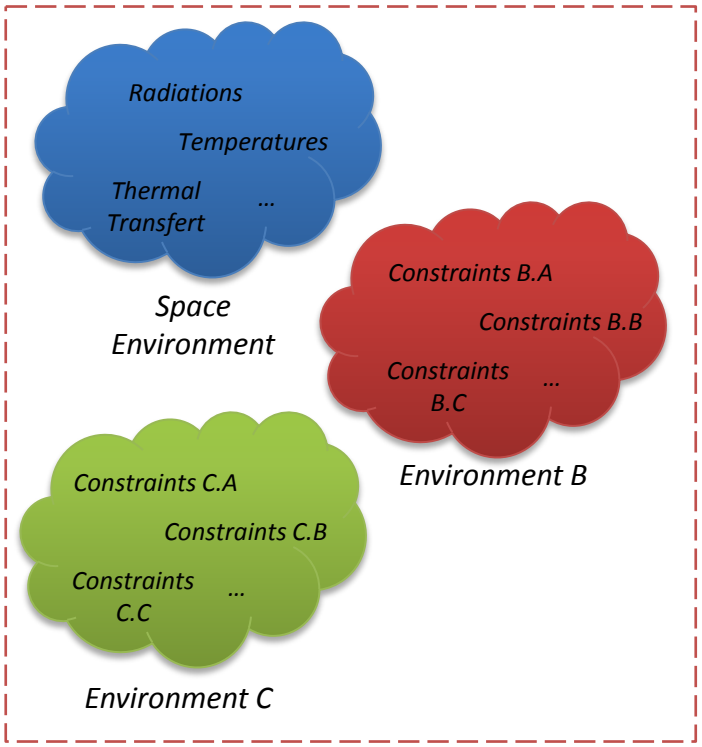
Constraints

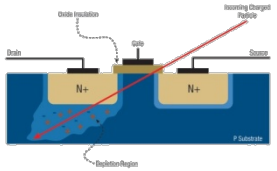
- Mass
- Cost
- Energy Consumption
- Performances
- Reliability Level
- Environmental
- Plug And Play (Modularity)
- Maintainability
- Memory
- …

Architectures Design



Embedded Systems And Reliability

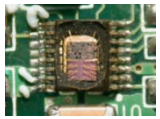


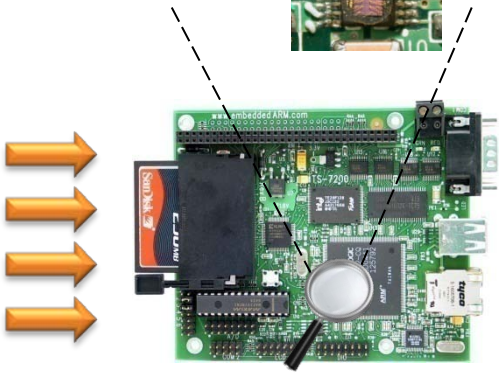


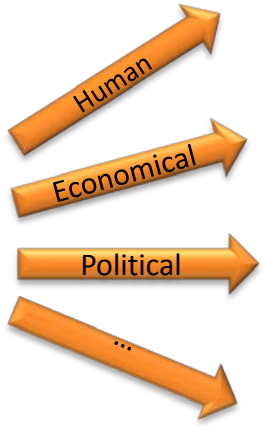
Effects

SEUs *0 -> 1*
1 -> 0

SELs







...

Constraints | Embedded Systems | Consequences

Space Environment
Effects And Consequences On µC

Effects

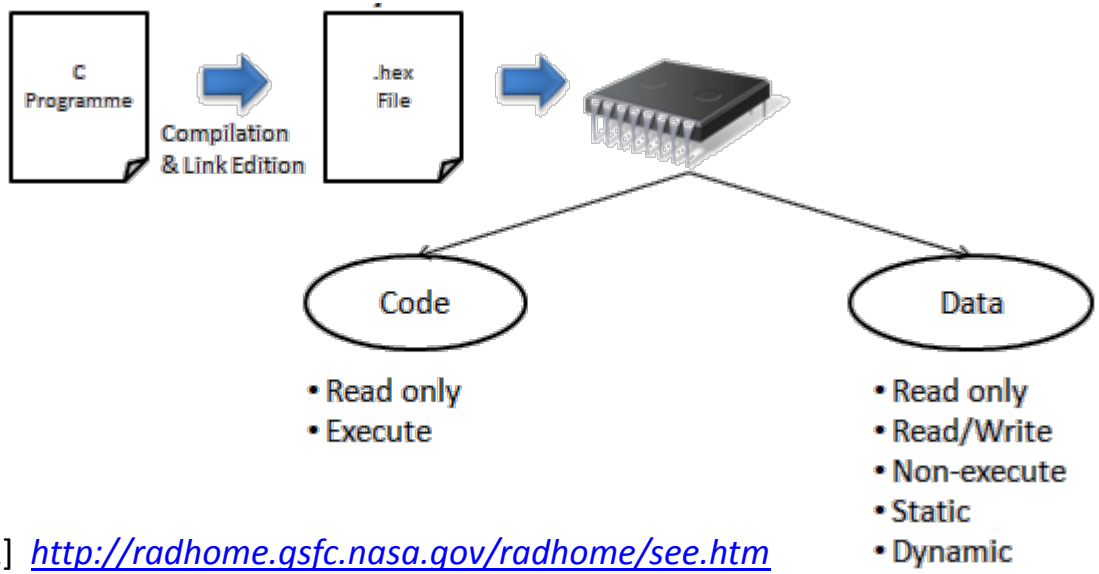
- Single Event Effects
  - Single Event Upsets (SEUs) => Soft Errors And Non-destructive
  - Single Event Latchups (SELs) => Hard Errors And "Destructive"
  - Single Event Burnout (SEBs) => Hard Errors And "Destructive"
  - … See [1]

