Radiation Tolerant Computing for Aerospace Applications
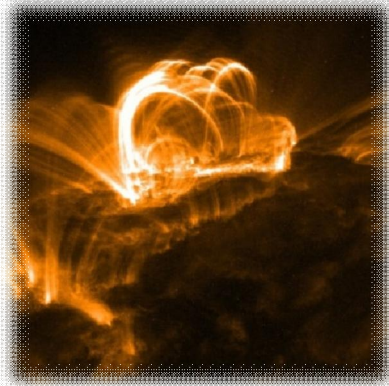
Brock J. LaMeres

Department of Electrical and Computer Engineering

Montana State University

Motivation

Radiation-Hardness for Aerospace Systems

- Cosmic radiation induces transients in integrated circuits
- Commercial processes are susceptible to Singe-Event-Upsets (SEUs)
- Aerospace systems must address this additional constraint

Mitigation Techniques

- A variety of approaches are used to achieve radiation-hardness:

1) Radiation by Architecture
- *Triple Modulo Redundancy, Fault Recovery Processes, COP*

2) Radiation by Design/Process
- *Substrate doping, Enclosed Layout Transistors, isolation trenches*

Motivation

Hasn't this been solved?

- Manned Missions Have Been Underway for 50 years

Mercury	Gemini	Apollo	Space Shuttle
1958-1963	**1965-1966**	**1968-1975**	**1975+**
(put a man in orbit)	(long duration in space)	(put a man on the moon)	(sustained space presence)

Atlas	Titan II	Saturn V	SRB + O_2/H_2 Tank

Motivation

Hasn't this been solved?

- Missions to Low Earth Orbits are protected from Radiation by the Earth's Magnetic Field
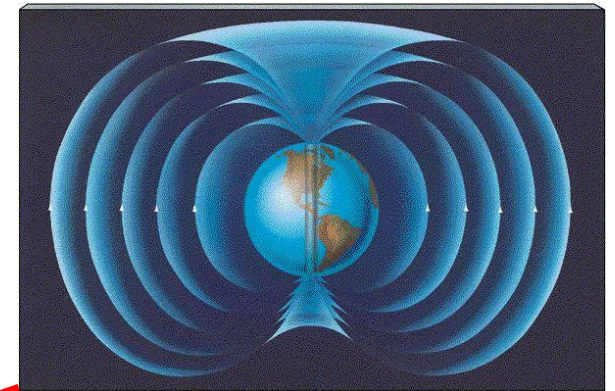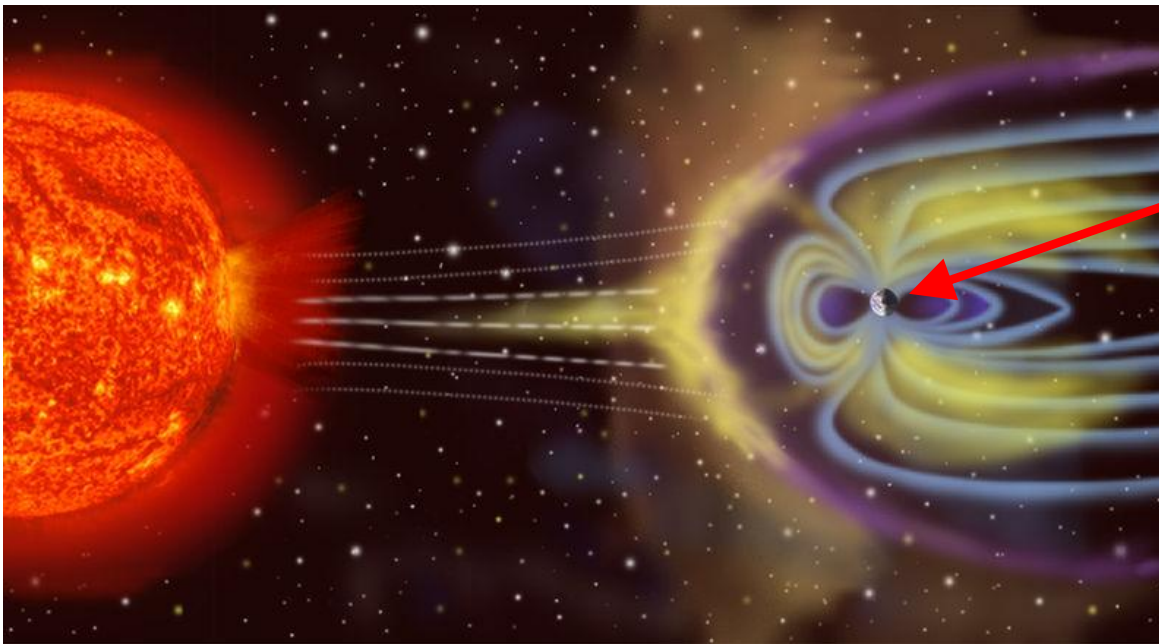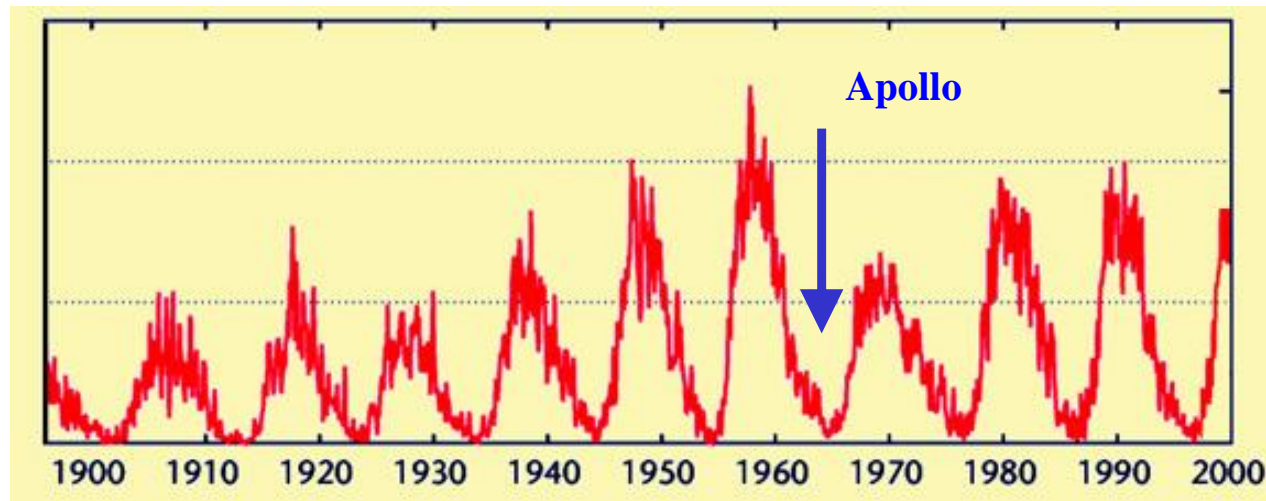
Motivation

