About OMICS Group

OMICS Group International is an amalgamation of Open Access publications and worldwide international science conferences and events. Established in the year 2007 with the sole aim of making the information on Sciences and technology 'Open Access', OMICS Group publishes 400 online open access scholarly journals in all aspects of Science, Engineering, Management and Technology journals. OMICS Group has been instrumental in taking the knowledge on Science & technology to the doorsteps of ordinary men and women. Research Scholars, Students, Libraries, Educational Institutions, Research centers and the industry are main stakeholders that benefitted greatly from this knowledge dissemination. OMICS Group also organizes 300 International conferences annually across the globe, where knowledge transfer takes place through debates, round table discussions, poster presentations, workshops, symposia and exhibitions.

About OMICS Group Conferences

OMICS Group International is a pioneer and leading science event organizer, which publishes around 400 open access journals and conducts over 300 Medical, Clinical, Engineering, Life Sciences, Pharma scientific conferences all over the globe annually with the support of more than 1000 scientific associations and 30,000 editorial board members and 3.5 million followers to its credit.

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YOSEMITE SPACE

Single Event Effects Induced by High Energy Protons in Gumstix

Kathleen Morse, Ph.D.

Founder of Yosemite Space

http://yosemitespace.com/

CASIS Sponsored Principal Investigator

Team:

Jeremy Zawodny – member of Yosemite Space

John Samson, Ph.D. – Honeywell Aerospace

Benefits of Gumstix in Space

- Small form factor:
  - Gum stick sized
  - Low power consumption (<1W)
  - PoP NAND and RAM enables board size
- Uses OMAP processors with ARM Cortex-A8 architecture
- Worked well in NASA's IPEX Cubesat mission
- Evaluated on ground and in space for radiation effects by Yosemite Space
- Being studied for use in the Dependable Multiprocessor (DM) by Honeywell.

IPEX

Ref: http://polysat.calpoly.edu/launched-missions/cp8-ipex/
https://directory.eoportal.org/web/eoportal/satellite-missions/

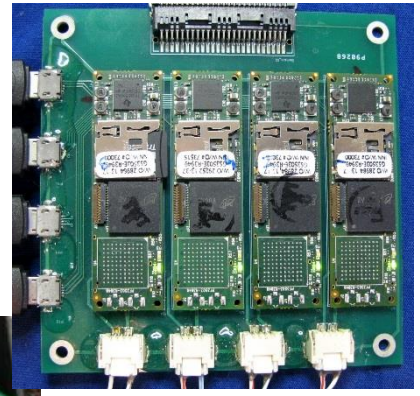
The Gumstix™ Low Earth Orbit (LEO) study is an important step towards their use in a fault tolerant computers.

YOSEMITE SPACE

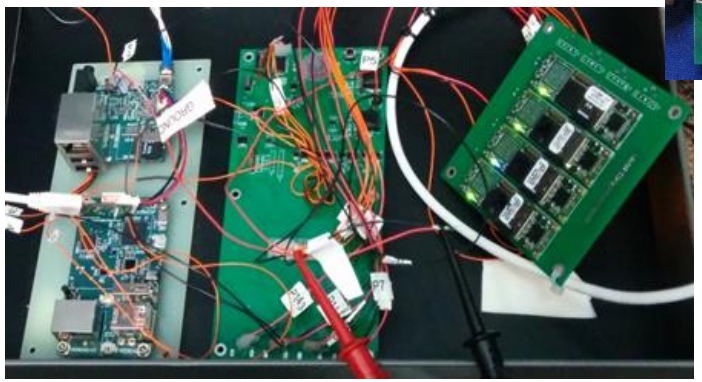
Ground and Space Based Testing

- Models tested include Earth, SandStorm and Water
- External watchdog detects SEEs, records and does a hard reboot
- ***Proton testing complete***
- Space Test on NREP – 11/15
- Payload Return - 2016