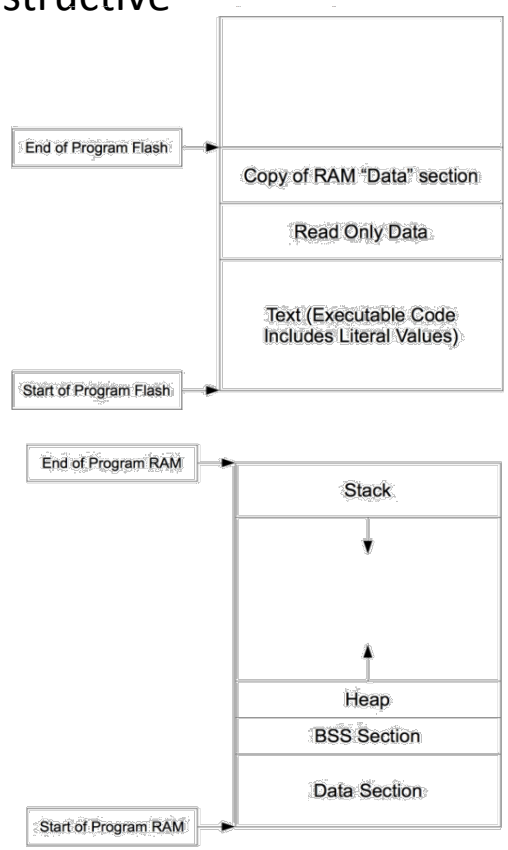
Transient pulses in logic

Bitflips in memory

Consequences

- Destruction of components
- Corruption of data





[1] http://radhome.gsfc.nasa.gov/radhome/see.htm

Mitigation techniques

"The goal of a fault-tolerant computer is to provide safety and liveness, despite the possibility of faults." *Fault-Tolerant Architecture, Daniel Sorin – 2009*

Fig. 1 - Fault Tolerance Process

TABLE 2.1: The Three Types of Redundancy.

TYPE OF REDUNDANCY	BASIC IDEA	SINGLE EXAMPLE
Physical (spatial)	Add redundant hardware	Replicate a module and have the two replicas compare their results
Temporal	Perform redundant operations	Run a program twice on the same hardware and compare the results of the two executions
Information	Add redundant bits to a datum	Add a parity bit to a word in memory