How Did Apollo Do It?

- Solar events which cause major radiation occur in 12 year periods

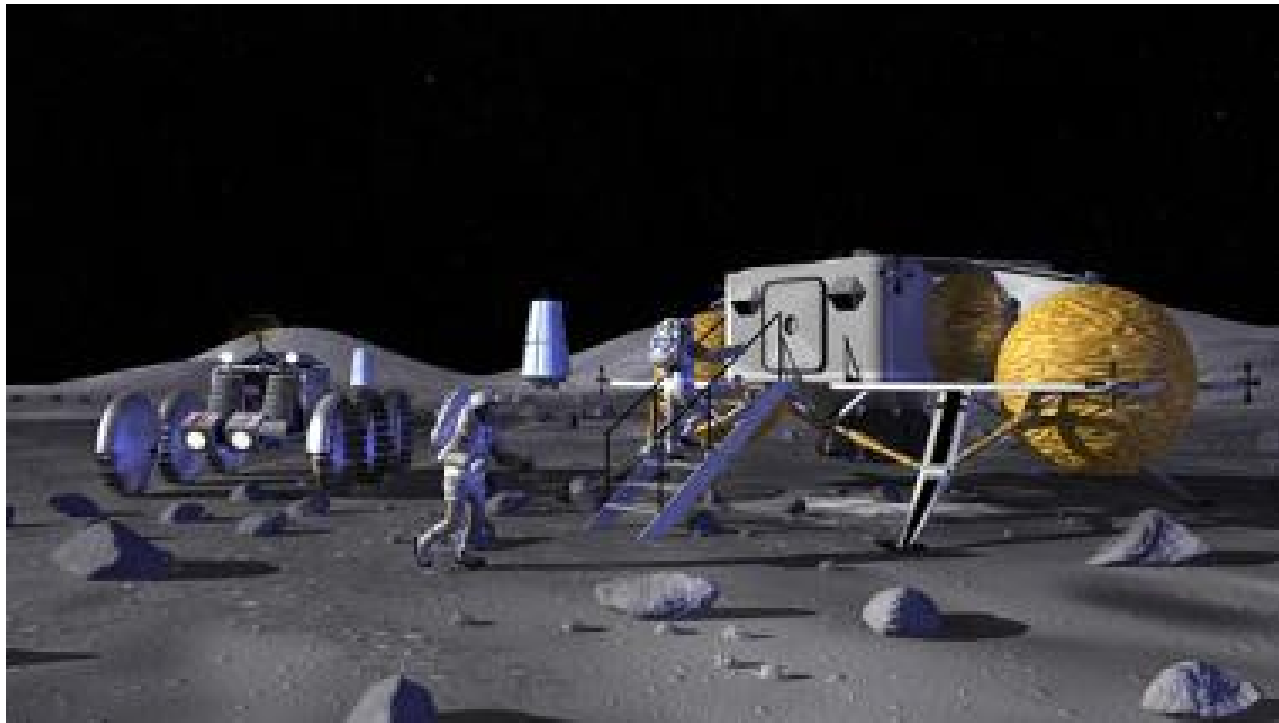- Apollo was timed to occur between solar events