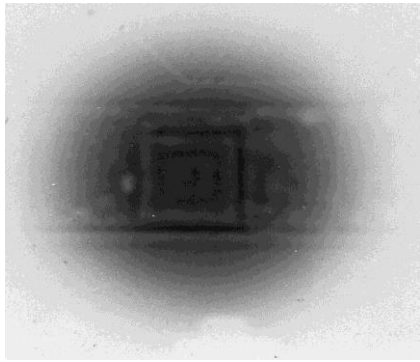
Gumstix Payload



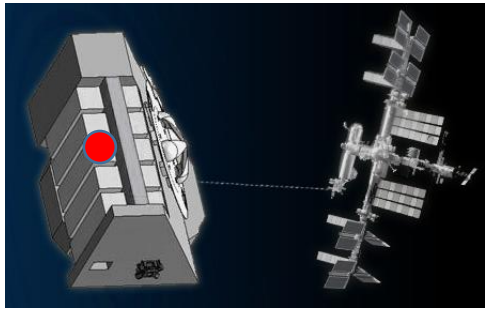
Flight Boards



Gumstix Radiograph



Nanoracks External Platform (NREP)

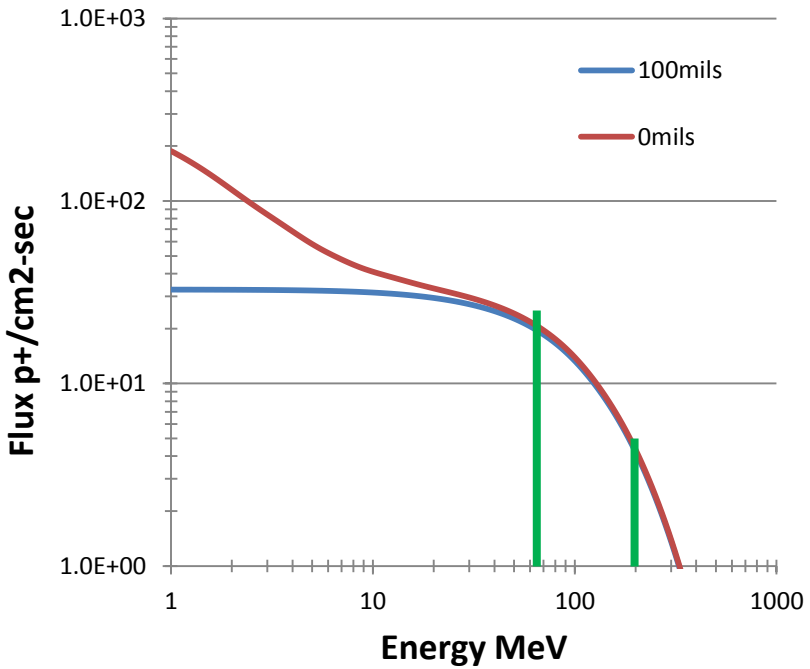


YOSEMITE SPACE

SEE Testing

Integral Proton Flux for LEO mission:

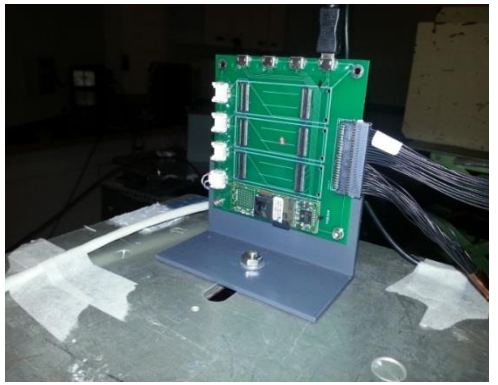
- Solar Max and Trapped



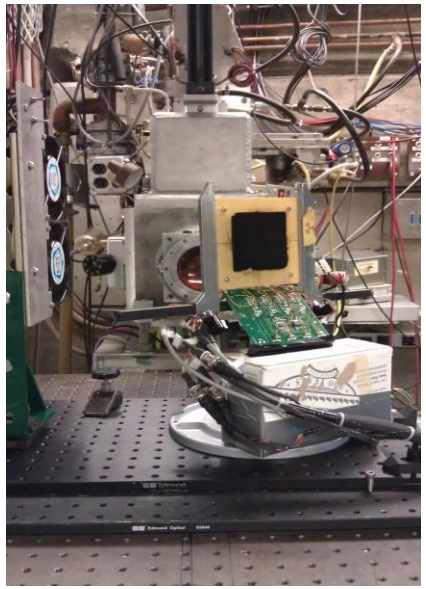
Proton Testing at Crocker Nuclear Labs (CNL) and Mass General Hospital (MGH):

