Update on Dependable Multiprocessor (DM) CubeSat Technology

2014 Summer CubeSat Workshop/ Small Satellite Conference

August 2014

Dr. John R. Samson, Jr.
Honeywell Aerospace, Defense and Space
Clearwater, FL
john.r.samson@honeywell.com

Honeywell

Outline

Honeywell

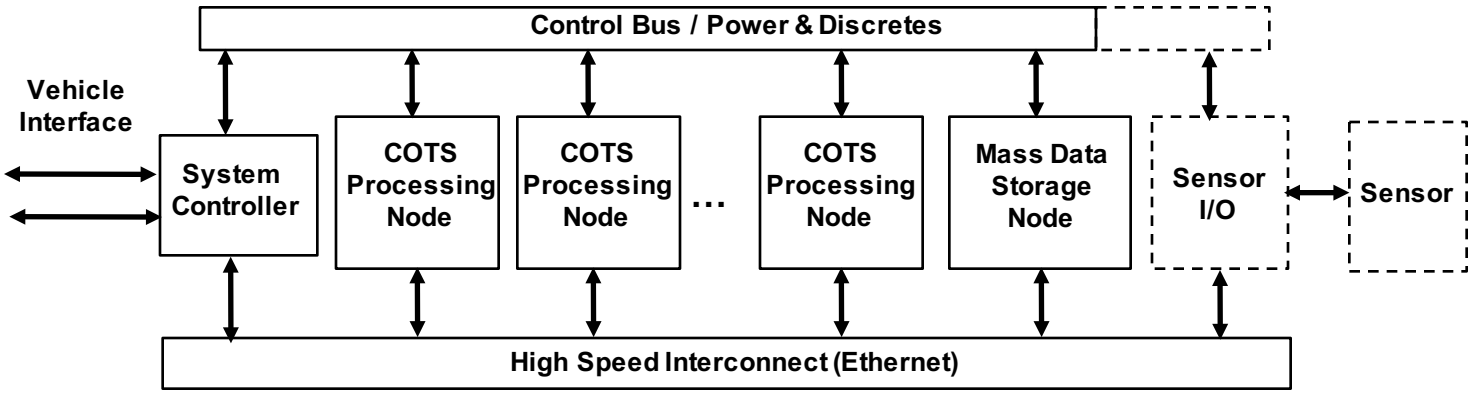
- Brief overview of DM technology
- Update on DM CubeSat technology development since 2012 Summer CubeSat Workshop
- Elicit interest in possible joint DM CubeSat and/or DM small satellite experiments
- Summary and Conclusion

DM Technology – What is it?

Honeywell

- **NASA-developed Dependable Multiprocessor (DM) technology**
  - Cluster of high-performance COTS processors that can fly in space
  - Operated under the control of a reliable system controller and technology-, platform-, and application-independent fault tolerant DM Middleware (DMM)
  - Flexible
    - -- user-configurable fault tolerance includes hybrid replication [temporal and spatial self-checking and TMR (Triple Modular Redundancy) for critical functions and ABFT (Algorithm-Based Fault Tolerance)]
  - Scalable
  - Low overhead
  - Easy to use