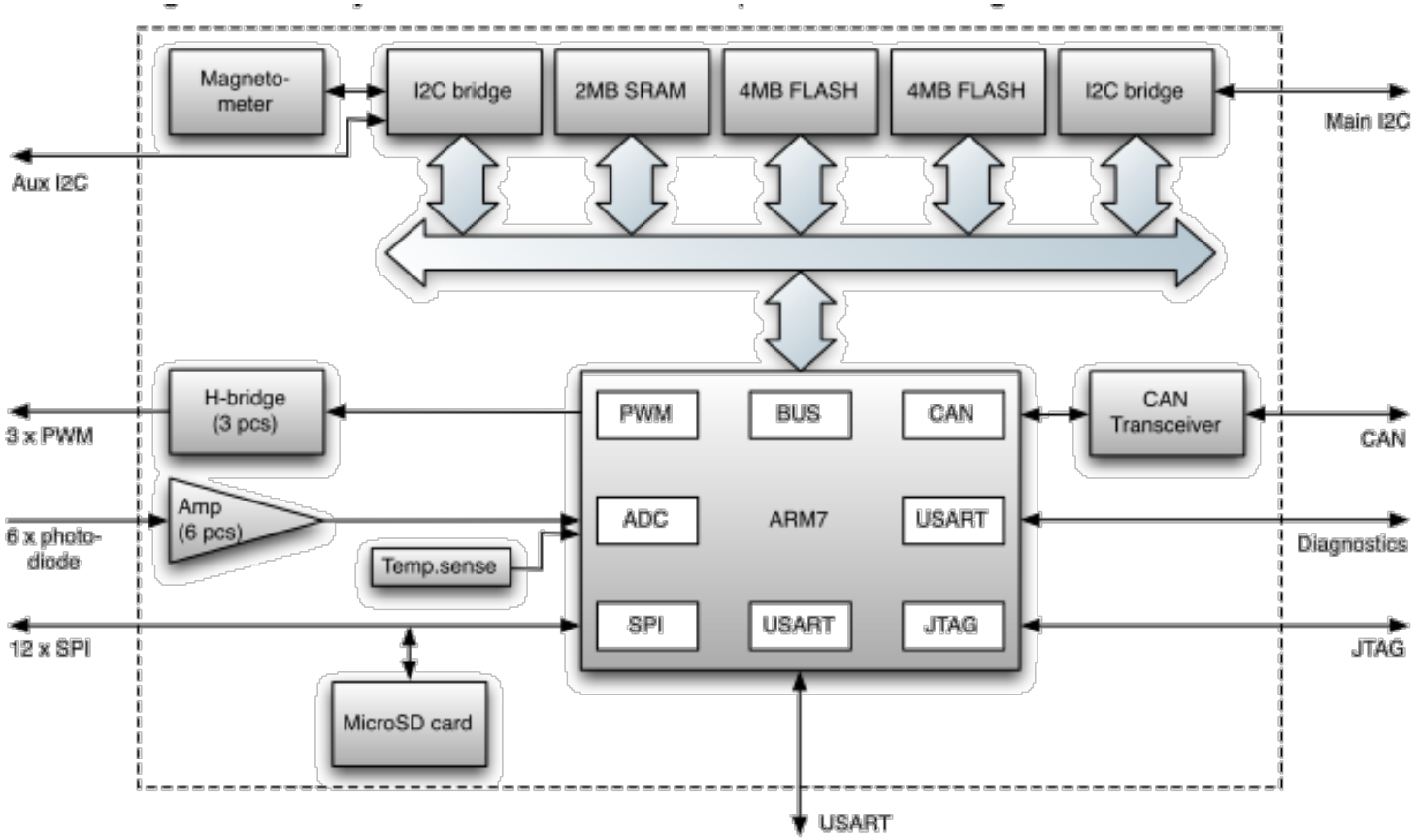
Error Detection : REDUNDANCY

The use of detection techniques implies the system to be :

- More expensive
- Less performances
- Need more memory

On-Board Computer For CubeSat

General architecture

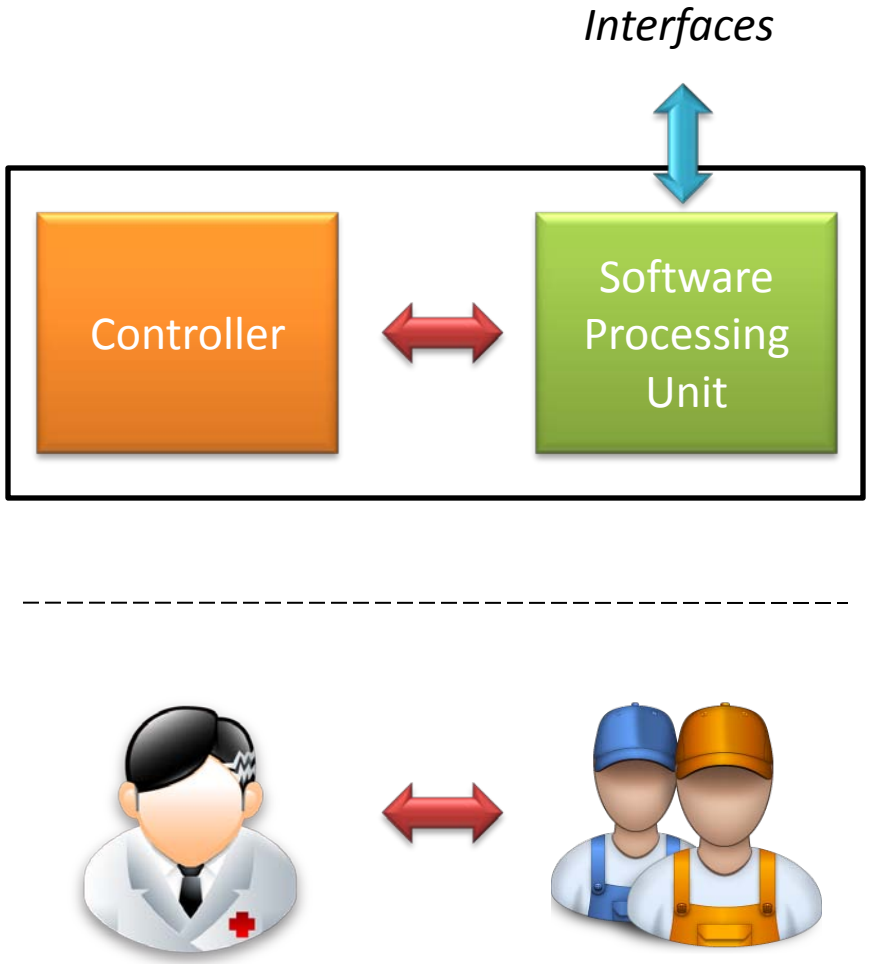


NanoMind A712C Block Diagram (GOMSPACE)