Model	Model ID	Lot Number	Proton Energy (MeV)	Test facility
Water	W3	72949	64.0	CNL
Water	W1	72949	64.8	MGH
Water	W4	72949	200.3	MGH
Earth	E3	73000	64.0	CNL
Earth	E1	73000	64.8	MGH
Earth	E5	73515	200.3	MGH
SandSTORM	S1	72281	64.0	CNL
SandSTORM	S5	72281	64.8	MGH
SandSTORM	S6	72281	200.3	MGH

SEE Testing



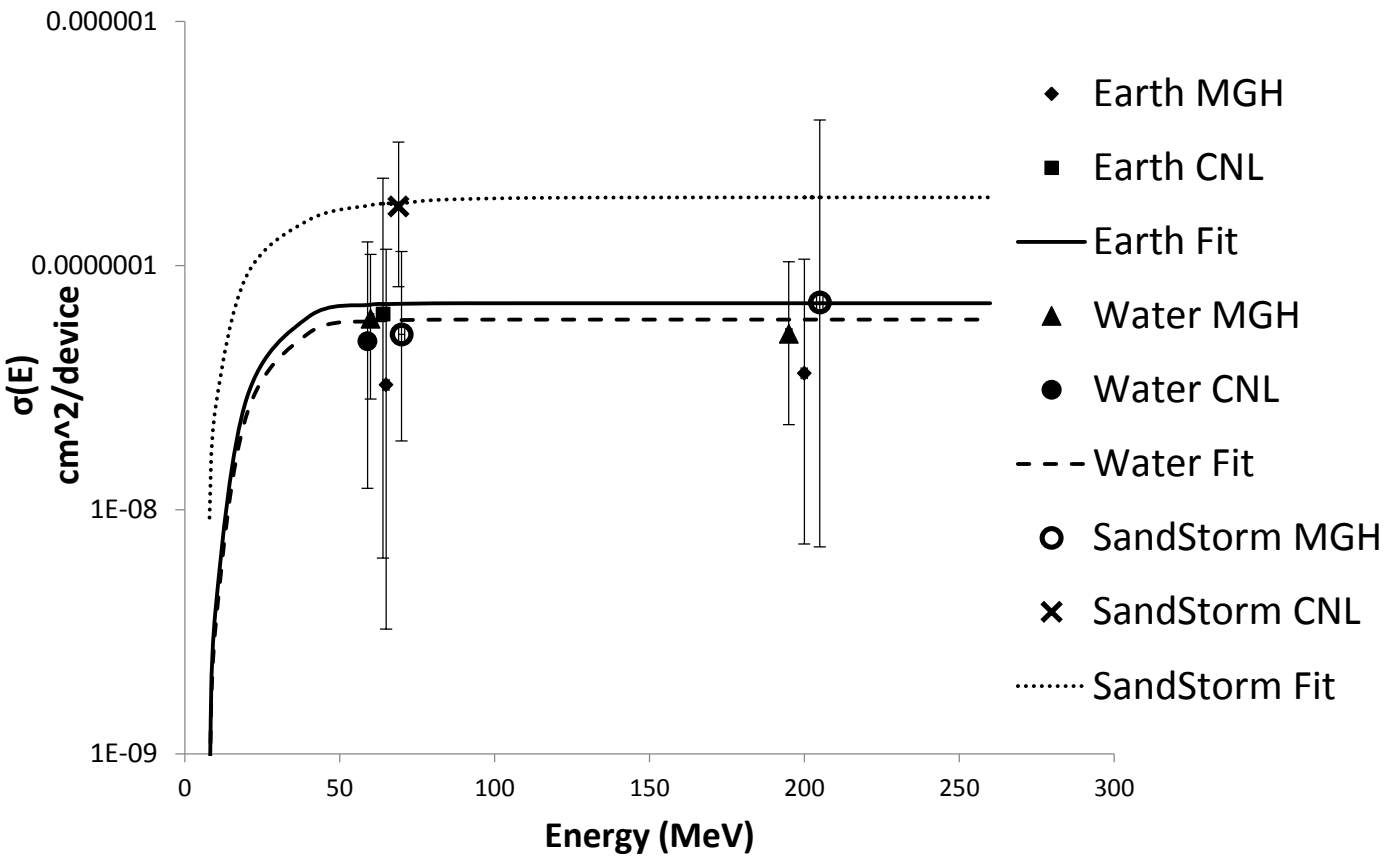
- Real time data acquisition during radiation exposure determines rate of SEEs
- Yosemite Space hardware and software monitors and records current draw (power consumption), application heartbeat (if present) and the SEU test suite results
- SEU Test Suite
  - Includes NEON, Matrix Multiply, and Workload tests
  - The suite logs:
    - number of errors generated
    - test duration
    - net time that the system has been running since the last reboot
  - Each log entry is time stamped and written to a microSD card
  - If the SEU test ran but generated no errors, 1 error was assigned to that test



