Acronym List

C&DH  Command and Data Handling
DSP  Digital Signal Processor
EO-1  Earth Observing 1
FPGA  Field Programmable Gate Array
GPU  Graphics Processing Unit
GSFC  Goddard Space Flight Center
NASA  National Aeronautics and Space Administration
POL  Point Of Load
WMAP  Wilkinson Microwave Anisotropy Probe
Outline

• NASA GSFC Overview
• Onboard Processing Needs
• General Requirements
• Current Onboard Processing Options
• Future Onboard Processing Solutions
• Enabling Heterogeneous Processing
• Summary
About GSFC

• Since 1959, NASA’s first Space Flight Center has been working to better understand our world, the solar system, and the universe

• We help answer humanity’s BIG QUESTIONS

• We TRANSFORM human understanding of Earth and Space.

• Nearly 300 successful missions including the World’s First Weather Satellite and the Hubble Space Telescope

• 2006 Nobel Prize in Physics [Big Bang/Cosmic Background]

• Hubble Supported 2011 Nobel Prize in Physics

• WMAP Team Awarded 2012 Gruber Prize for Cosmology
A Diverse Mission Portfolio

To be presented by Wesley A. Powell at the IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), Washington DC, May 1-3, 2016.
Why Are We Here?

How Do We Survive and Thrive?

What Is Out There?

Goddard focus is on earth and space science, and the research and technology needed to pursue new science.

To be presented by Wesley A. Powell at the IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), Washington DC, May 1-3, 2016.
Onboard processing needs for NASA missions span many applications and have widely varying performance requirements

- Low power embedded processing for instrument and subsystem control
- Command and data handling (C&DH) functions
- Science instrument data processing
- Autonomous spacecraft control

Of these, *science instrument data processing* and *autonomous spacecraft control* present the most challenging performance requirements.
Science Instrument Data Processing

- For missions where sensor data rates exceed downlink data rates, onboard processing can perform data reduction
  - RFI detection within radiometer data
  - SAR processing
  - Cloud detection for earth imagers
  - Classification and selection of hyperspectral data

- Onboard processing can also provide low latency data products
  - Fire detection in hyperspectral data
  - Gamma ray burst location

- Close loop instrument control also requires onboard processing
  - Adaptive optics

To be presented by Wesley A. Powell at the IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), Washington DC, May 1-3, 2016.
Autonomous Spacecraft Control

• Future missions will require increased onboard processing for autonomous spacecraft control functions
  – Rendezvous and docking
  – Landing
  – Diagnostics
  – Mission planning

Restore-L Mission Concept
General Requirements

• While specific requirements vary from mission to mission, several general requirements drive our onboard processing solutions
  – Radiation tolerance
  – Power efficiency
  – Fault tolerance
  – Low life cycle cost
  – Minimal mission risk

Space Radiation Environment

To be presented by Wesley A. Powell at the IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), Washington DC, May 1-3, 2016.
Current Onboard Processing Options

• General Purpose (Single Core) Processors
  – BAE RAD750 processor
  – Broad Reach BRE440
  – Maxwell SCS750
  – Coldfire

• FPGA Logic
  – Xilinx Virtex-5
  – Microsemi RTAX

• Emerging Multi-core Processors
  – Dual core
  – Quad core

• Additional processing performance is needed for our future applications

To be presented by Wesley A. Powell at the IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), Washington DC, May 1-3, 2016.
Future Onboard Processing Solutions

- Future processing devices can provide significant advancement beyond the current state of the art
  - Next generation multi-core processors
  - Coprocessors (DSP, GPU)
  - Next generation FPGAs

- However, none of these device types is optimal for all processing tasks

- Heterogeneous architectures employing multiple processor types (based on mission specific processing needs) are needed to efficiently implement future onboard processing systems
Enabling Heterogeneous Processing

- Further development is needed to enable heterogeneous processing systems for future missions

- Device “building blocks”
  - Processing devices
  - Memory
  - Onboard networks
  - Point-Of-Load (POL) power converters
  - Printed wiring boards

- Flexible architectures combining these devices to meet mission specific needs
  - Processing requirements and performance
  - Radiation tolerance
  - Fault tolerance
  - Power efficiency
  - Reliability
Enabling Heterogeneous Processing

• Heterogeneous modelling and benchmarking capability
  – Explore processing algorithms
  – Explore mapping to heterogeneous architecture options
  – Assess impact of radiation and fault tolerance techniques

• Application development tools
  – Code portability across multiple processor types
  – Trace and debug across multiple processor types
  – Verification tools for applications distributed across multiple processor types and for radiation and fault mitigation techniques

• Run time tools
  – Dynamic allocation of processing tasks to processing resources
  – Power awareness
  – Fault awareness
Summary

• Of the many NASA GSFC onboard processing applications, *science instrument data processing* and *autonomous spacecraft control* present the most challenging performance requirements.

• Several options exist for implementing onboard processing systems, but additional processing performance is needed.

• Heterogeneous architectures employing multiple processor types (based on mission specific processing needs) are needed to efficiently implement future onboard processing systems.

• Further development is needed to enable heterogeneous processing systems for future missions.

To be presented by Wesley A. Powell at the IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), Washington DC, May 1-3, 2016.