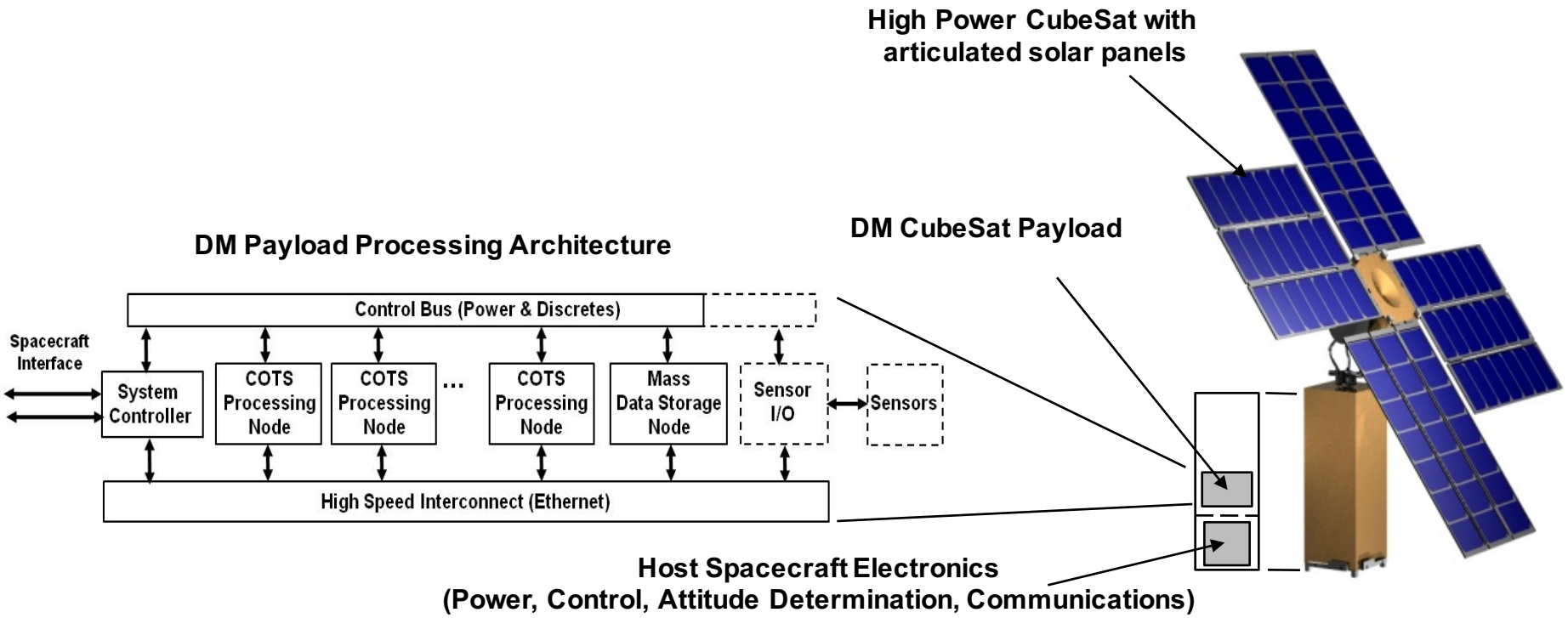
Simple DM Flight Experiment System



The technology-, platform-, & application-independent DM Middleware (DMM) is DM technology; DM technology is not the underlying hardware

SMDC TechSat Flight Experiment Configuration

Honeywell



Combines two key technologies on one spacecraft:

