DANISH NATIONAL SPACE CENTER

DTU

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

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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

- **C**ompatibility with design
- **O**bservation
- **T**ime
- **S**tudy

- **T**otal dose tests
- **I**rradiation with particles
- **D**amage 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

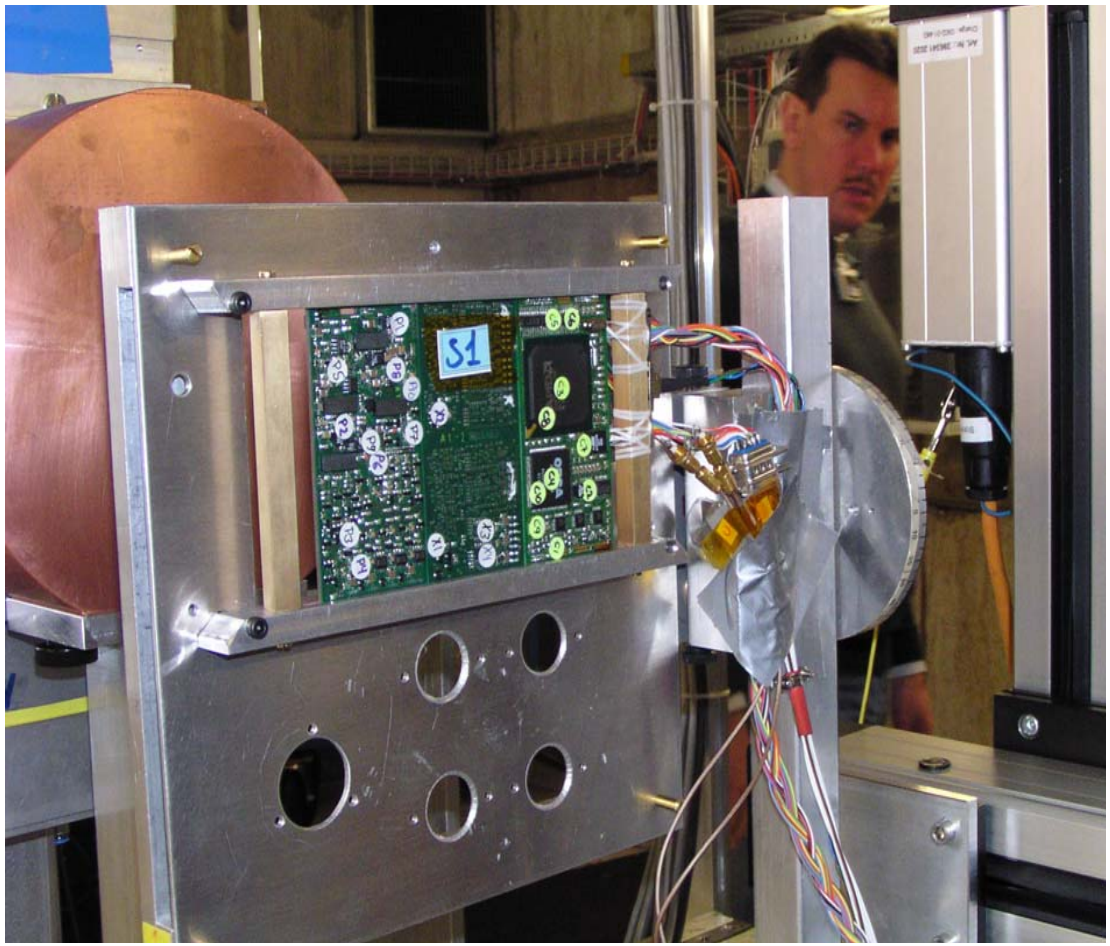
- EEC protection on FLASH RAM and SDRAMs
- 2 bits detection, 1 bit correction is used
- Double bit flips means system reboot

