An Orbit-specific Fault-injector for FPGA-based Systems for Aerospace

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Table of contents

The MIST Lab - mistlab.ca

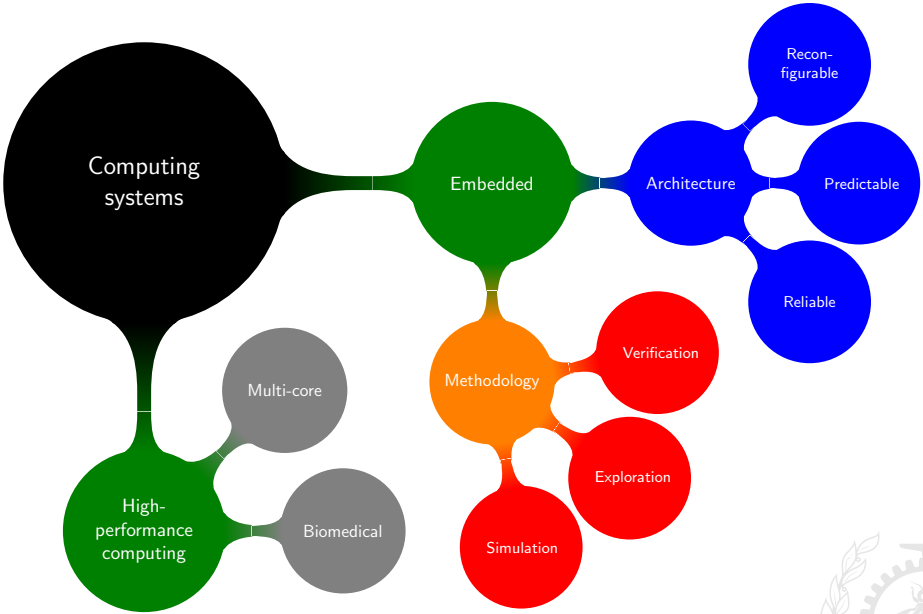
- Dedicated to embedded systems for aerospace

Activities and tools

- Computer Architecture (RISC-V, probabilistic systems)
- Human physiology (Auditory Orientation Aid)
- Thermal analysis (ICTherm - ictherm.com)
- Radiation tolerance (MORFIN - github.com/mistlab)
- Adaptive Systems and Optimization

- 2 postdocs (this fall), 6 PhD students, 1 MSc student, 2-3 interns
- Lab funded by NSERC, FRQNT, CAE, Altera

Our research in a nutshell



Motivation

- Adaptive systems are up and coming
  - Reduce the cost of space electronics
  - Increase reliability and device lifetime
  - Adapt to unforeseen consequences
- How to test adaptive reliability?

Motivational example

- Changing the level of fault-tolerance per mission phase
- More functionality/lower reliability vs.
- Reduced functionality/higher reliability

Objective

Our Objective

- To realize an orbit-specific Fault Estimator and Injector for FPGA based systems

Fault-injection can't replace radiation testing

- However, a realistic fault-injector can detect problems earlier
- Allows for testing reliability transitions

- Mission-specific orbital state vectors
- Modelling of the space environment
- Find the fault rate related to specific conditions

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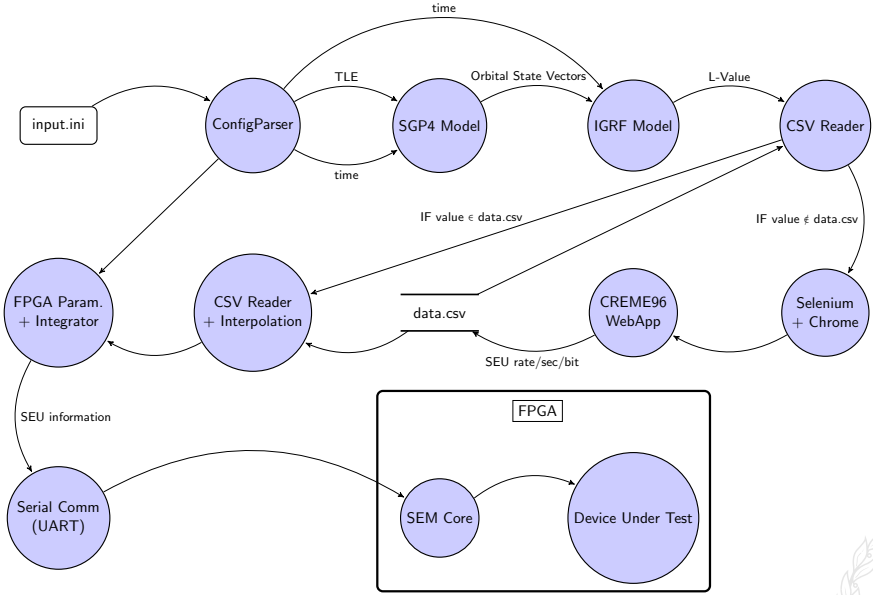
MORFIN: MIST Lab Orbital Fault Injector