1) high power CubeSat
2) COTS high-performance parallel processing

SMDC TechSat DM Phase 2 Breadboard

Honeywell

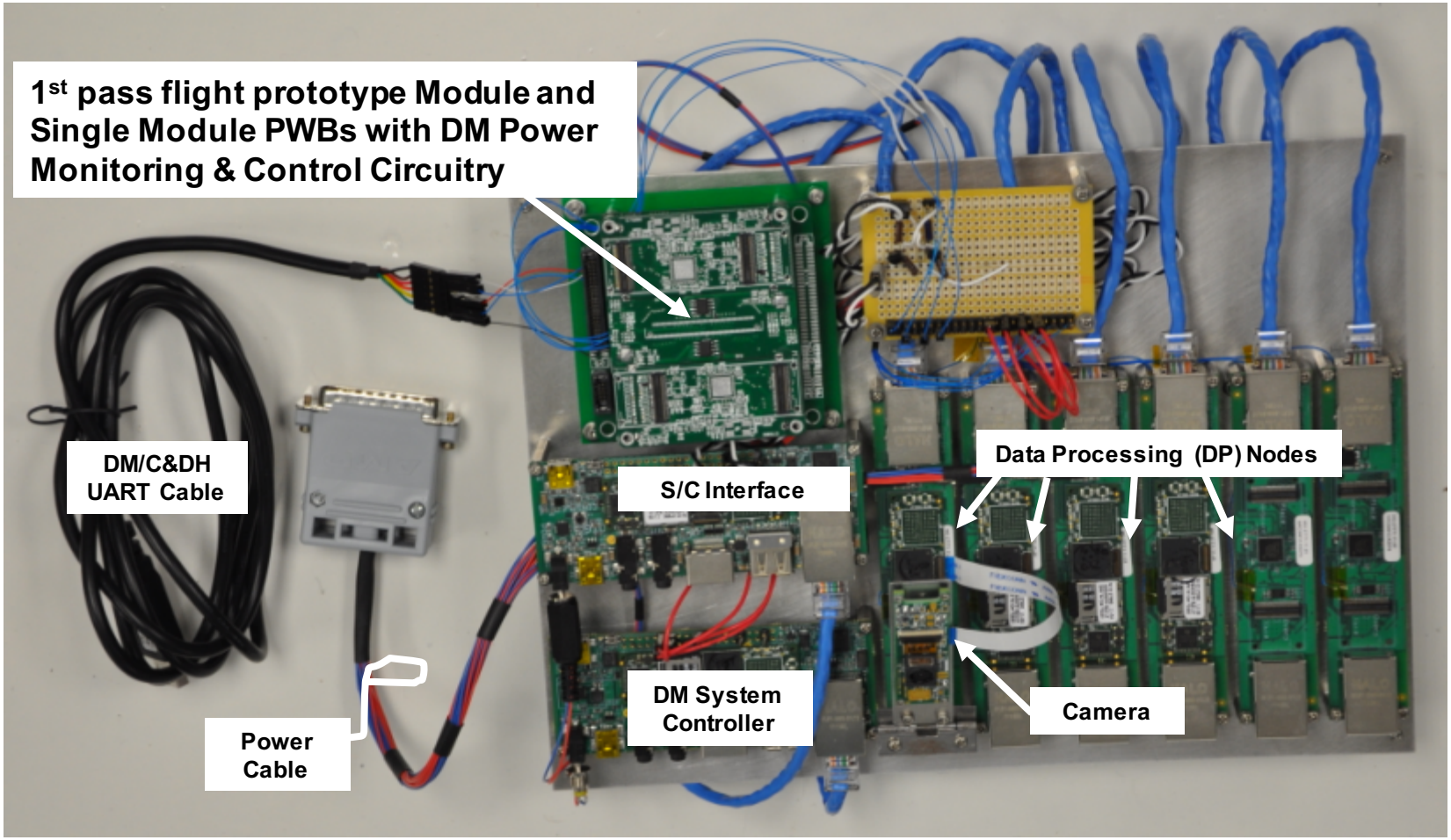


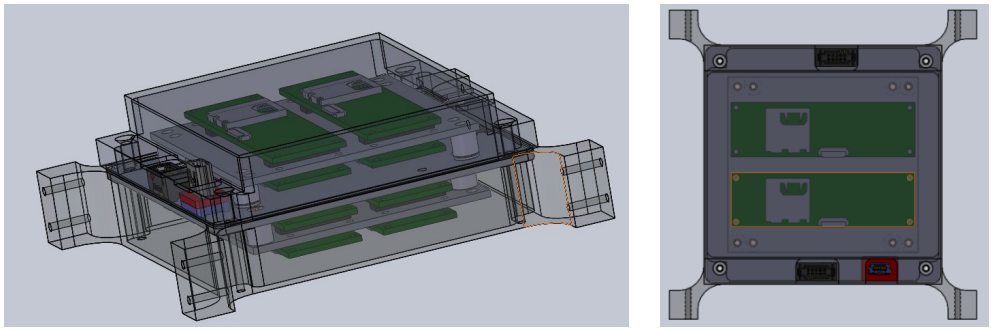
Photo courtesy of Morehead State University

SMDC TechSat Phase 2 F-Cubed Demo - DM Payload Processor Flight Prototype

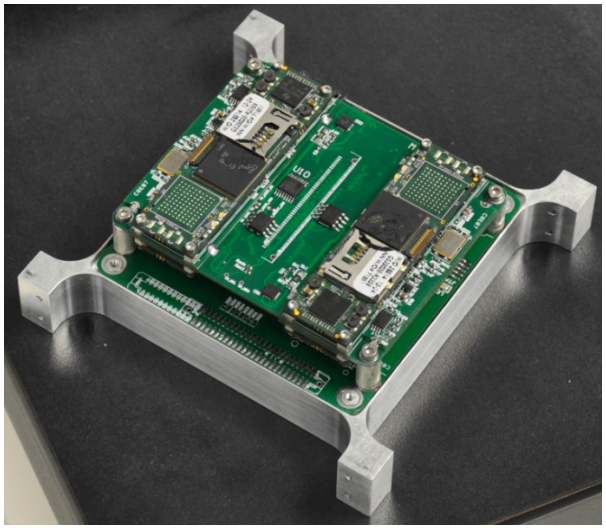
Honeywell

- 75 mm x 75 mm x 35 mm
- Cluster of DM Processor Modules
- Ethernet Switch
- DM Power Management Circuitry
- USB Port
- Power Port
- Ethernet Port
- Room for 100 Pins of Interfaces (GPIO, SPI, UART, Camera, etc.)

