NASA GSFC Perspective on Heterogeneous Processing

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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.
## Acronym List

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

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A Diverse Mission Portfolio

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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.
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
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
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
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

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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.

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