- Ensemble of models (SGP4, IGRF, CREME96) to provide realistic fault injection
- Fault-rates computed per orbit section: useful to test reconfigurable systems
- Injects directly on Xilinx FPGAs (soon Altera)

Improved system lifetime

- Adaptive fault detection system
- Adaptive mapping to reduce system wear (radiation & thermal)

The framework



Resources

What is MORFIN?

- A simple python script!

- The SGP4 model is used to convert Two-Line Elements to Orbital State Vectors
- Spacepy is used for extracting the L-shell parameters
- The script uses Selenium for the CREME96 automation
- FPGA cross-section and shielding parameters

Fault injection

- Done using the Xilinx SEM core (limited to the DUT)
- Soon using Altera Fault Injection Debugger
- Fully automated (integrator and random)

CREME96 Interpolation

ISSUE: CREME96 is slow!

- 10 to 15 minutes per data point
- Can we reduce the calls to the website?

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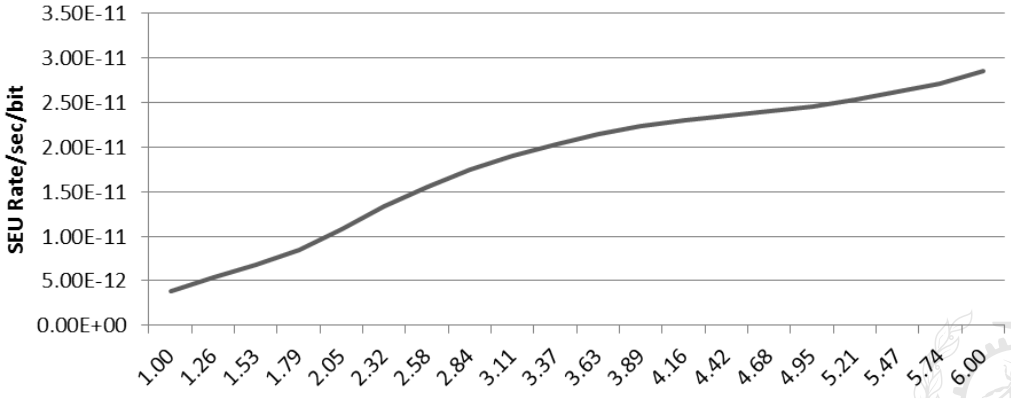

CREME96 Interpolation

- Orbits are split into predefined sections
- Linear and cubic interpolation between maxima
- Database of L-shell parameters and associated SEU rate
  - Depends on solar conditions
- Substantially reduced access to CREME96

Results

- 1000x faster results for known orbital sections (test months in minutes)
- Less than 0.5% error

Validation

- Validated against the ISS Virtex-4 parameters
  - Virtex-4 placed outside the ISS
  - Contains small test circuits
  - Records Single Event Effects
- Fault-rates produced by MORFIN match experimental results

NASA/ESA Adaptive Hardware and Systems

- Communication and space application conference
- Brings together space experts from Europe and the US

Wrap-Up

MORFIN

- Realistic orbit-specific fault injector
- Open source python script
- Automated fault injection
- Useful for self-adaptive and self healing systems

Other Activities

- NASA/ESA Adaptive Hardware and Systems 2015

The End

Questions?

http://mistlab.ca