CAD Models



Flight Prototype



Design is scalable and re-usable in future CubeSat applications

Figures and photo courtesy of Morehead State University

DM Payload Processor Flight Prototype

Honeywell

DM Subsystem Flight Experiment prototype fabricated by Morehead State University

Partially-Integrated SMDC TechSat (circa 9/5/12)

Honeywell

Photo courtesy of Morehead State University

Space for pop-up mechanism for articulating array

EPS including batteries

DM CubeSat Payload Processor Subsystem

Space for C&DH Subsystem

Space for Communication Subsystem & Antenna Stowage

Integrated SMDC TechSat Phase 2 Demo (9/26/12)

Honeywell

Photo showing fully-deployed articulating mechanism

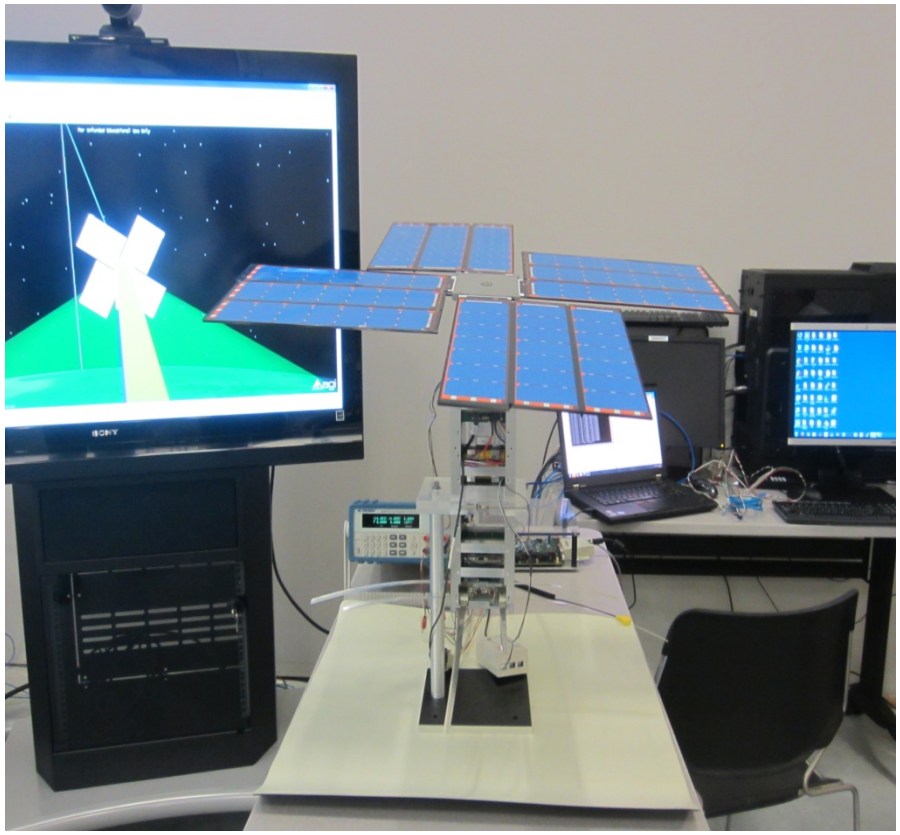
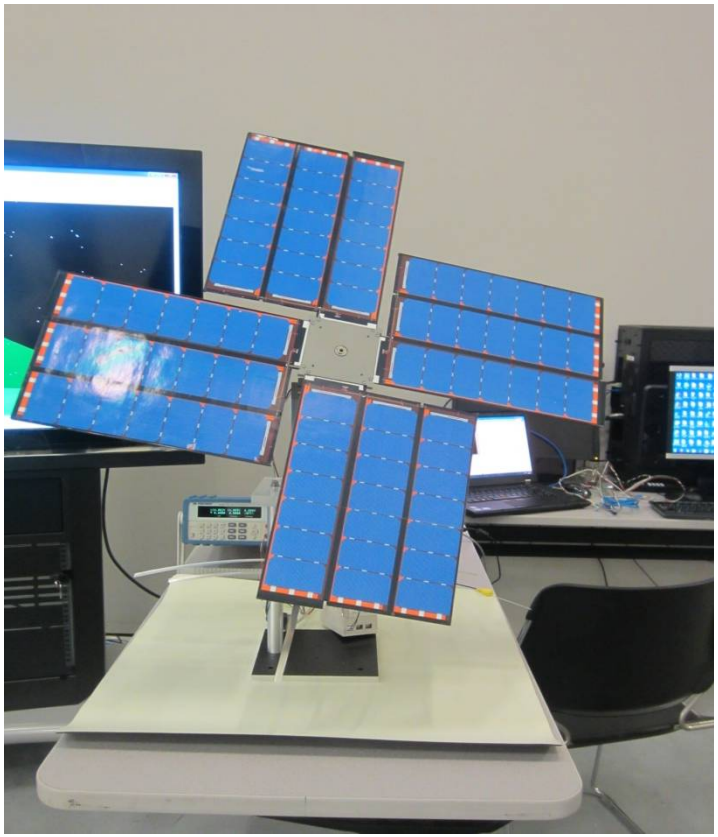