Apollo

Solar Activity

1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
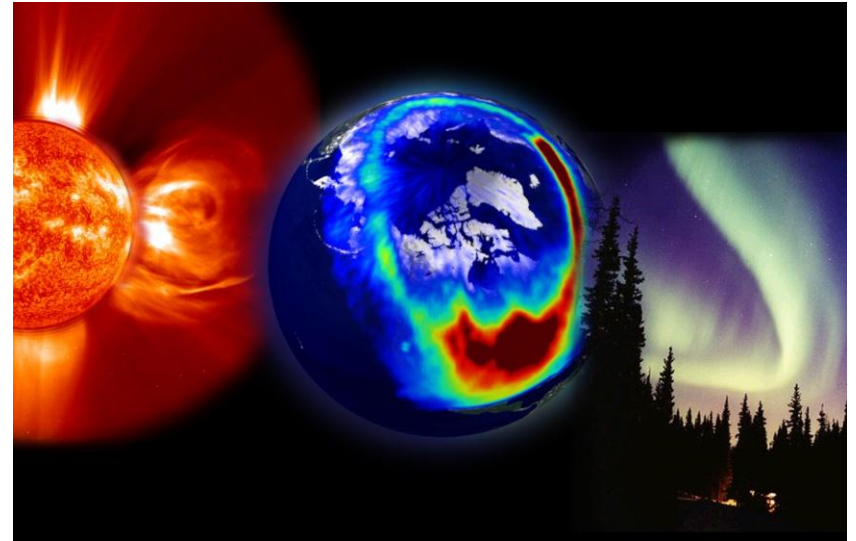
Motivation

Why not time it again?

- it's a different mission now, we want 10 yrs + outside of the magnetosphere

Lunar Surface Systems
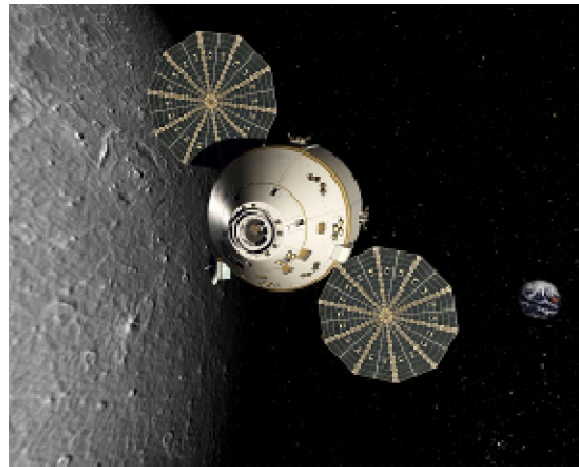
Motivation

Constellation – the next generation…

Ares I & V Launch Vehicles

Altair Lunar Lander

Orion Crew Exploration Vehicle

Orion Re-entry

Motivation

The Drawback of Rad-Hard Processors

A. Keys, J. Adams, R. Darty, M. Patrick, M. Johnson, & J. Cressier "Radiation Hardened Electronics for Space Environments (RHESE) Project Overview", IPPW-6, 23-27 June 2008
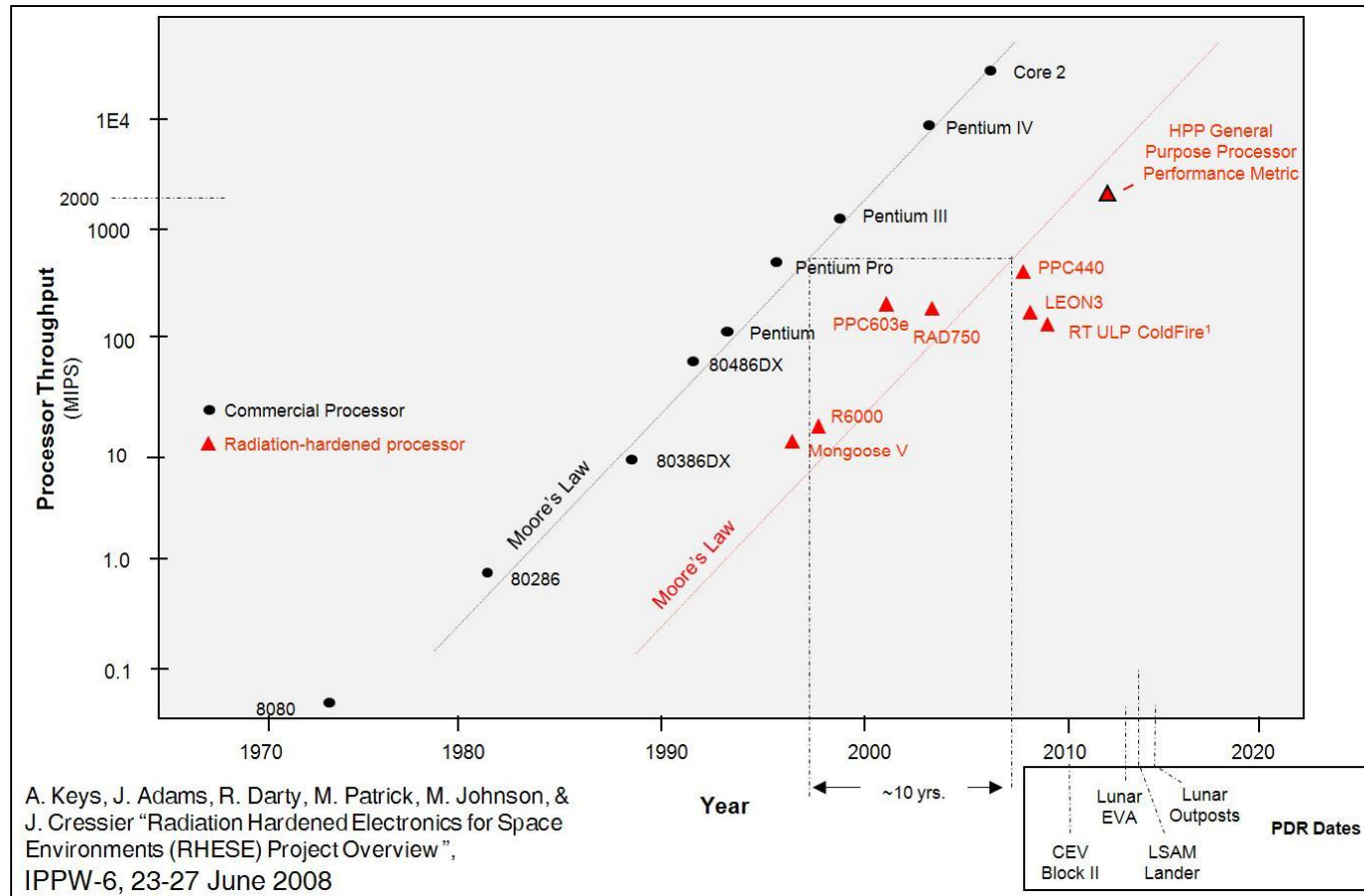
Radiation-Hardness translates into slower performance and more power consumption

