SpaceCube On-Board Science Data Processing

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NASA/GSFC Science Data Processing Branch
On-Board Science Data Processing

**ESDS On-Board Processing**
- Data Volume Reduction
- Compression
- Calibration / Correction
- Classification
- Product Generation
- Autonomy
- Event / Feature Detection
- Real-time / Direct Broadcast

**Hybrid Science Data Processing**
- CPU
- FPGA
- DSP

**GSFC SpaceCube On-Board Processor**
- 10x-100x computing performance
- Lower power (MIPS/watt)
- Lower cost (commercial parts)
- Radiation tolerant (not hardened)
- Software upset mitigation
# SpaceCube Family Overview

<table>
<thead>
<tr>
<th>Unit</th>
<th>Mission</th>
<th>Notes</th>
<th>Specs</th>
<th>Stats</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpaceCube 1.0a</td>
<td>Hubble Servicing Mission 4</td>
<td>Relative Navigation Sensors Experiment STS-125 May 2009</td>
<td>4”x4” card (2) Virtex4</td>
<td>Size: 5”x5”x7” Wt: 7.5 lbs Pwr: 37W</td>
<td>2009 Flight</td>
</tr>
<tr>
<td>SpaceCube 1.0b</td>
<td>MISSE-7 (ISS)</td>
<td>added RS-485, RHBS, STS-129 Nov 2009</td>
<td>4”x4” card (2) Virtex4</td>
<td>Size: 5”x5”x7” Wt: 7.5 lbs Pwr: 32W</td>
<td>In Flight</td>
</tr>
<tr>
<td>SpaceCube 1.0c</td>
<td>DEXTRE Pointing Package (ISS)</td>
<td>Original RNS unit, w/added 1553 &amp; Ethernet</td>
<td>4”x4” card (2) Virtex4</td>
<td>Size: 5”x5”x7” Wt: 7.5 lbs Pwr: 40W</td>
<td>Final stages of Implementation</td>
</tr>
<tr>
<td>SpaceCube 1.5</td>
<td>SMART (DoD/ORS)</td>
<td>adds GigE &amp; SATA, commercial parts, sounding rocket flight</td>
<td>4”x4” card (1) Virtex5</td>
<td>Size: 5”x5”x4” Wt: 4 lbs Pwr: &lt; 20W</td>
<td>Under Development</td>
</tr>
<tr>
<td>SpaceCube 2.0</td>
<td>Earth/Space Science Exploration missions</td>
<td>Std 3U form factor, GigE, SATA, Spacewire, cPCI</td>
<td>4”x6” card (2) Virtex5 (1) SIRF</td>
<td>Size: 5”x5”x7” Wt: &lt; 10 lbs Pwr: 20-40W</td>
<td>Under Development</td>
</tr>
<tr>
<td>SpaceCube 2.0 Mini</td>
<td>CubeSats, Sounding Rocket, UAV</td>
<td>“Mini” version of SpaceCube 2.0, CubeSat form factor</td>
<td>2.5”x2.5” card (1) Virtex5/SIRF</td>
<td>Size: 3.5”x3.5”x3.5” Wt: 3 lbs Pwr: &lt;10W</td>
<td>Under Development</td>
</tr>
</tbody>
</table>
Current SpaceCube Systems

SpaceCube 1.0a

SpaceCube 1.5

SpaceCube 1.0b
## Processor Comparison

<table>
<thead>
<tr>
<th>Processor</th>
<th>MIPS</th>
<th>Power</th>
<th>MIPS/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIL-STD-1750A</td>
<td>3</td>
<td>15W</td>
<td>0.2</td>
</tr>
<tr>
<td>RAD6000</td>
<td>35</td>
<td>10-20W</td>
<td>2.33(^1)</td>
</tr>
<tr>
<td>RAD750</td>
<td>300</td>
<td>10-20W</td>
<td>20(^2)</td>
</tr>
<tr>
<td>SPARC V8</td>
<td>86</td>
<td>1W(^3)</td>
<td>86(^3)</td>
</tr>
<tr>
<td>LEON 3FT</td>
<td>60</td>
<td>3-5W(^3)</td>
<td>15(^3)</td>
</tr>
<tr>
<td>GSFC SpaceCube 1.0</td>
<td>3000</td>
<td>5-15W</td>
<td>400(^4)</td>
</tr>
<tr>
<td>GSFC SpaceCube 2.0</td>
<td>5000</td>
<td>10-20W</td>
<td>500(^5)</td>
</tr>
</tbody>
</table>

Notes:
1 – typical, 35 MIPS at 15 watts
2 – typical, 300 MIPS at 15 watts
3 – processor device only ... total board power TBD
4 – 3000 MIPS at 7.5 watts (measured)
5 – 5000 MIPS at 10 watts (calculated)
On-Board Image Processing

Long Range Camera on Rendezvous

Short Range Camera on Deploy

GSFC SpaceCube 1.0a - Hubble SM 4 (May 2009):
- Autonomous Rendezvous and Docking Experiment
- Hosted camera AGC and two Pose algorithms

STS-125 Payload Bay
GSFC SpaceCube 1.0b (Nov 2009)
• “Radiation Hardened by Software”
• Autonomous Landing Application
• Collaboration with NRL

<table>
<thead>
<tr>
<th>Orbit</th>
<th>ISS</th>
</tr>
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<tbody>
<tr>
<td>Days Up</td>
<td>340 days</td>
</tr>
<tr>
<td>Total SEUs</td>
<td>95</td>
</tr>
<tr>
<td>Avg SEUs/FPGA/Year</td>
<td>25.5</td>
</tr>
<tr>
<td>Functional Errors</td>
<td>0</td>
</tr>
</tbody>
</table>
On-Board Data Reduction

Accomplishments

SAR Nadir Altimetry Results (FY07)

On-board processing yields lossless 6:1 data volume reduction

Difference < 0.1%
On-Board Data Reduction

Accomplishments

SAR Mapping Results (FY09)

On-board product generation yields factor of 165x data volume reduction

Original Matlab Output

SpaceCube Output

Difference < 1%
On-Board Products

Accomplishments

- Classification
- Product Generation
- Event Detection
HyspIRI Demonstration Testbed

HyspIRI SpaceCube IPM Testbed

- VSWIR Simulator
  - 816 mbps
- TIR Simulator
  - 210 mbps
- 4 x 440 MHz PPC
  - 1 GByte RAM
  - Rocket I/O
  - 10 GByte SSR
- Spacecube 2.0 Development System
- X-Band D/L Simulator
  - 15 mbps

Cloud Classifier
SpaceCube 2.0 Block Diagram

- Power Card
- SpaceCube2 Processor Card
- FLASH Memory Card
- Mission Unique I/O

Connections:
- Spacewire / LVDS / MGT / GigE / Mission Unique High-speed

Specifications:
- Standard 3U Card Form Factor
- Nominal Box Level Parameters:
  - Size 5”x5”x7”, Weight 10-15 lbs, Power 10-20 watts
Coming Soon ...

SpaceCube 2.0

SpaceCube “Mini”