On-Board Computer For CubeSat

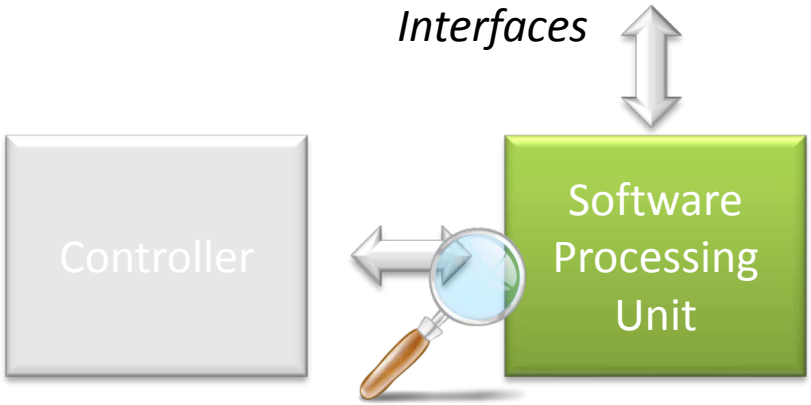
Our approach : Secure_ODB project (1/3)

1. Real-time overview of internal ressources
   1. What is working or not
   2. Flash/RAM State
   3. Statistical information on errors
   4. …
2. Estimation of threat based-on environment sensing : radiation & t° sensors (Need a calibration)
3. Dynamique reprogramming or reconfiguration of the Software Processing Unit

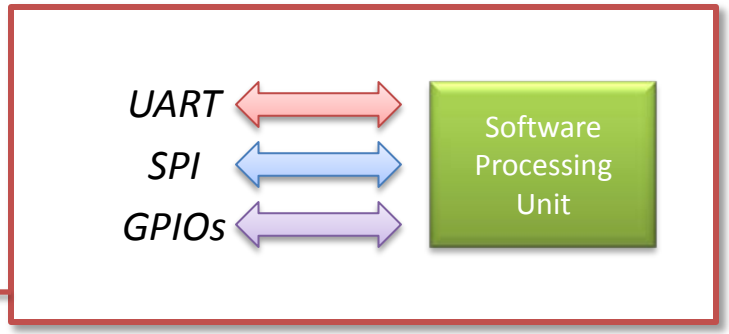


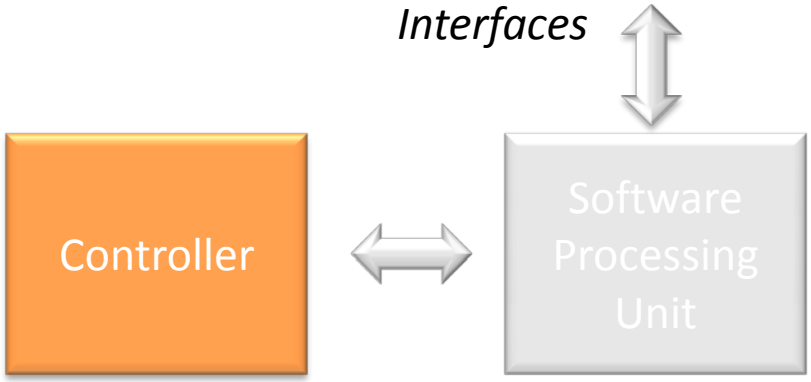
On-Board Computer For CubeSat

Our approach : Secure_ODB project (2/3)