NEON Test

- Performs floating point multiplication and division operations in a tight loop
- It is compiled with ARM vector floating point (VFP)
- Exercises the NEON Floating Point Unit (FPU)
- SEUs are detected by comparing output for correctness and compared to a known correct value.
- Less than 0.1% of DRAM is exercised

Test Results: NEON



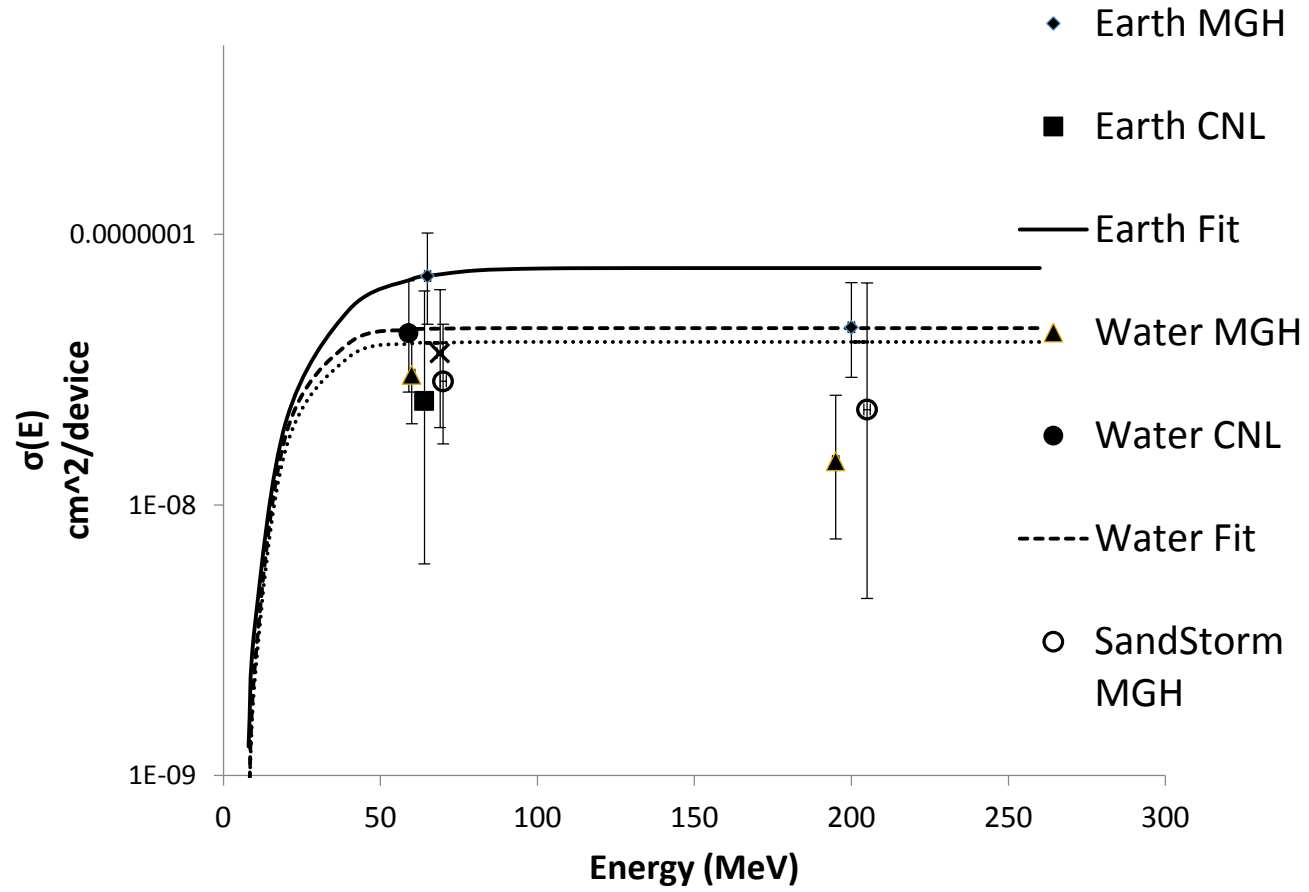
Weibull Fit Parameters	Earth	Water	Sand STORM	Units
Onset Energy	7	7	7	MeV
Saturation Cross-Section	7.00E-8	6.00E-8	1.9E-7	cm2/device
Width	20.0	20.0	20.0	MeV
Shape Factor	1.5	1.5	1.0	-