Our Approach

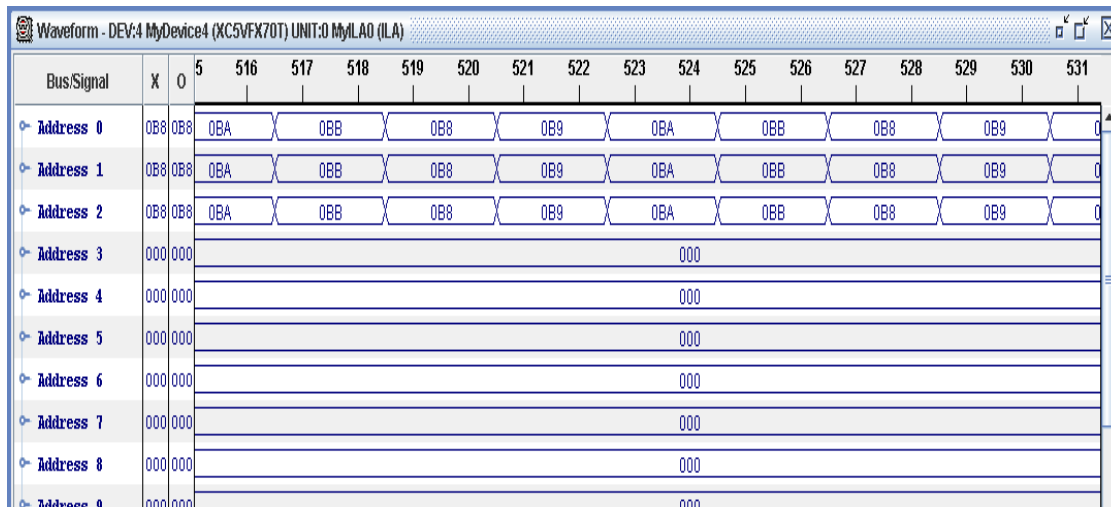## Spatial Avoidance of Radiation Strikes Using Programmable HW

- Redundant Processors (spares)