- ARM Cortex-M3 Based µC (NXP LPC1788)
- Boot loader in ROM Memory
- FreeRTOS



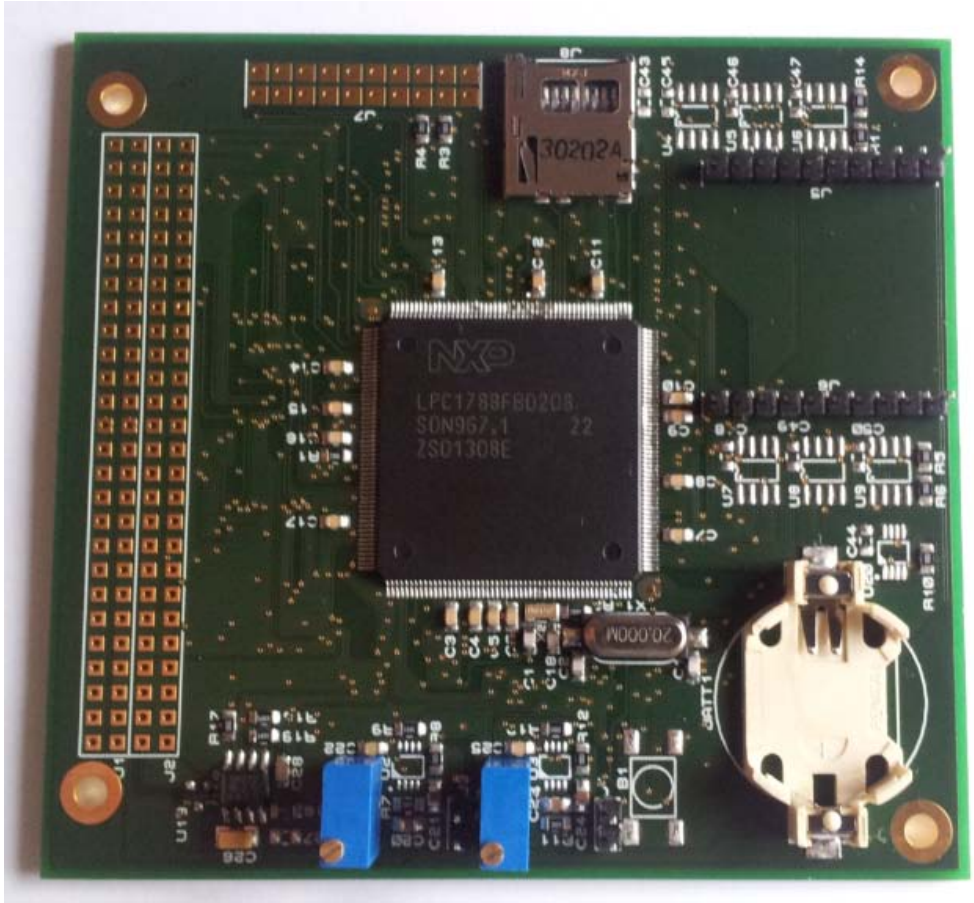


- Less performances than Software Processing Unit
- Reliable

Must be protected against energetic particles strikes (Radiation)

On-Board Computer For CubeSat

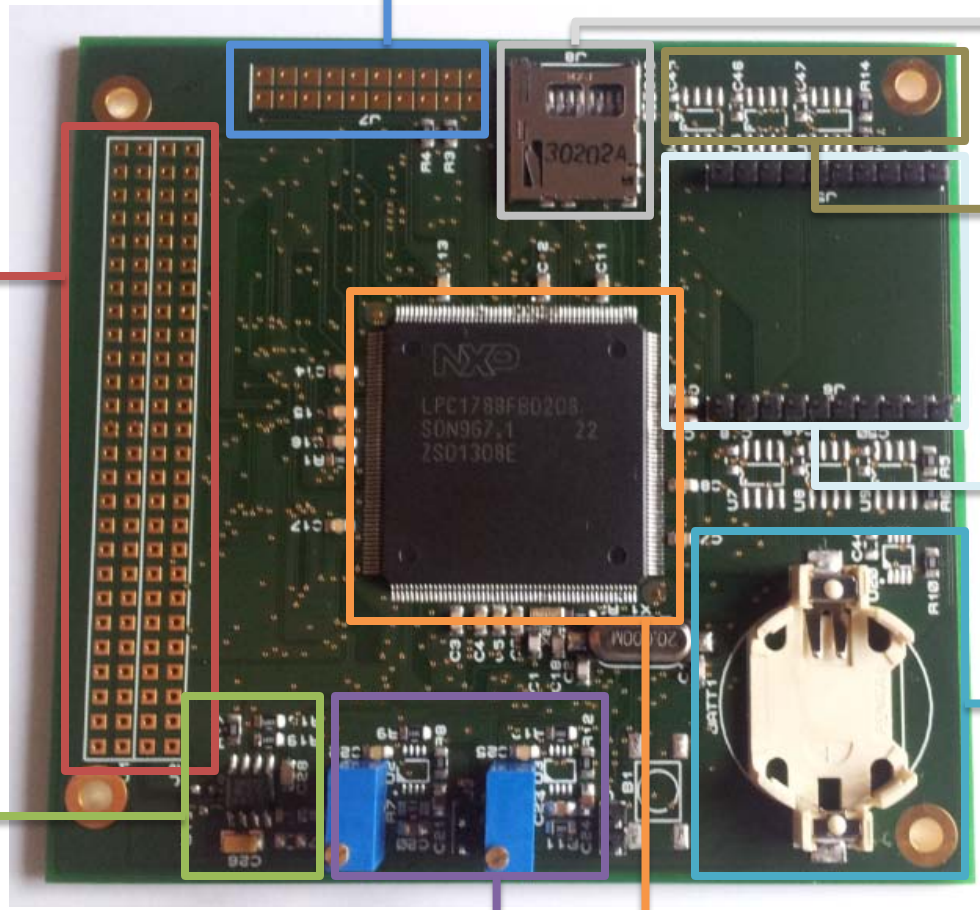
Our approach : Secure_ODB project (3/3)



