NASA GSFC Perspective on Heterogeneous Processing

Wesley A. Powell

Assistant Chief for Technology
NASA Goddard Space Flight Center (GSFC)
Electrical Engineering Division (Code 560)

wesley.a.powell@nasa.gov
301-286-6069
### Acronym List

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&amp;DH</td>
<td>Command and Data Handling</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital Signal Processor</td>
</tr>
<tr>
<td>EO-1</td>
<td>Earth Observing 1</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
</tr>
<tr>
<td>GPU</td>
<td>Graphics Processing Unit</td>
</tr>
<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>POL</td>
<td>Point Of Load</td>
</tr>
<tr>
<td>WMAP</td>
<td>Wilkinson Microwave Anisotropy Probe</td>
</tr>
</tbody>
</table>
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

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.
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.
Humanities Big Questions

- 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.
Facilities
Onboard Processing Needs

- 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

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.
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
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

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.
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

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.
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

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.
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.