- SEUs as bit flips are logged during tests together with the bit addresses

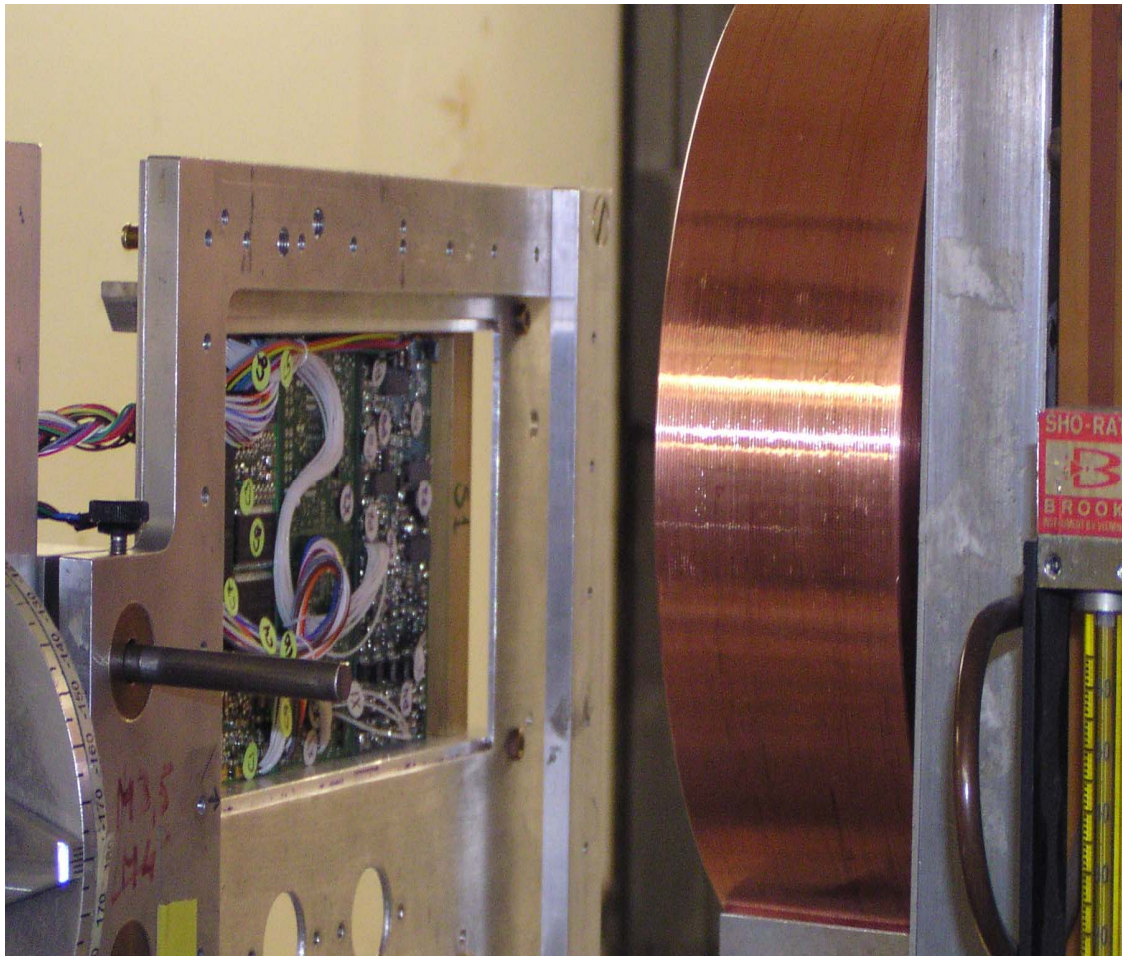
System Functionality

- 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 E^7 /cm^2/s
- Mean fluence 9.3 E^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

OR2T06A5T144	Lattice Semiconductor	FPGA
ELANSC520-100	AMD	CPU
HY57V651620BLTC-10S	Hynix / Hyundai	64 Mbit SDRAM
AT49BV1614T-11TI	ATMEL	FLASH
AT27C512R	ATMEL	64K * 8 OTP EPROM
MAX1081AEUP	MAXIM	8 chn. 10 bit ADC
MAX1444EHJ	MAXIM	10 bit ADC
MAX3031EESE	MAXIM	Quad Line Driver
MAX3096ESE	MAXIM	Quad Line Receiver
LT1242IS8	Linear Technology	Pulse Width Modulator