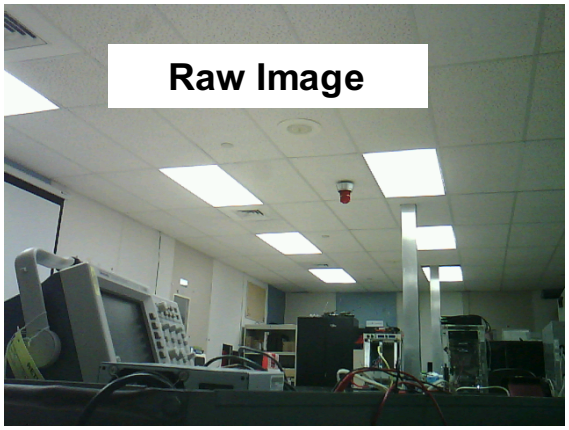
Photo showing solar panels in an articulated position



Photos courtesy of Morehead State University

Ground-Commanded Programmable Data Compression – JPEG 2000

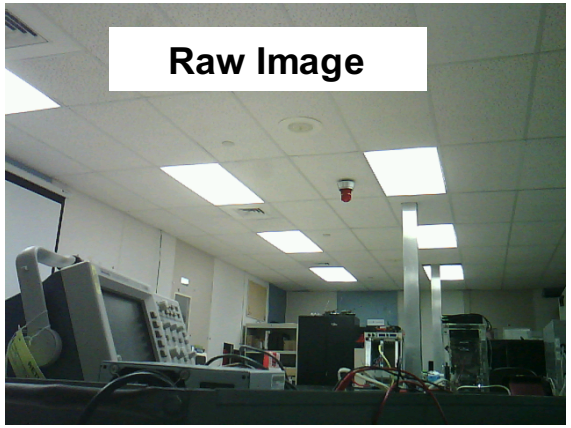
Honeywell



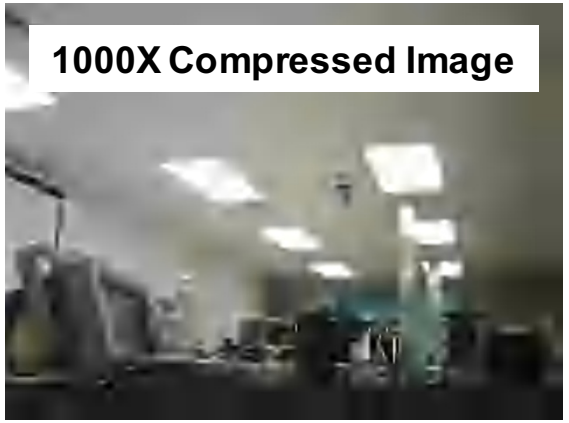
Raw Image Size: 921654 Bytes
Frame Time: 15 seconds

Compressed Image Size: 435734 Bytes
Execution Time: 2.449 seconds

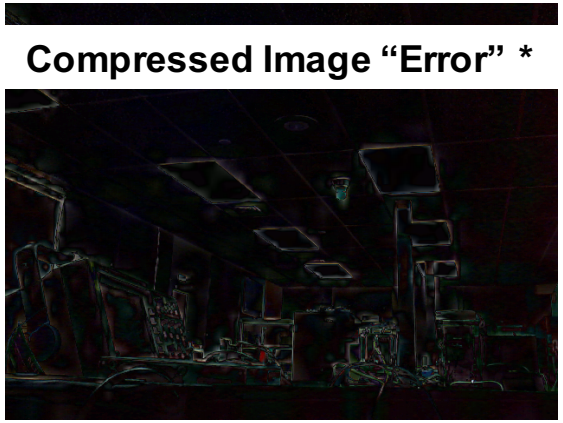
Average R error = 0.0 ^
Average G error = 0.0 ^
Average B error = 0.0 ^



Raw Image Size: 921654 Bytes
Frame Time: 15 seconds



Compressed Image Size: 922 Bytes
Execution Time: 3.041 seconds



Average R error = 11.183 ^
Average G error = 8.626 ^
Average B error = 9.947 ^

* ABS [Raw Image Pixel (x,y) – Compressed Image Pixel (x,y)]
^ Average difference in pixel value over the entire image (8-bit pixel data; range 0 - 255)