YOSEMITE SPACE

Matrix Multiply Test

- Tests basic arithmetic processing and memory functionality
- Consists of a large number of multiply and accumulation operations
- SEUs are detected with comparing the processed output with a precomputed Golden Standard.
- Exercises less than 3% of the DRAM

Test Results: Matrix Multiply



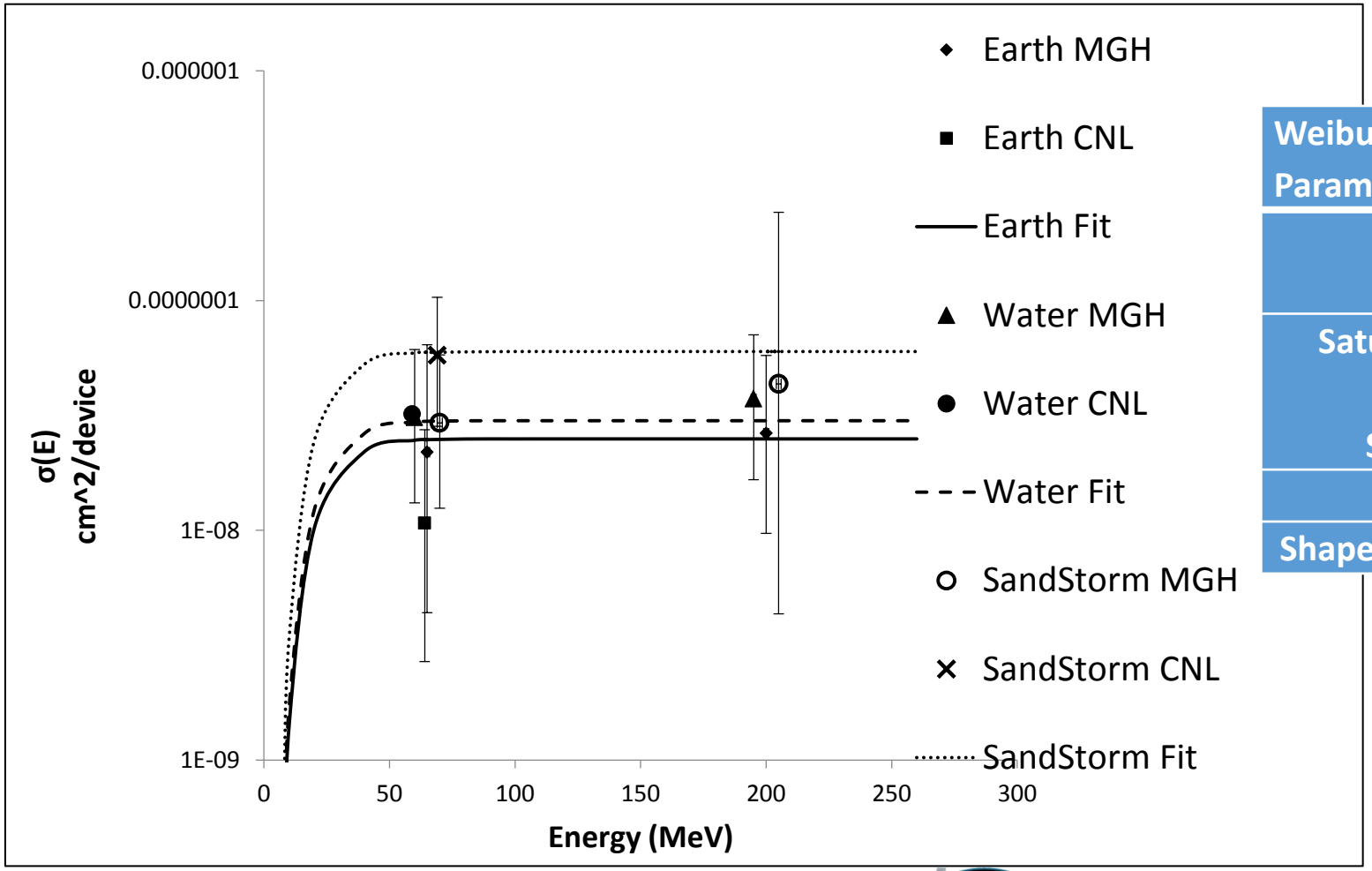
Weibull Fit Parameters	Earth	Water	Sand STORM	Units
Onset Energy	6	7	7	MeV
Saturation Cross-Section	7.50E-8	4.50E-8	4.0E-8	cm2/device
Width	30.0	20.0	20.0	MeV
Shape Factor	1.5	1.5	1.5	-

YOSEMITE SPACE

Workload Test

- The workload starts with a pre-computed data file containing pairs of 1MB strings and MD5 checksums of those strings.
- The workload computes a new MD5 checksum for each string and compares it with the precomputed checksum.
- Exercises nearly 80% of DRAM

Test Results: Workload



Weibull Fit Parameters	Earth	Water	Sand Storm	Units
Onset Energy	7	7	7	MeV
Saturation Cross-Section	2.50E-8	3.00E-8	6.0E-8	cm2/device
Width	20.0	20.0	20.0	MeV
Shape Factor	1.5	1.5	1.5	-

YOSEMITE SPACE

