GOES-R SpaceWire Implementation

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International SpaceWire Conference 2007
Dundee, Scotland, UK
September 17, 2007
GOES-R SpaceWire Implementation Agenda

• GOES-R Mission
• SpaceWire ASIC Development
• BAE ASIC Test Card
• Reliable Data Delivery Protocol
• Flight Data System Test Bed
GOES-R Mission

- GOES-R observes and helps predict local weather events, including thunderstorms, tornadoes, fog, flash floods, and other severe weather.

- Aids the monitoring of dust storms, volcanic eruptions, and forest fires.

- Search and Rescue Satellite Aided System (SARSAT) support.

- Contributes to the development of worldwide environmental warning services and enhancements of basic environmental services.

- Improves the capability for forecasting and providing real-time warning of solar disturbances.

- Provides data that may be used to extend knowledge and understanding of the atmosphere and its processes.
GOES-R Mission

GOES Communications System (Simplified)
GOES-R Mission

Smokin' Florida
1245 UTC 11 May 2007
GOES-12 visible
SpaceWire ASIC Development

- Produced under NASA Glenn Research Center/GSFC development contract.
- GSFC missions currently using this chip: GOES-R and LRO.
- Based on flight heritage BAE RAD750 Bridge II chip
  -- Uses verified GSFC SpaceWire core.
- Provides the capability to implement a 4 port SpaceWire “system” on a chip.
  -- All GOES-R SpaceWire related requirements are implemented in the chip.
## BAE SpaceWire ASIC Physical Characteristics

<table>
<thead>
<tr>
<th><strong>Clock Speed</strong></th>
<th>Base: 80MHz, SW: 268MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process Technology</strong></td>
<td>0.25 um CMOS, 5 level metal</td>
</tr>
<tr>
<td><strong>Die Size</strong></td>
<td>12.7 mm. by 12.7 mm.</td>
</tr>
<tr>
<td><strong>Cells (gates)</strong></td>
<td>4.6m cells (2.1m gates)</td>
</tr>
<tr>
<td><strong>PCI Peak Bandwidth</strong></td>
<td>128 MB/s write, 90 MB/s read</td>
</tr>
<tr>
<td><strong>Signal I/O</strong></td>
<td>503 (45 test)</td>
</tr>
<tr>
<td><strong>Power Supply</strong></td>
<td>2.5 V core, 3.3 V I/O (+/- 10%)</td>
</tr>
<tr>
<td><strong>Power Dissipation</strong></td>
<td>3 W</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
<td>-55°C to +125°C</td>
</tr>
<tr>
<td><strong>Radiation Hardness</strong></td>
<td>Latch-up immune 200krads TID 1E⁻¹⁰ errors/ bit day</td>
</tr>
<tr>
<td><strong>Packaging</strong></td>
<td>624 pin Column Grid Array with flip-chip C4 mount</td>
</tr>
</tbody>
</table>
BAE ASIC Test Card

- GOES-R designed and fabricated custom PCI card to test BAE ASIC.
  -- Prototype GRDDP code for the EMC.
  -- ASIC performance testing.
  -- Key elements of GOES-R flight data system test bed.

- 4Mb SRAM, 1.5Mb ECC SRAM, 128Mb SDRAM, 32Mb ECC SDRAM, 256k EEPROM

- Mezzanine connectors for FPGA card to PCI2.

- Used with an Intel motherboard running Windows XP.

- Work in process to move to PowerPC/VxWorks environment.
BAE ASIC Test Card
Reliable Data Delivery Protocol (RDDP) Rationale

• Addresses data loss due to bit errors on a SpaceWire physical link.
  -- At GEO, GOES-R instruments scan 24/7.

• Assuming $10^{-12}$ bit error rate at 100Mbps.
  -- This is about 24 bit errors per 24 hour period.
  -- 1 bit error = a lost packet.
  -- With a maximum packet size of 65k this BER can yield about 4 million bits lost per day.