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

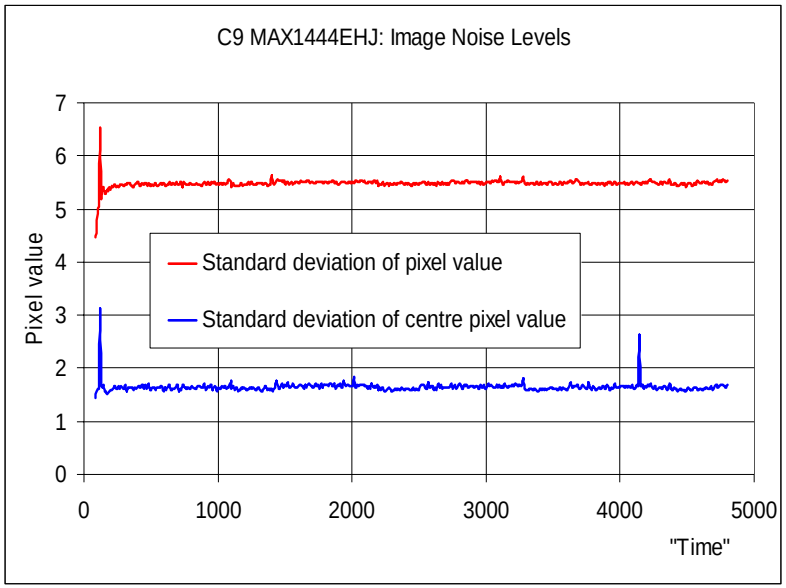
- MAX3096ESE

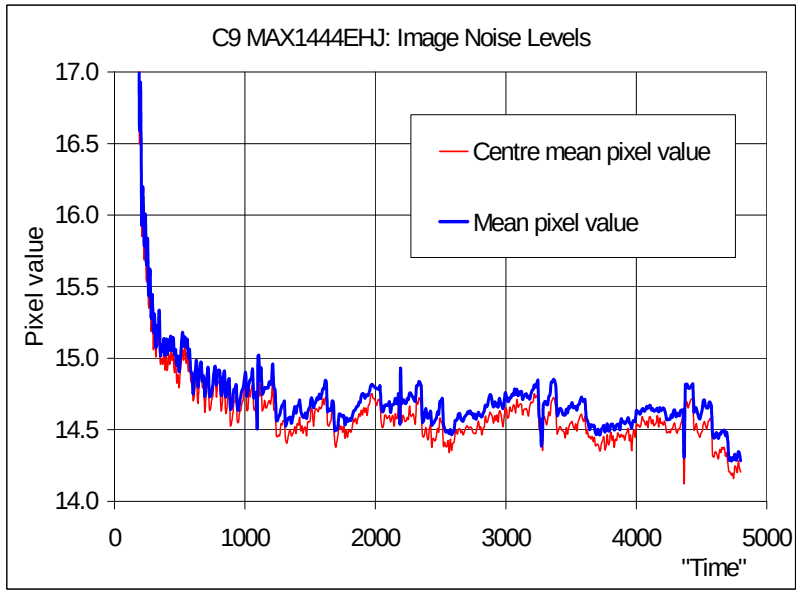
MAX3031EESE MAX3096ESE

- 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.

MAX1444EHJ and OR2T06A5T144





- 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 .

