Proton Testing of Micro Advanced Stellar Compass
TEC-QCA Support Activity to PROBA-II

Presentation by Helle K. Aage hka@oersted.dtu.dk
And Peter B. Guldager pbg@oersted.dtu.dk

8th ESA/ESTEC D/TEC-QCA Final Presentation Day
January 23th & 24th 2007
PROBA-II

Spacecraft technology miniaturisation

• Attitude measurement sensors
• Attitude control systems
• Integrated data handling
• Enhanced payload and others

Miniature: Micro Advanced Stellar Compass
Micro Advanced Stellar Compass

• The micro-Advanced Stellar Compass (µASC) is a highly advanced and fully autonomous star tracker designed to connect 4 camera heads, developed and produced by the Measurement and Instrumentation Systems (MIS) Section of the Ørsted Department at the Technical University of Denmark (DTU).

• The µASC attitude sensor delivers in real-time up to 32 real time attitudes per second a three-axes attitude of its reference frame with respect to the J2000 inertial reference frame at any user specified epoch.

• The data delivered by the µASC can directly be used to control the attitude of the satellite.
Test Facilities

• The SEU tests were performed at the Paul Scherrer Institute 14-15 February 2006 by the Space Instrumentation Group at Ørsted•DTU, Denmark with participation from ESA/ESTEC

• The Danish National Space Center would like to thank ESA for the economic support and kind assistance (and time) from Dr. Reno Harboe Sørensen and Dr. Frederic Teston from ESA.
COTS: ASC and µASC

- Compatibility with design
- Observation
- Time
- Study

- Total dose tests
- Irradiation with particles
- Damage investigation
Latch-Up Protection

- Several latch-up protection circuits for groups of components operating together
- Increased current consumption mean shut-down and reboot of the entire system to prevent destruction.
- Latch-up protection circuits proved their efficiency with success during heavy ion tests.
Correction Mechanisms

• EEC protection on FLASH RAM and SDRAMs
• 2 bits detection, 1 bit correction is used
• Double bit flips means system reboot

• SEUs as bit flips are logged during tests together with the bit addresses
System Functionality

- All components on board
- Size of test board
- Unintentional irradiation
- Current consumption & System response
- Cross sections
- Irradiation sequence
- Test board set-up
- Proton energy
- Versus single component response
- Selected components
Layout: Board Size and Set-Up
Collimator - and Unintentional Irradiation
Beam Parameters for PSI tests

- 15mm planar beam
- Mean flux $7.2 \times 10^7$ /cm$^2$/s
- Mean fluence $9.3 \times 10^9$ /cm$^2$
- Mean dose 500 rad(Si)
- Proton energy 223 MeV (32 MeV)
- HY57V651620BLTC-10S: 38, 50, 72, 101, 151, 210 and 223 MeV
## Components w/ Special EGSE Test Programs

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Manufacturer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR2T06A5T144</td>
<td>Lattice Semiconductor</td>
<td>FPGA</td>
</tr>
<tr>
<td>ELANSC520-100</td>
<td>AMD</td>
<td>CPU</td>
</tr>
<tr>
<td>HY57V651620BLTC-10S</td>
<td>Hynix / Hyundai</td>
<td>64 Mbit SDRAM</td>
</tr>
<tr>
<td>AT49BV1614T-11TI</td>
<td>ATMEL</td>
<td>FLASH</td>
</tr>
<tr>
<td>AT27C512R</td>
<td>ATMEL</td>
<td>64K * 8 OTP EPROM</td>
</tr>
<tr>
<td>MAX1081AEUP</td>
<td>MAXIM</td>
<td>8 chn. 10 bit ADC</td>
</tr>
<tr>
<td>MAX1444EHJ</td>
<td>MAXIM</td>
<td>10 bit ADC</td>
</tr>
<tr>
<td>MAX3031EESE</td>
<td>MAXIM</td>
<td>Quad Line Driver</td>
</tr>
<tr>
<td>MAX3096EESE</td>
<td>MAXIM</td>
<td>Quad Line Receiver</td>
</tr>
<tr>
<td>LT1242IS8</td>
<td>Linear Technology</td>
<td>Pulse Width Modulator</td>
</tr>
</tbody>
</table>
Star Tracking Using 9-Star-Stimulator