• The RDDP provides a simple low cost approach to bring potential data loss to a very small number.
RDDP Rationale Cont.

• Provides easy to implement common approach to SpaceWire error management across all GOES-R instrument and spacecraft interfaces.

• GOES-R does not have to pay multiple contractors for solving the same problem.

• Allow bi-directional communications between multiple data sources/sinks over a single SpaceWire connection.

• GOES-R provides RDDP technical support to all instrument and spacecraft implementers.
  -- A one-stop-shop for the resolution of SpaceWire/RDDP issues.
RDDP Development

• “Off-the-shelf” protocols were modeled early in the GOES-R program.

• The complexity and processing requirements of these protocols were judged to be excessive for GOES-R needs.

• The first RDDP implementation used a 4 byte header and was GOES-R specific.

• As protocol development progressed, GOES-R made a decision to make the RDDP open to any interested user.
  -- Increased header to 8 bytes
  -- Received a PID (238) from the SpaceWire Working group
RDDP Features

• Provides 2 services: Reliable Delivery (RD) and Urgent Message (UM).
  -- RD requires a positive ACK from the receiver.
  -- UM is fire-and-forget.

• Allows up to 96 virtual channels on a single physical SpaceWire connection.
  -- Virtual channels are defined by destination and source SpaceWire Logical Addresses (SLA) pairs.
  -- Virtual channels operate independently of each other.

• The RDDP utilizes an 8 byte header and an 8 bit CRC trailer.

• Simple point-to-point full duplex interface or networked environment.
RDDP Features

- Allows mixing of low, medium, and high rate data channels on 1 single SpaceWire connection.
- Implements a sliding window to improve efficiency.
- Programmable window size, timeout, and retry parameters by virtual channel.
- Host processor impact is minimal – only needs to move memory contents over PCI.
RDDP Features

Instrument

Virtual Ch. 32
Science Data

Virtual Ch. 34
Health/Safety/Eng. TLM

Virtual Ch. 33
Commands

Virtual Ch. 35
Ancillary Data

Virtual Ch. 36
“Time at the tone”

Time Sync
Phys Layer

Spacecraft

Virtual Ch. 33
Commands

Virtual Ch. 35
Ancillary Data

Virtual Ch. 36
“Time at the tone”

Virtual Ch. 32
Science Data

Virtual Ch. 34
Health/Safety/Eng. TLM

Time Sync
Phys Layer

1 ea. 2 Twisted pair SpaceWire Cable 2 to 400Mbps
Flight Data System Test Bed

- Currently consists of 5 workstations all interconnected with 5 meter cables.
  -- 2 FPGA (modified JWST SWTS) based systems and 3 ASIC based systems.
  -- SWTS FPGA based cards are COTS.

- All drivers and application software were developed/modified by GOES-R.
  -- Test Bed hardware and software details are available through the NASA Technology Transfer Office.
Flight Data System Test Bed

ASIC Software -
• The ASIC has an on-chip embedded microcontroller (EMC) and RAM.
  -- The RDDP resides and is executed inside the ASIC.

• RDDP uses BAE supplied tools and is written in C.

• Host processor impact is minimal – only needs to move memory contents over PCI0.

GSE Software -
• Customized version of GSFC common GSE software.

• Written in C.
Flight Data System Test Bed

Port-to-Port SpaceWire cable
Flight Data System Test Bed
Flight Data System Test Bed

Reliable Data Delivery Protocol

16K Science Data Packets - dropped packets.

Instrument

C&DH
Flight Data System Test Bed Results – 132Mhz SpW Clock

• Processor utilization is ~10% with EMC running at 33Mhz.

• A virtual channel using 90% of available bandwidth (30kbyte packets) allows adequate time for all ACKs and other virtual channels.

• Reliably handles better than 25k packets (100 byte pkts.) per second. -- 50k interrupts per second.

• Long term tests (> 5 billion 16kbyte packets) completed with no data loss.