- Real Time Reconfiguration
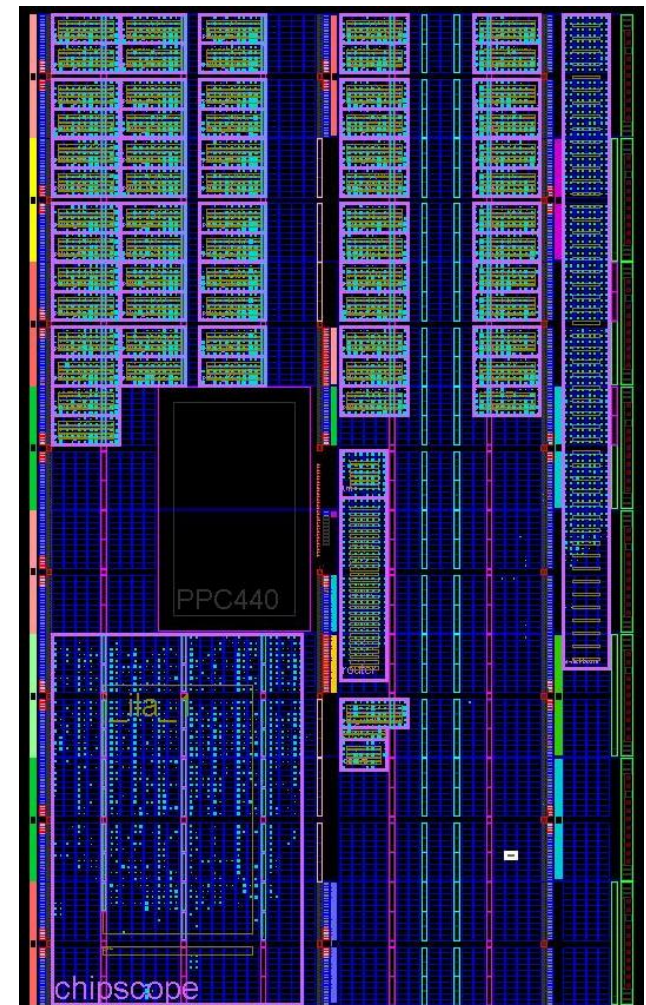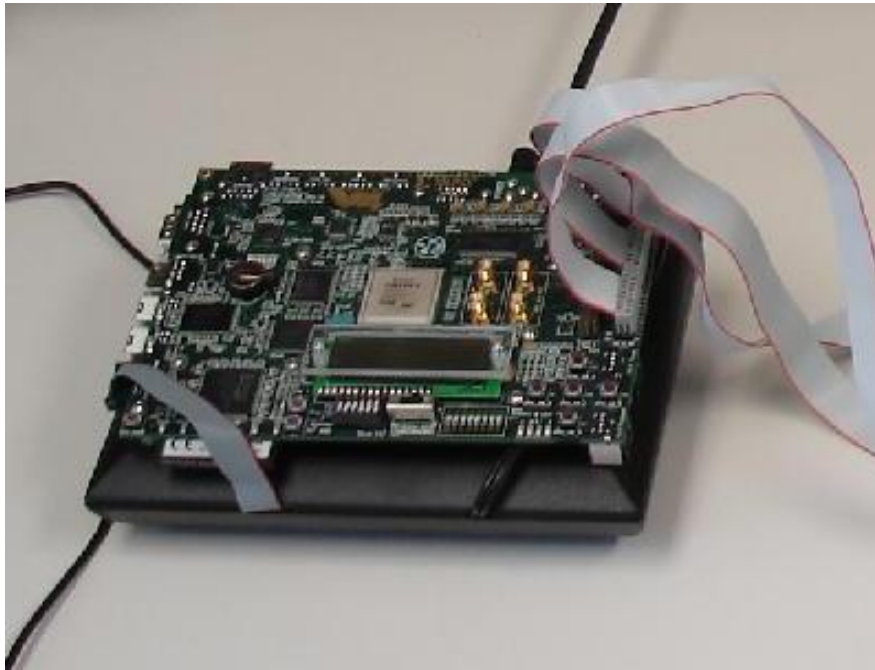
Our Approach
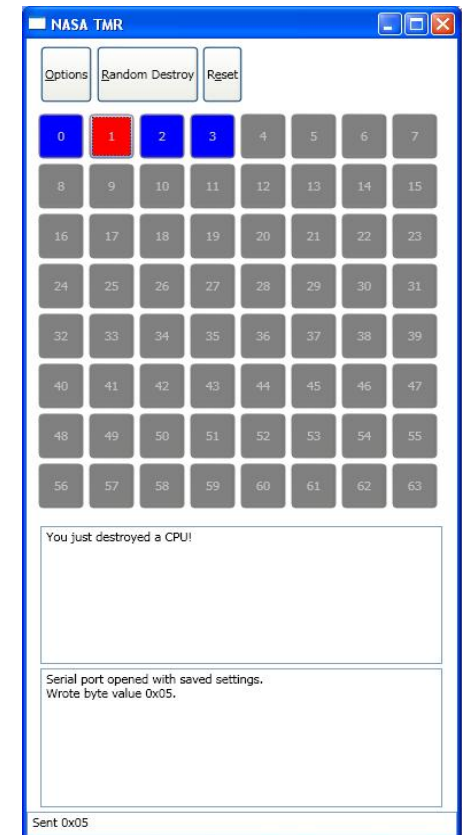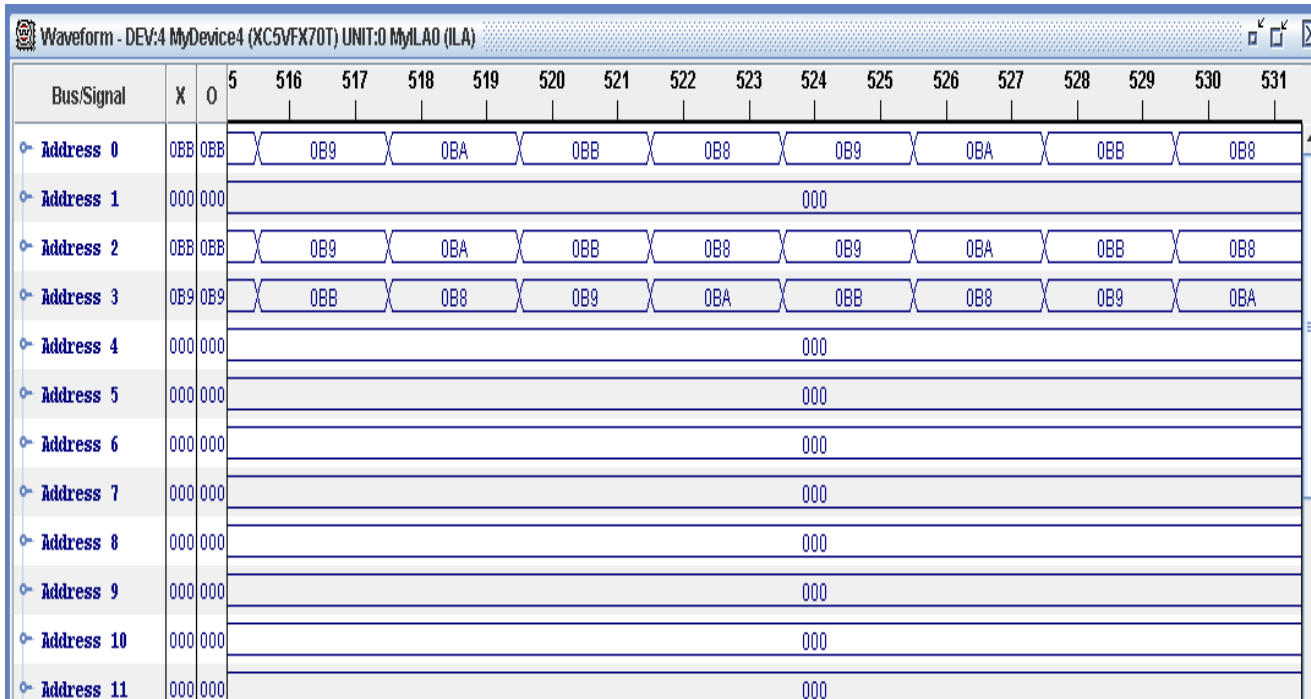
Three Processors Run in Synch