Current Development & Validation Activities

Honeywell

- CASIS/AMA ground-based & ISS flight experiment Gumstix™ radiation testing
  - ground-based proton testing completed (8/13 & 1/14)
  - flight experiment hardware integrated with NREP (7/14)
  - scheduled for launch to ISS (10/14)
  - 6-month on-orbit flight experiment
- CASIS/Honeywell/MSU ISS DM TRL 7 technology validation flight experiment
  - proposal in final reviews
  - flight unit based on MSU-designed SMDC TechSat Phase 2 flight prototype
  - projected launch date 10/15
  - 6-month on-orbit flight experiment
- Demonstration of DM-controlled heterogeneous cluster of Gumstix™ and Zync boards
  - multi-core and FPGA fabric
- Cal Poly has one (1) Gumstix™ on-orbit
  - launched as part of IPEX experiment in December 2013
  - Gumstix™ EarthSTORM COM performing image data processing

Summary & Conclusion

Honeywell

DM Is A Low Risk Onboard Processing Solution

- Leverages $14M of NASA NMP ST8 DM technology development through TRL6 technology validation and preparation for a TRL7 flight experiment
- Leverages Honeywell-funded development of DM CubeSat technology
- Leverages SMDC-funded development of SMDC TechSat technology
- Significant risk reduction already completed
  - -- preliminary radiation testing of the Gumstix™ COTS components
  - -- built and demonstrated a DM CubeSat testbed
    - --- demonstrated DM end-to-end space-ground command and telemetry over RF link
    - --- used existing ST8 DM software including DMM, spacecraft interface, and ground command and telemetry software
    - --- demonstrated real-time, ground commanded, on-orbit programmable image compression
  - -- successful SMDC TechSat Flat-Sat demonstration (9/11)
  - -- successful SMDC TechSat F-cubed DM flight prototype demonstration (9/12)
- Additional Gumstix™ proton testing performed
- On-orbit Gumstix™ radiation performance to be characterized & validated with ISS flight experiment
- One (1) Gumstix™ successfully operating on-orbit (Cal Poly experiment)

Acknowledgements

Honeywell

- The Dependable Multiprocessor * effort was funded under NASA NMP ST8 contract NMO-710209
- The DM CubeSat effort to date has been carried out on Honeywell internal investment
- The successful SMDC TechSat Flat-Sat Demo was supported by Radiance Technologies, Inc., Morehead State University, and Tethers Unlimited, Inc.
- SMDC TechSat Phase 2 effort was funded by SMDC under Honeywell subcontract 2011-12-164-001 to MSU

For more information contact:

Dr. John R. Samson, Jr.
Honeywell Defense & Space,
Clearwater, FL
john.r.samson@honeywell.com
(727) 539 – 2449

* The Dependable Multiprocessor (DM) project was originally known as the Environmentally-Adaptive Fault-Tolerant Computer (EAFTC) project