Estimated SEE rate over 180 Day mission

Gumstix Model	Processor Model	SEU Rate			SEFI Rate	SEL Rate
		Matrix Multiplier	Workload	NEON		
SandSTORM	Sitara AM3703	P: 17, H:35	P: 26, H: 52	P: 82, H:163	P: 1.7	P: 20.4
Water	OMAP 3530	P: 20, H:39	P: 13, H: 26	P: 26, H:52	*	*
Earth	OMAP 3503	P: 31, H:61	P: 11, H:22	P: 31, H:61	P:1.1	*

P: Proton
H: Heavy Ion

- Fitted proton data, Crème 96, and SPENVIS are used to predict these rates
- FOM approach estimates 2 SEU from heavy ions for any 1 SEU event from protons
  - An average of 85 SEUs are expected during a 180 day mission
  - SEFI and SEL rates from heavy ions can only be determined from heavy ion testing

YOSEMITE SPACE

PoP DRAM Testing

- DRAM exercised during proton radiation exposure.
- All devices passed their memory tests prior to radiation exposure.
- All devices failed their memory tests after exposure to 64.8MeV and 64MeV proton radiation.
- Months later, the number of stuck bits was quantified.
- Most stuck bit annealed out after 12 hour, unbiased at 85C. This indicates a microdosing mechanism.