Top view

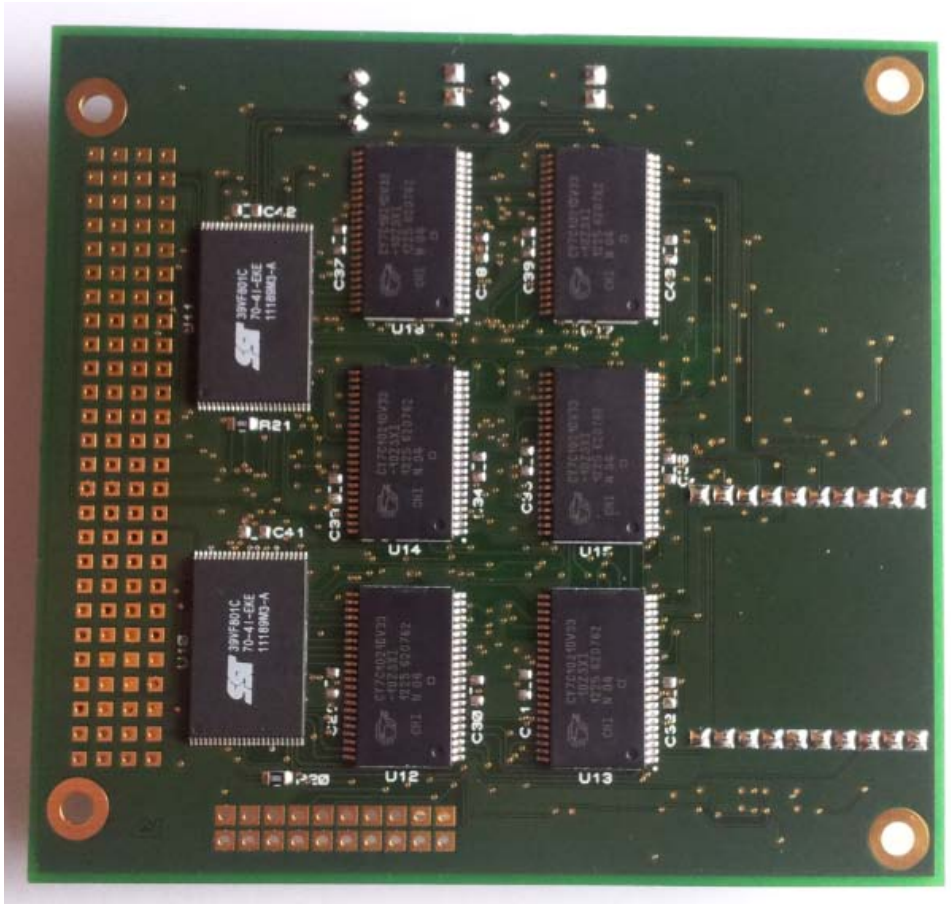
On-Board Computer For CubeSat

Our approach : Secure_ODB project (3/3)