- Triple Modular Redundancy (TMR)

- Voter Circuit Checks for Errors
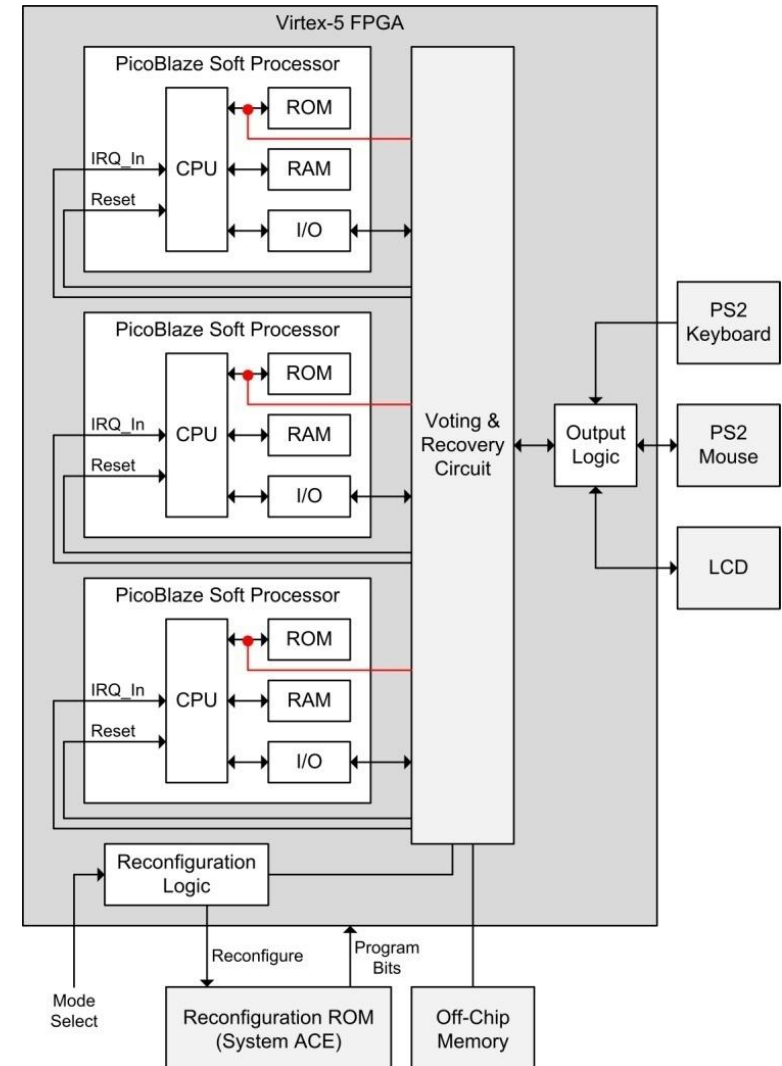
Our Approach