GS Label	fluence	Stuck bits			TEST FACILITY	Energy (MeV)	Date of Exposure	Stuck Bits Post Anneal	Date of Analysis
W3	3.22E9	2	3	3	CNL	64	8-1-13	1	12.5 months
W2	2.52E9	2	3	3	CNL	64	8-1-13	0	12.5 months
W1	3.28E9	3	4	4	MGH	64.8	1-25-14	1	8 months
W4	1.63E9	0	0	0	MGH	200.3	1-25-14	0	8 months
E3	1.03E9	0	0	0	CNL	64	8-1-13	0	12.5 months
E2	2.52E9	1	3	1	CNL	64	8-1-13	0	12.5 months
E1	2.23E9	3	1	1	MGH	64.8	1-25-14	0	8 months
E5	1.95E9	0	0	0	MGH	200.3	1-25-14	0	8 months
S1	9.67e8	0	0	0	CNL	64	8-1-13	0	12.5 months
S2	2.52E9	0	0	0	CNL	64	8-1-13	0	12.5 months
S5	2.45E9	1	1	1	MGH	64.8	1-25-14	0	8 months
S6	6.74E8	0	0	0	MGH	200.3	1-25-14	0	8 months
F3	2.52E9	3	2	2	CNL	64	8-1-13	0	12.5 months
F4	1.06E9	0	0	0	CNL	64	8-1-13	0	12.5 months

Conclusions

- No significant difference in SEU cross-sections between Gumstix models
- Earth and SandSTORM had similar SEFI rates. Water did not show any SEFI events at 200.3MeV
- SEL data was only obtained for the SandSTORM and Earth models. Water was tested under similar conditions but latch-up was not observed
- No catastrophic latch-up was observed
- Stuck bits in DRAM observed after proton exposures at 64MeV and 64.8MeV.

Acknowledgements

- The Gumstix ISS flight experiment effort is being performed under CASIS (Center for the Advancement of Science in Space) grant GA-2013-115.

- The project will being flown as an ISS National Laboratory flight experiment.

- The authors would like to acknowledge the contributions of Matthew Smith (Honeywell Aerospace, Defense & Space) for his help analyzing the results of the ground-based radiation tests.

- The authors would like to acknowledge Drs. Steve Guertin, Larry Edmonds and Philippe Adell of JPL for their input of the analysis of stuck bits in RAM.

