Radiation Damage in SRAM and Flash Memory

James Duvall
Matt Shepherd
Nate Sherman
Tyler Green
Mission Overview: Objective

- The objective of this mission is to determine the correlation between increased cosmic radiation with altitude and the rate at which soft errors occur in Static Random Access Memory (SRAM) and Flash Memory.
- The relationship, if any, among the magnetic field of the earth, the incident radiation, and error rate will be studied.
- We expect to prove that the soft error rate increases with altitude due to an increase in cosmic radiation.
Mission Overview: Underlying Science/Theory

- SRAM and Flash Memory are susceptible to soft errors due to the large amounts of transistors that they rely on.
- When radiation hits a transistor, it can cause a bit flip within the transistor (1 becomes a 0 or a 0 becomes a 1).
- These bit flips can cause undesired writes and for the wrong data to be written.
- This problem increases as the transistor sizes decreases (decreased critical charge.)
Mission Overview: Related Research

• Many experiments have been done on the effects of ionizing radiation on SRAM and Flash Memory.
• NASA and JPL have been the agencies doing much of the research, especially when related to cosmic radiation. (Nguyen, D.N.)
• An experiment was carried out by students at the University of Kuwait that was very similar to our experiment.(Alpisher,A)
Mission Overview: Related Research Continued

• These experiments have shown that increases in ionizing radiation increases the rate at which soft errors occur. (Alpisher, A)
• It has been shown that cosmic radiation is affected/influenced by the earth’s magnetic field.
  – A charged particle’s path bends in a magnetic field
• It has also been seen that a large enough dose of radiation can completely destroy electronic devices.
• SRAM is more susceptible to soft errors than Flash Memory. (Alpisher, A)
Mission Overview: Related Research Continued

- Most of this research was carried out in a laboratory setting, using artificial radiation sources.
- Our experiment will allow for error rates to be determined in real life conditions and compared against cosmic irradiation rates.
Design

Assembled Payload

Exploded View
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Base</td>
</tr>
<tr>
<td>B</td>
<td>Spring Plate</td>
</tr>
<tr>
<td>C</td>
<td>Spring Assembly</td>
</tr>
<tr>
<td>D</td>
<td>Lock Plate</td>
</tr>
<tr>
<td>E</td>
<td>Core Locking Blades</td>
</tr>
</tbody>
</table>
Manufacturing

3D Printed Inner Core Components
Assembled Inner Core
Fiberglass Inner Core Cylinder
Polyurethane Foam Mold
Interfacing with the Memory
# Test 1: Drop Test

<table>
<thead>
<tr>
<th>Objective:</th>
<th>Determine structural integrity of payload upon landing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure Name:</td>
<td>Drop Test</td>
</tr>
<tr>
<td>Completion Date:</td>
<td>July 2, 2013</td>
</tr>
</tbody>
</table>

## Test Setup Overview:
Payload was dropped from an elevated platform that was 15’ 3” high onto a hard dirt surface. Structural integrity was determined upon recovery.

## Test Details:
- Electronics were simulated with weighted foam mockups
- Flight cord was not integrated during the test

## Results:
Top acrylic lid fractured upon impact but the inner core remained intact. This showed that all electronics would have most likely survived the impact.

## Open Issues:
If an SD shield fastener becomes detached during flight the memory chip could be released out the top of the payload.
# Test 2: Stair Test

<table>
<thead>
<tr>
<th>Objective:</th>
<th>Determine structural integrity of payload upon possible re-inflation of parachute after landing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure Name:</td>
<td>Stair Test</td>
</tr>
<tr>
<td>Completion Date:</td>
<td>July 3, 2013</td>
</tr>
</tbody>
</table>

| Test Setup Overview: | Payload was pushed down a flight of 24 steel stairs that were 6 ¾ in. high and 44 in. wide. |

<table>
<thead>
<tr>
<th>Test Details:</th>
<th>Open Issues: If an SD shield fastener becomes detached during flight the memory chip could be released out the top of the payload.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Electronics were simulated with weighted foam mockups</td>
<td></td>
</tr>
<tr>
<td>• Flight cord was not integrated during the test</td>
<td></td>
</tr>
</tbody>
</table>

| Results: | Top acrylic lid slightly fractured upon impact but the inner core remained intact showing that all electronics would have most likely survived impact. |

|  |  |
**Test 3 : Whip Tests**

**Objective:** Determine structural integrity of payload under worst case scenario acceleration and impact forces from other payloads.