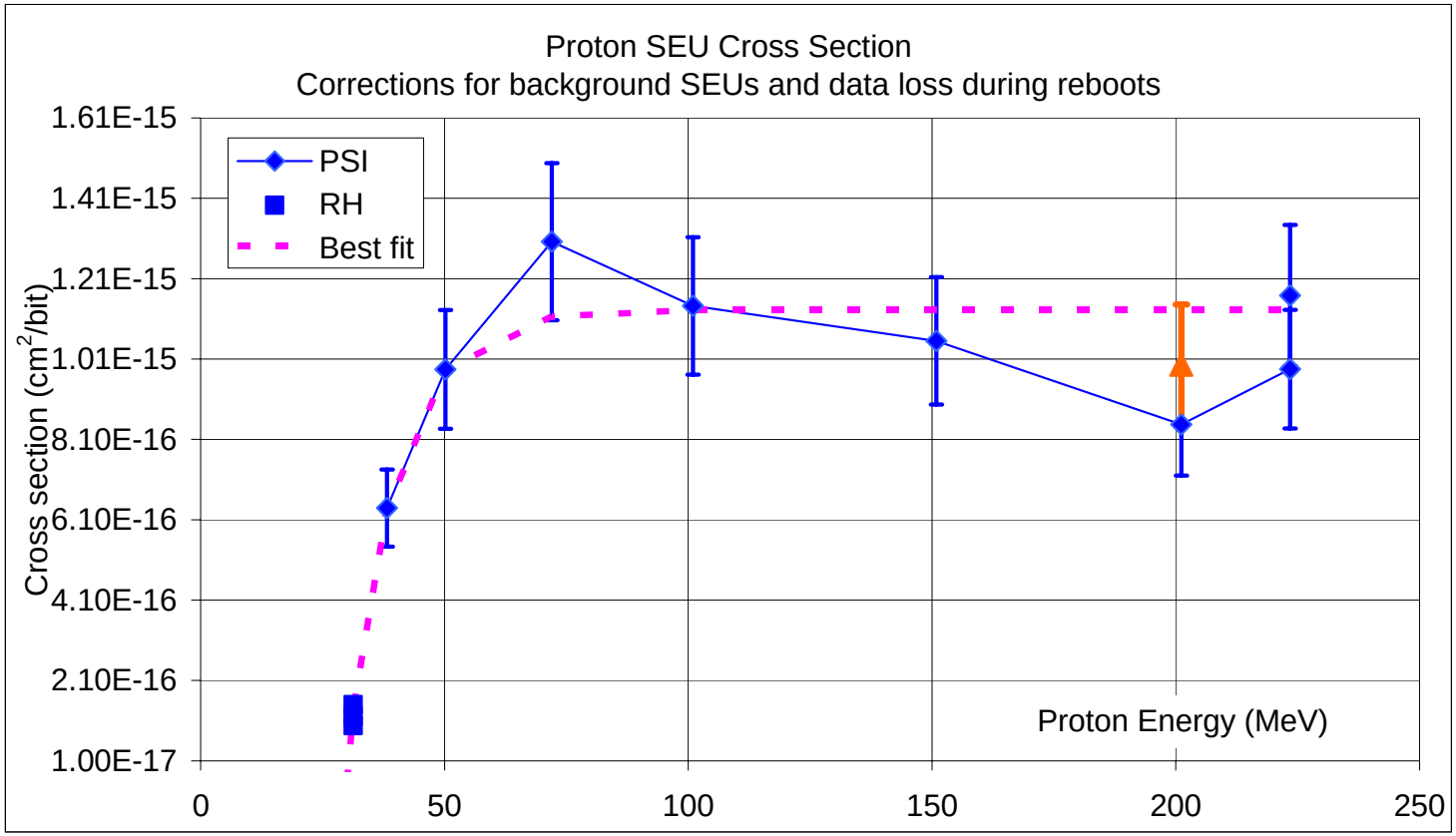
HY57V651620BLTC-10S: SEUs & Exceptions

MeV	38	50	72	101	151	210	223
SEUs	44	74	129	189	435	521	525/606

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

MeV	38	50	72	101	151	210	223
Exc.	0	0	1 0D	1 10	2 02	1 02	7/6 02

HY57V651620BLTC-10S: Cross Sections



Cross Sections: SDRAM and CPU

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

- SDRAM $< 4\ E^{-8}\ cm^2$/device
- SDRAM $< 1.5\ E^{-15}\ cm^2$/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