YOSEMITE SPACE

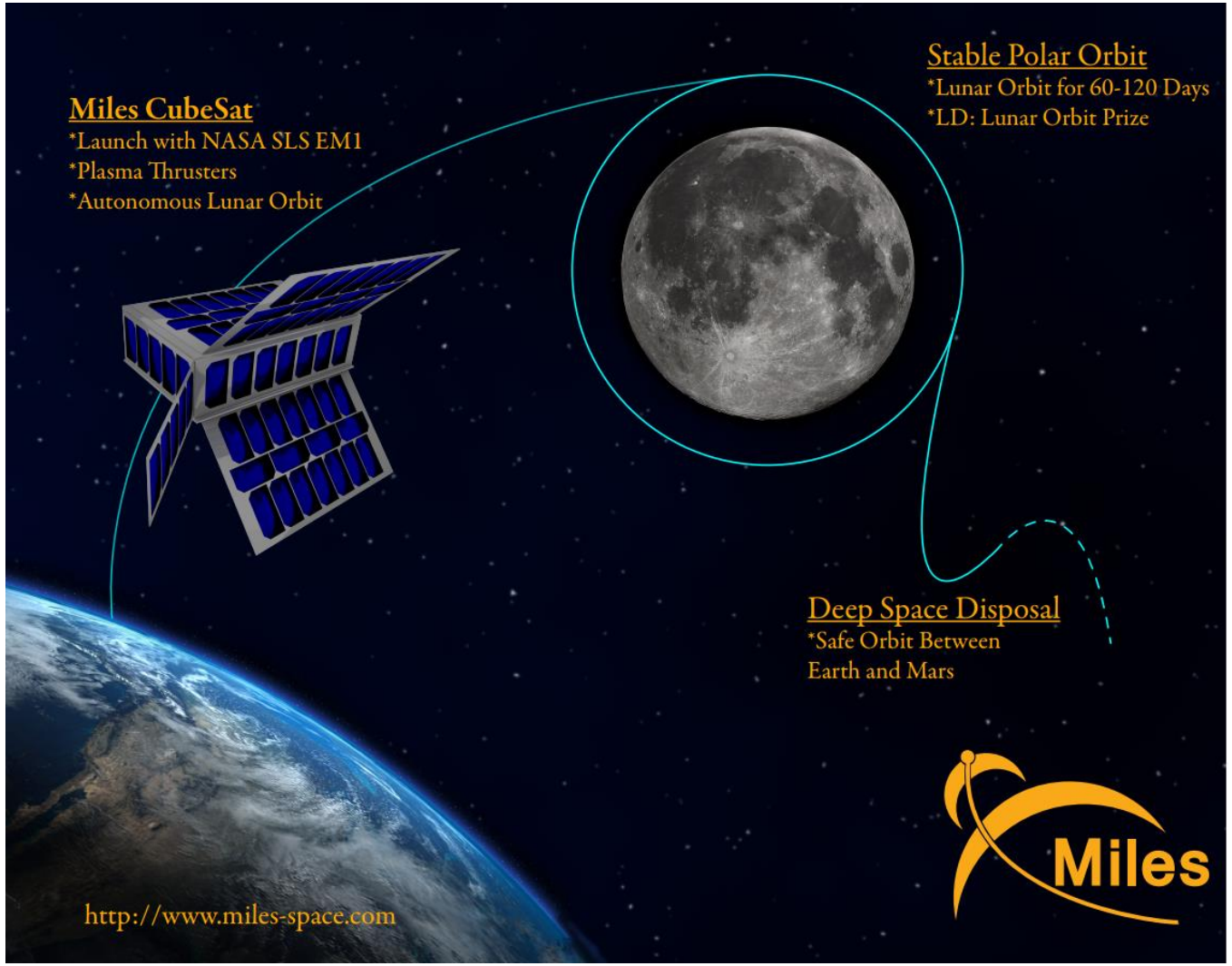
What is RACP? Reliable Affordable Cubesat Processor

- Multi-processor fault tolerant space computer that integrates current generation SoC
- Compatible with existing CubeSat products
- Design allows for graceful degradation and minimal interruptions in processing
- Supports multiple sensor platforms
- Components screened through ground and space radiation testing

"Other upcoming hybrid platforms share some of the same concepts, but the degree of adaptability and performance capabilities of RACP is superior.“- NASA SBIR review

YOSEMITE SPACE

RACP for Deep Space



RACP Features:

- Fault tolerance
- Data Integrity
- High Compute Performance
  - Average of 2000 MIPS/Watt
  - Top performance: 15,000 MIPS, 1,250 MFLOPS, 5,650 MOPS
- Run a Linux operating system
- Components of RACP screened for radiation tolerance
- Design is not specific to a single model of SoC
- Supports data processing on multiple sensors
- Small in Size and Weight (target size of 9cm by 9cm)
- Consumes 0.53 Watts at low end of performance

YOSEMITE SPACE

Yosemite Space Team

Dr. Morse is the majority owner and founder of Yosemite Space. She leads Yosemite Space in exploring how to advance the state of the art in aerospace. Current work focuses on using state of the art (SOA) System on Chip (SoC) processors reliably in space to support autonomy and remote sensing needs of CubeSats and small satellites. She is leading the hardware development of RACP.

Mr. Zawodny serves as the lead software engineer at Yosemite Space. His is developing software for the embedded Linux platform used on SoCs. He developed Yosemite Space's radiation test monitoring software and hardware. He leads software development of RACP.

Mr. Chapman supports ongoing research and development activities as a senior engineer. Mr. Chapman has 47 years of aerospace experience including electronics design and fabrication, mechanical design and fabrication, optomechanical component design and fabrication, vacuum system design, fabrication, and assembly.

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