**Procedure Name:** Overhead Whip Test, Drop Whip Test

**Completion Date:** July 8, 2013

---

**Overhead Whip Test Setup**

**Overview:** Payload was swung overhead for 30 seconds then a sudden directional change was implemented.

**Test Details:** Electronics were simulated with weighted foam mockups and a 6 ½ foot flight string was attached.

---

**Drop Whip Test Setup**

**Overview:** Payload was dropped from an elevated surface secured to an 8 ft. flight string to stop the fall.

**Test Details:** Electronics were simulated with weighted foam mockups.

---

**Results:** Slight impression in outer foam core from washers connecting the polyurethane foam to the fiberglass core. Otherwise, payload remained structurally intact.

**Open Issues:** None.
Test 4 : Vacuum Test

**Objective:** Determine if the high voltage Geiger Muller circuit will operate at the lowest pressure environment of the flight.

**Procedure Name:** Bell Jar Vacuum Test

**Completion Date:** July 19, 2013

**Test Details:** The pressure was dropped to 603 Pascal and held for 5 minutes to simulate lowest pressure in flight. Pressure was then brought back to room temperature and the payload was

**Test Setup Overview:** Payload was powered on and then placed inside the bell jar vacuum.

**Results:** Geiger Muller tube counted radiation hits properly and the micro SD card successfully recorded them.

**Open Issues:** None.
## Test 5: Geiger Muller Tube Calibration

<table>
<thead>
<tr>
<th><strong>Objective:</strong> Determine if the Geiger Muller circuit is accurately calibrated.</th>
<th><strong>Test Setup Overview:</strong> Geiger Circuit was placed two meters away in the path of a known amount of Cesium 137. Readings were taken for three minutes.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedure Name:</strong> Calibration Test</td>
<td><strong>Test Details:</strong> An average of 21,320 counts per minute (cpm) of beta and gamma radiation were seen. Converting into mR/hr the radiation readings were compared to the known amount provided by the lab technician.</td>
</tr>
<tr>
<td><strong>Completion Date:</strong> July 17, 2013</td>
<td><strong>Results:</strong> Geiger Muller tube read 17.5 mR/hr and the data sheet showed approximately 18 mR/hr showing the calibration is accurate.</td>
</tr>
<tr>
<td><strong>Open Issues:</strong> None.</td>
<td></td>
</tr>
</tbody>
</table>
Test 6: Day in the Life

Objective: Determine if all components will function properly for the duration of the flight.

Procedure Name: Day in the Life Test

Completion Date: July 23, 2013

Test Details: An average of 21,320 counts per minute (cpm) of beta and gamma radiation were seen. Converting into mR/hr the radiation readings were compared to the known amount provided by the lab technician.

Results: All components functioned properly throughout the entirety of the test. This instilled confidence in us that the device will function the entire duration of the flight.

Open Issues: None.
## Test 7: Cold Test

**Objective:** Determine if all components will function at the lowest temperature that will be encountered for an extended period of time.

**Procedure Name:** Cold Test

**Completion Date:** July 25, 2013

---

### Test Setup Overview

Placed the completed payload inside an ice chest with 15 pounds of dry ice for two hours.

---

### Test Details

The ice chest was maintained at –69.6 degrees Celsius throughout the test. The internal temperature of the payload was monitored by a Trendicator to ensure the temperature did not drop below zero degrees Celsius.

---

### Results

All components were able to be held above zero degrees Celsius until two hours and fifteen minutes in. At that point the battery powering the two heaters had died.

---

### Open Issues

Condensation forming on the inside of the lid may affect the electronics on the top tray.
Choosing a Heating System

Temperatures vs. Time

- **Temperature [°C]**
- **Time [min]**

**Internal:**
- Hand Warmers
- Heaters

**GM Tube:**
- Heaters
- Hand Warmers

Choosing a Heating System
Expected Results

- Cosmic radiation should increase as altitude increases.
  - A decrease may be seen, but this will be understood
- Increase will be due mainly to lower air density.
- The increase should be very fast (cosmic radiation has been seen to increase 90 times from sea level to 30,000 feet (source))
Launch One Data

Internal Temperature versus Altitude

Radiation versus Altitude
Launch One Data

- An error in dataflow caused memory error data to be invalid

Magnetic Field versus Altitude
Second Launch

• A few items needed to be fixed
  – Removal of “idle” mode
    • Caused Arduino to never read data after a reset
  – Have heater initiation depend on pressure change, not altitude
    • Altitude software tended to get stuck
    • Have backup heaters (hand warmers)
  – Dataflow needed to be 4 bytes wide, versus 1 byte initially
Launch Two Data

Temperature versus Altitude

Radiation versus Altitude
Lessons Learned

• A special focus should be paid to communication architecture, especially that for which the most critical data will pass.

• Test your payload as much as possible. You can never test enough to simulate the actual flight of the payload.

• Ensure that your activation sequence is as close to flawless as possible seeing that the whole project is dependent on this function.

• It’s alright to be ambitious, but be sure to choose a project that is within reason for the time frame allotted.
Any Questions?