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

<table>
<thead>
<tr>
<th>Programme</th>
<th>Years</th>
<th>摘要</th>
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</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>1958-1963</td>
<td>(put a man in orbit)</td>
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<tr>
<td>Gemini</td>
<td>1965-1966</td>
<td>(long duration in space)</td>
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<tr>
<td>Apollo</td>
<td>1968-1975</td>
<td>(put a man on the moon)</td>
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<tr>
<td>Space Shuttle</td>
<td>1975+</td>
<td>(sustained space presence)</td>
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Atlas | Titan II | Saturn V | SRB + O₂/H₂ 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

Solar Activity

Apollo
Motivation

Why not time it again?

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

Constellation – the next generation…

Ares I & V Launch Vehicles

Altair Lunar Lander

Orion Crew Exploration Vehicle

Orion Re-entry

“Radiation Tolerant Computing for Aerospace Applications”
Motivation

The Drawback of Rad-Hard Processors

Radiation-Hardness translates into slower performance and more power consumption

“Radiation Tolerant Computing for Aerospace Applications”
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

“Radiation Tolerant Computing for Aerospace Applications”
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