- Stimulator update mode
- House keeping frequency 1 Hz
- Bitwash frequency 1/min
- Debug to trap RAM bitflips
- Exception handling logging
- Watchdog timeout 2s for rapid recovery

- LT1242IS8, ELANSC520-100, MAX1081AEUP, HY57V651620BLTC-10S
Star Tracking Using 9-Star-Stimulator
Monitoring Image Statistics

• Stimulator update mode
• House keeping frequency 1 Hz
• Bitwash frequency 1/min
• Debug to trap RAM bitflips
• Exception handling logging
• Watchdog timeout 2s for rapid recovery
• Debug variance flag for monitoring statistics

• OR2T06A5T144, MAX1444EHJ
Power Cycling the Instrument

- Reboot continuously
- Reading from PROM (bootstrap and safe-mode software)
- Reading from Flash (application mode software)
- Attitude packet transmission leads to reboot
- Exception handling logging
- Final reboot after end of irradiation

- AT49BV1614T-11TI, AT27C512R
Verifying Telemetry Quality

- Special program for test of line driver
- Memory dump
- Performance evaluation based on checksum errors
- Very low telemetry packet size for better statistics (100 bytes)
- No attitude determination: Stand-by mode
- Exception handling logging
- Watchdog timeout 2s for rapid recovery

- MAX3031EESE
Verifying Telecommand Quality

- Special program for test of line receiver
- Continuous House keeping requests at 0.1 Hz
- Performance evaluation based on checksum errors
- No attitude determination: Stand-by mode
- Exception handling logging
- Watchdog timeout 2s for rapid recovery

- MAX3096ESE
MAX3031EESE  MAX3096ESE

- MAX3031 generates the 422 signal levels for the telemetry transmission. The telemetry port was sending continuously during the test, i.e. with a duty cycle of 100% while the debug duty cycle was 5%. No component transmission errors on either of the ports were observed during the test.

- MAX3096 transforms the 422 signal levels for the telecommand interface to low voltage signals. No errors were seen for TC-commands during the test of the MAX3096EESE. However, the test caused a reboot and a high number of SEUs was observed because 1/3 of the area of an adjacent SDRAM was irradiated, too.
- No critical signatures in the standard deviation measurements were observed. Slight increase in gain values (AGC level).
- The MAX1444EHJ showed a one-time occurrence of a single minor spike in the centre image (100 by 100 pixels) standard deviation. The spike corresponds to a transient image hotspot.
HY57V651620BLTC-10S: SEUs & Exceptions

<table>
<thead>
<tr>
<th>MeV</th>
<th>38</th>
<th>50</th>
<th>72</th>
<th>101</th>
<th>151</th>
<th>210</th>
<th>223</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEUs</td>
<td>44</td>
<td>74</td>
<td>129</td>
<td>189</td>
<td>435</td>
<td>521</td>
<td>525/606</td>
</tr>
</tbody>
</table>

- 0D General Protection Error
- 02 Double Bit Flip
- 10 Floating Point Error

<table>
<thead>
<tr>
<th>MeV</th>
<th>38</th>
<th>50</th>
<th>72</th>
<th>101</th>
<th>151</th>
<th>210</th>
<th>223</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exc.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0D</td>
<td>1</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

- 02 7/6 02
HY57V651620BLTC-10S: Cross Sections

Proton SEU Cross Section
Corrections for background SEUs and data loss during reboots

Cross section (cm²/bit)

Proton Energy (MeV)
Cross Sections: SDRAM and CPU

- CPU < 3.3 E^{-10} \text{ cm}^2/\text{device}
- Reboots observed during test due to exceptions
  0D general protection error concerning RAM read/write procedures

- SDRAM < 4 E^{-8} \text{ cm}^2/\text{device}
- SDRAM < 1.5 E^{-15} \text{ cm}^2/\text{bit}
Occasional SEUs (from SDRAM)
Otherwise no effect

- LS1242IS8
  Tested twice
  1 reboot

- MAX1081AEUP
  No latch-ups
  No reboots

- AT27C512R
- AT49BV1614T-11TI
  Tested together
  No reboot problems encountered
Thank You

Danish Team with ESA/ESTEC