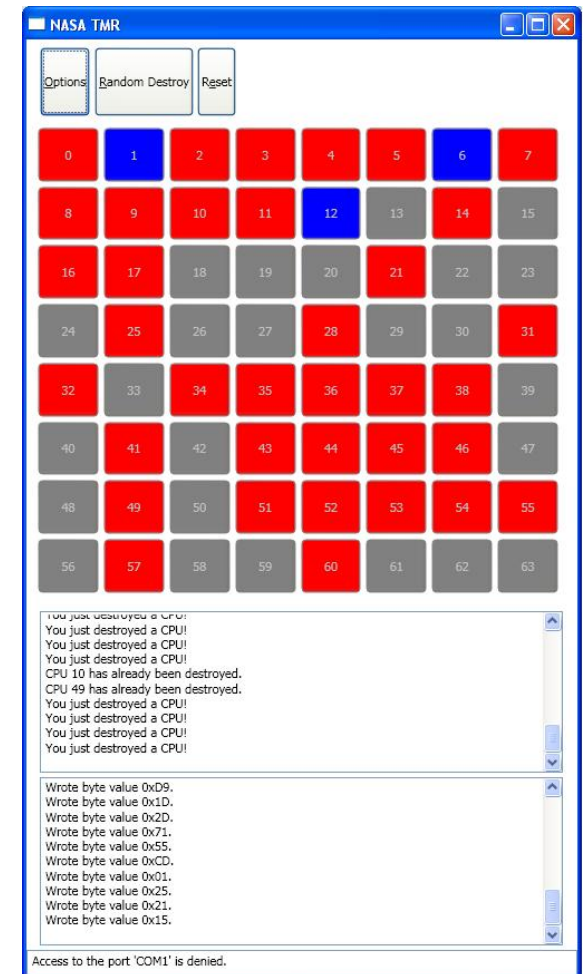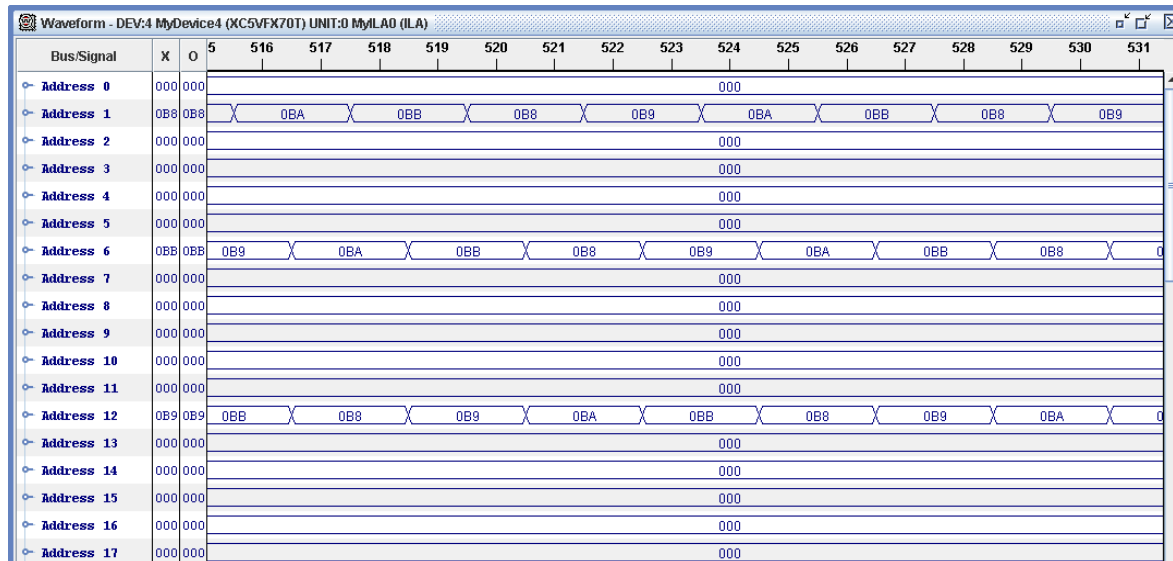## If Errors Are Detected in a Processor, Another One is Brought Online

- TMR is still in tact

Our Approach

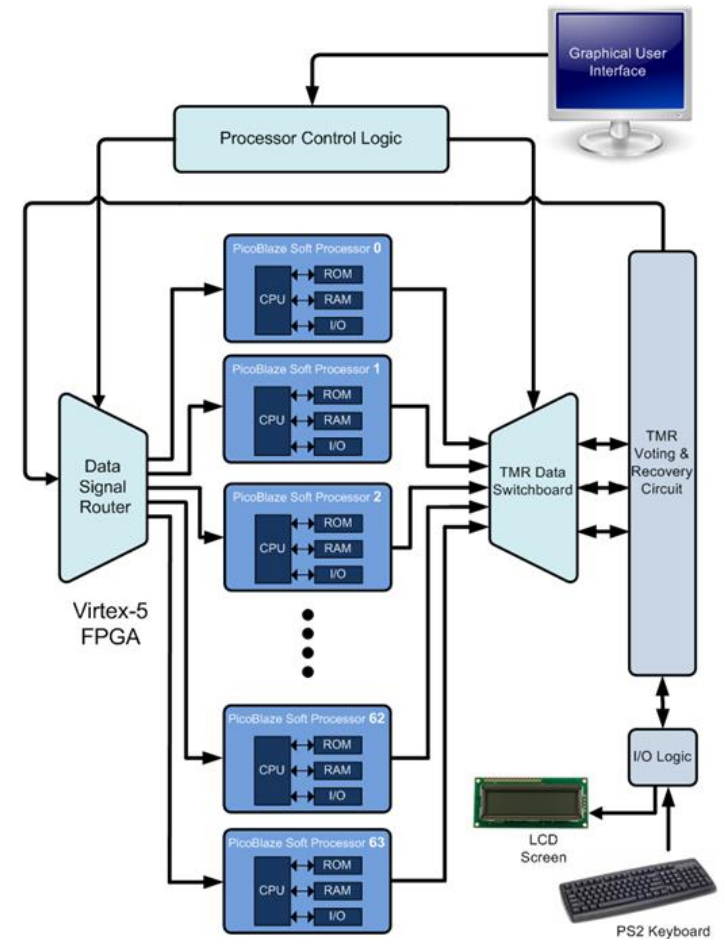## System Continues to operate in the presence of radiation