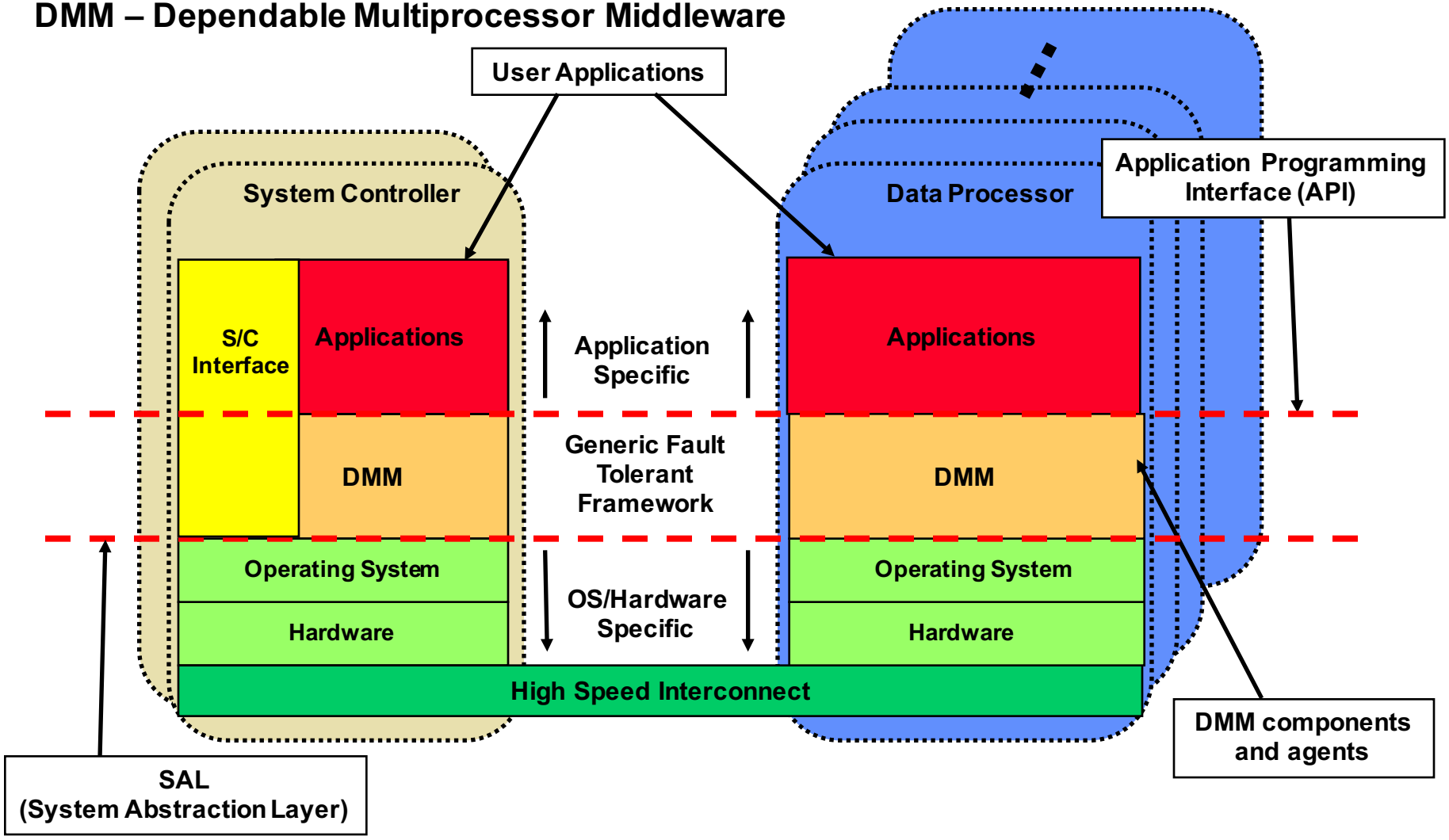
Track 7 - Spacecraft Avionics Systems, Subsystems, and Technologies at the 2015 IEEE Aerospace Conference (March 2015, Big Sky, MT) has a popular session, 7.07 - Avionics Technologies for Small Satellites, Nano-Satellites, and CubeSats

Back-up Charts

DMM Top-Level Software Layers

Honeywell

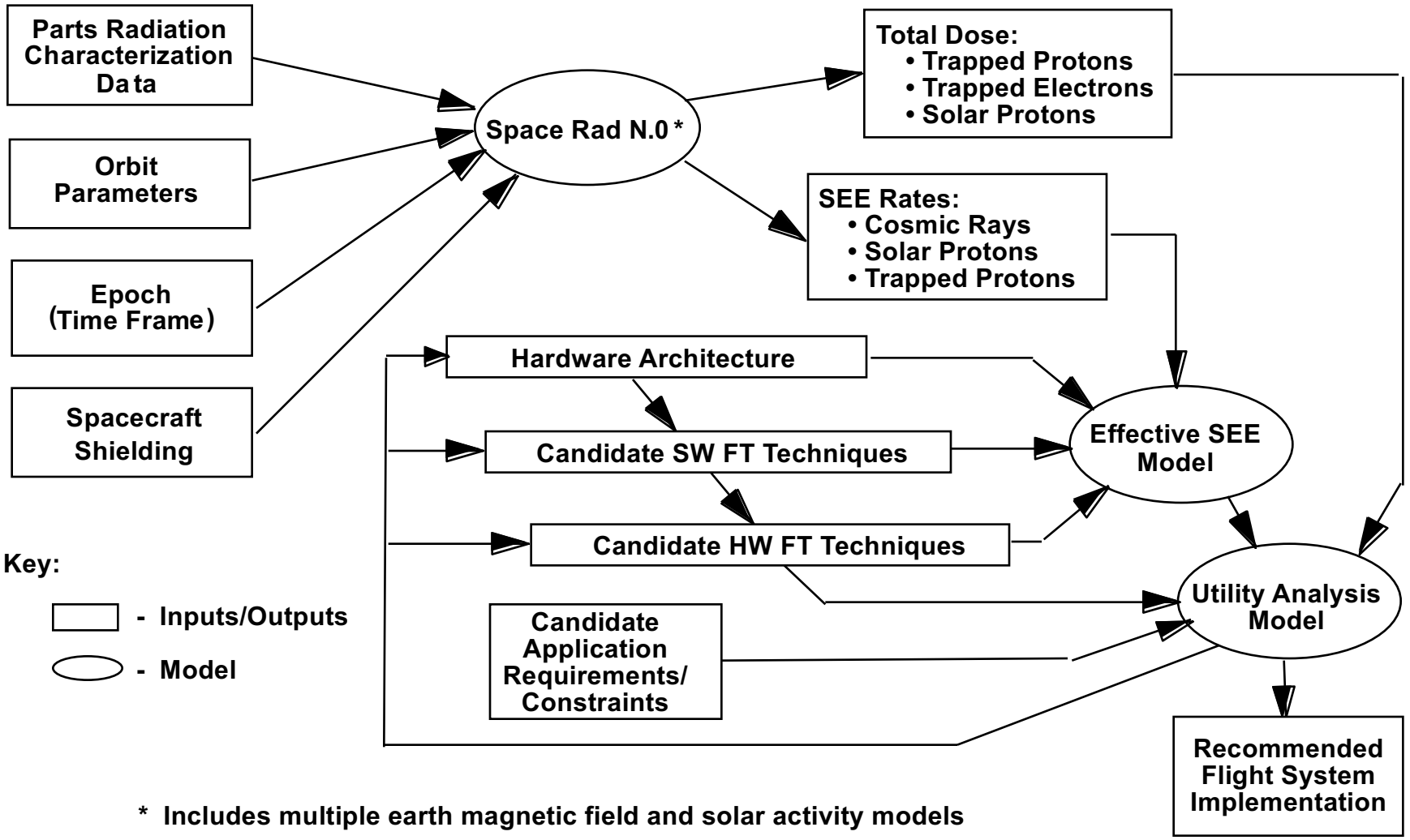
DMM – Dependable Multiprocessor Middleware