On-Board Computer For CubeSat

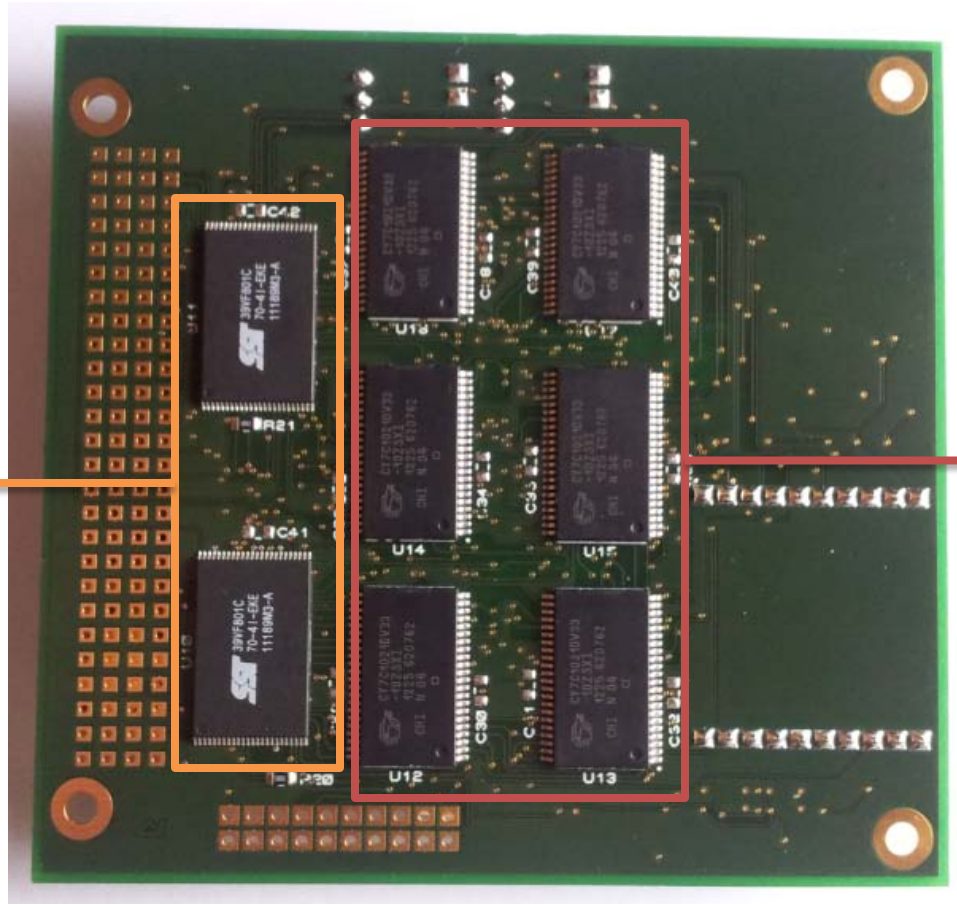
Our approach : Secure_ODB project (3/3)



Bottom view

On-Board Computer For CubeSat

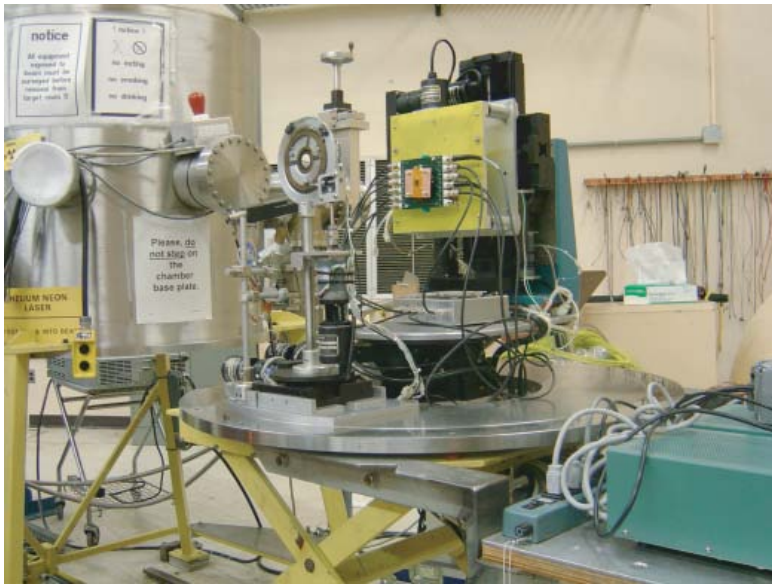
Our approach : Secure_ODB project (3/3)