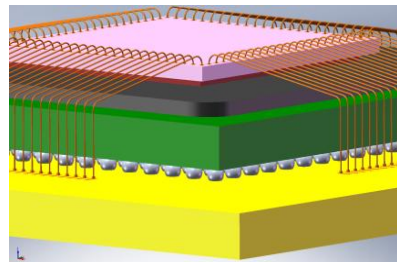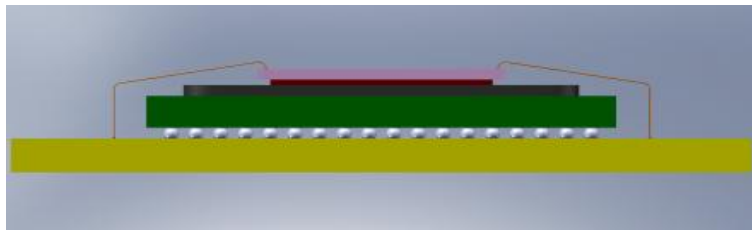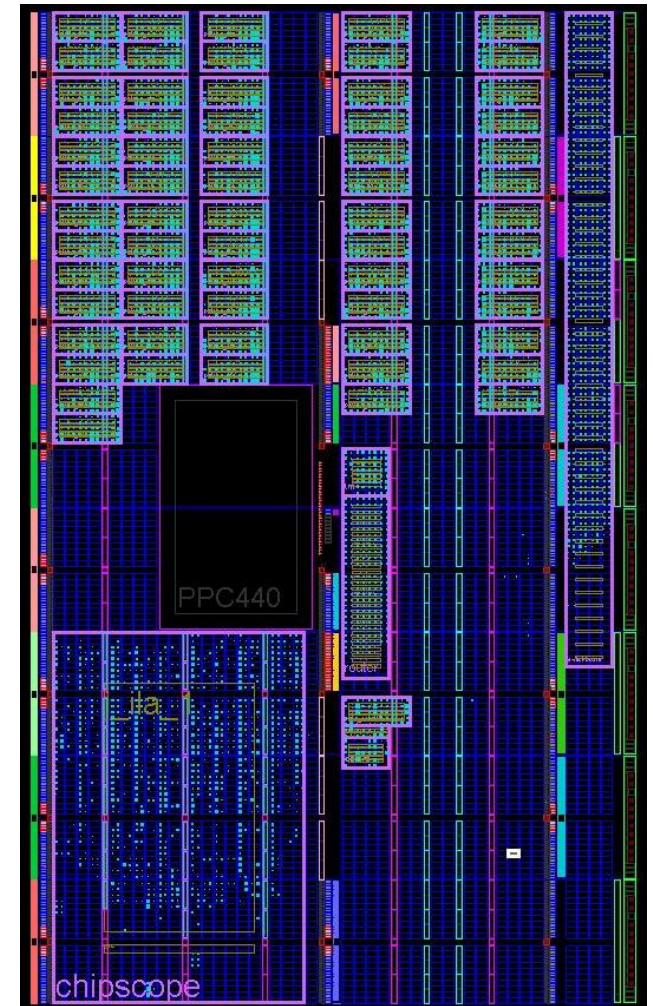- Damaged regions can sometimes be repaired.
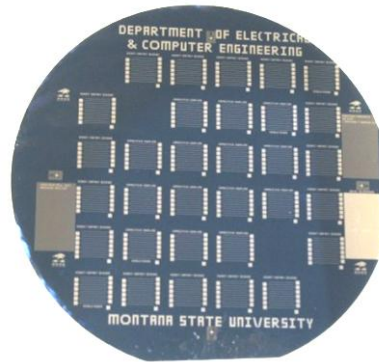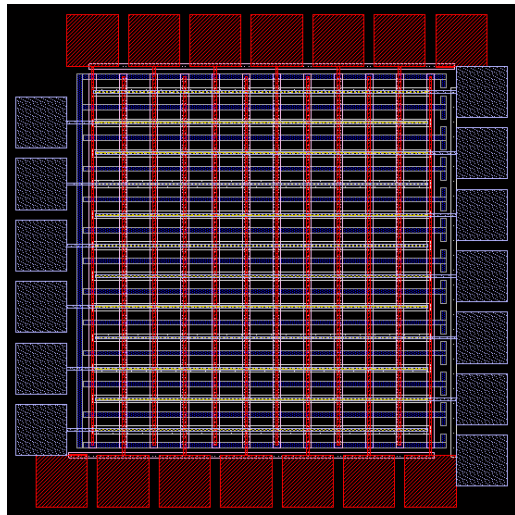
Our Approach

What happens during a recovery?

- Processors must be rebooted, reinitialized, and resynched

Our Approach

Integrated Sensor Can Be Coupled with FPGA For More Robustness

Questions