The technology-, platform-, & application-independent DM Middleware (DMM) is DM technology; DM technology is not the underlying hardware

Process Flow for Migrating COTS Technology to Space

Honeywell



* Includes multiple earth magnetic field and solar activity models

References (1 of 2)

Honeywell

[1] Samson, Jr., John R., "Small, Light-Weight, Low-Power, Low-Cost High Performance Computing for CubeSats (& Nano-Sats, Small Sats, Large Sats, UAVs, HAAs, et al.)," *Proceedings of the 2014 IEEE Aerospace Conference*, Big Sky, MT, March 5, 2014.

[2] Samson, Jr., John R., "Dependable Multiprocessor (DM) – High Performance Computing for CubeSats (& Nano-Sats, Small Sats, Large Sats, UAVs, HAAs, et al.)," Space and Missile Defense Symposium, Huntsville, AL, August 13, 2013.

[3] Samson, Jr., John R., "Update on Dependable Multiprocessor CubeSat Technology Development," *Proceedings of the 2012 IEEE Aerospace Conference*, Big Sky, MT, March 5, 2012.

[4] Samson, Jr., John R., "Implementation of a Dependable Multiprocessor CubeSat", *Proceedings of the 2011 IEEE Aerospace Conference*, Big Sky, MT, March 6-11, 2011.

[5] Samson, John, Jr., "Dependable Multiprocessor (DM) Implementation for Nano-satellite and CubeSat Applications (Challenging Packaging for High Performance Embedded Computing)," *14th High Performance Embedded Computing Workshop*, M.I.T. Lincoln Laboratory, September 16, 2010.

References (2 of 2)

Honeywell

[6] Samson, John, Jr., et al., "Post-TRL6 Dependable Multiprocessor Technology Developments," *Proceedings of the 2010 IEEE Aerospace Conference*, Big Sky, MT, March 7-11, 2010.

[7] Samson, John, Jr., et al., "NMP ST8 Dependable Multiprocessor: Technology and Technology Validation Overview," *Proceedings of the 48th AIAA Aerospace Science Meeting Conference*, Orlando FL, January 4-8, 2010.

[8] Grobelny, Eric M,. et. al, "NMP ST8 Dependable Multiprocessor: Technology Validation Approach and Results," *Proceedings of the 48th AIAA Aerospace Sciences Meeting Conference*, Orlando FL, January 4-8, 2010.

[9] Samson, John, Jr. and Eric Grobelny, "NMP ST8 Dependable Multiprocessor: TRL6 Validation – Preliminary Results," *Proceedings of the 2009 IEEE Aerospace Conference*, Big Sky, MT, March 8-13, 2009.