Update on Dependable Multiprocessor (DM) CubeSat Technology

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Small Satellite Conference

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Outline

• 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?

- 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
Combines two key technologies on one spacecraft:
1) high power CubeSat
2) COTS high-performance parallel processing
SMDC TechSat DM Phase 2 Breadboard

1st pass flight prototype Module and Single Module PWBs with DM Power Monitoring & Control Circuitry

Photo courtesy of Morehead State University
SMDC TechSat Phase 2 F-Cubed Demo - DM Payload Processor Flight Prototype

- 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.)

Design is scalable and re-usable in future CubeSat applications

Figures and photo courtesy of Morehead State University
DM Subsystem Flight Experiment prototype fabricated by Morehead State University
Partially-Integrated SMDC TechSat (circa 9/5/12)

- 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

Photo courtesy of Morehead State University
Integrated SMDC TechSat Phase 2 Demo (9/26/12)

Photos courtesy of Morehead State University

Distribution A: Approved for Public Release; Distribution Unlimited. USASMDC/ARSTRAT Release # 4035 10 March 2014
Ground-Commanded Programmable Data Compression – JPEG 2000

Raw Image Size: 921654 Bytes
Frame Time: 15 seconds

Lossless Compressed Image
Compressed Image Size: 435734 Bytes
Execution Time: 2.449 seconds

Raw Image

1000X Compressed Image
Compressed Image Size: 922 Bytes
Execution Time: 3.041 seconds

* 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

• 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

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

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• 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.

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* 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
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

Key:
- Inputs/Outputs
- Model

* Includes multiple earth magnetic field and solar activity models