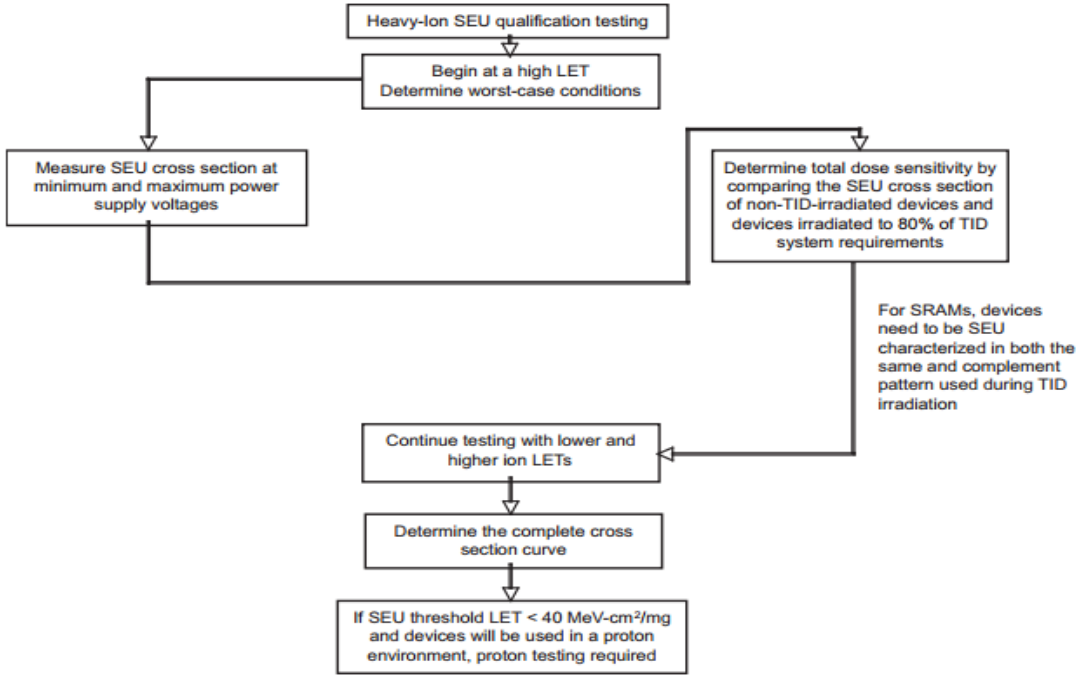


Functional And Validation Tests

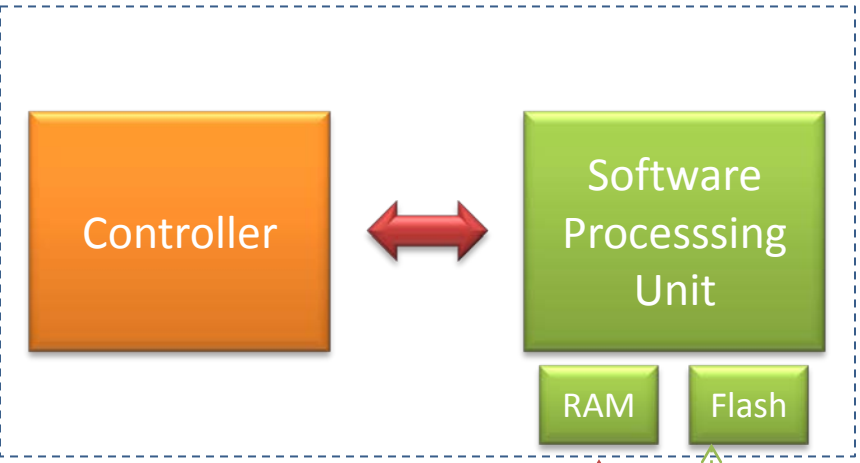
Test Facilities

- Brookhaven National Laboratory SEUTF (heavy ion)
- Lawrence Berkeley Labs 88" Cyclotron (heavy ion)
- Texas A & M University Cyclotron (heavy ion)
- Paul Scherrer Institute (heavy ion)
- University of California at Davis Crocker Nuclear Lab (proton)
- Indiana University Cyclotron (proton)
- …

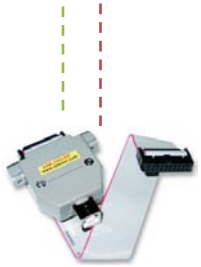




Functional Tests And Validation



JTAG-Based Injection Fault System



Random

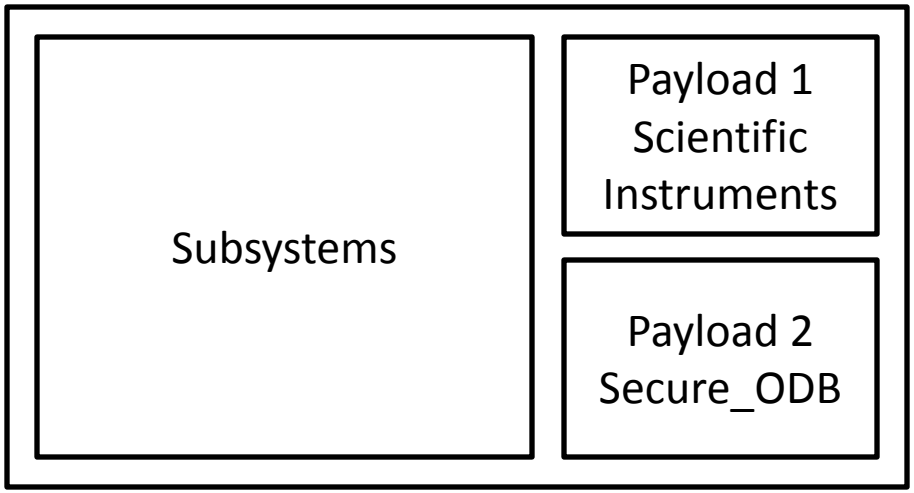
Script

Functional Tests And Validation

QB50 project

"QB50 has the scientific objective to study in situ the temporal and spatial variations of a number of key constituents and parameters in the lower thermosphere (90-320 km) with a network of about 40 double CubeSats, separated by a few hundred kilometres and carrying identical sensors."

- Launch scheduled in 2015



Conclusion And Perspectives

- On-Board Computer (Prototype 1) has just been done
  - Functional tests will be perform next weeks
  - Validation tests (QB50 or Facility tests)
- Definitive choice of the controller (doctor) : CPLD, µC 8-bits, other ?
- Contact Marquette University => Similar hardware architecture
- Questions ?