Appliqué Sensor Interface Module: An Enabling Technology For Space PnP Systems

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Lt Jeffrey Scott
Project Lead, Compact Avionics
Space Electronics Branch,
Space Vehicles Directorate,
Air Force Research Laboratory,
Kirtland Air Force Base, N.M.
Overview

• Background
• ASIM in SPA
• Current Status
• Demonstrations
• Future ASIM Work
Operationally Responsive Space

President’s National Security Presidential Directive/NSPD-40, 6 Jan 2005
“Demonstrate an initial capability for operationally responsive access to and use of space —providing capacity to respond to unexpected loss or degradation of selected capabilities, and/or to provide timely availability of tailored or new capabilities—to support national security requirements;…”

TacSat Demonstration Objectives

**Satellites**
- Spacecraft recurring cost < $20M
- Less than 1 year development time
- Enable rapid integration of new technologies and payloads (i.e Plug-n-Play capable)
- Payload mass three-times bus mass
- Militarily significant payloads
- Designed for ~ 1 year mission life

**Launch**
- Launch from call-up < 6 days
- Launch costs < $10M

**Checkout, Ops, Theater Integration**
- On-orbit check-out < 4 hours
- Theater & global tasking/data dissemination
- Lean ops < 4 people
Responsive Space

1 Day or Less
- Rapid Initialization
  - Autonomous checkout & calibration

2.4 Days
- Launch
  - Satellite/booster integration
  - Pre-launch test

2-3 Days
- User Call Up
  - Design satellite
  - Assemble satellite
  - Integrate payload(s)
  - Test

Information for Warfighter
- Payload(s) to meet identified shortfalls or gaps
- Real-time, Dynamic IP Addressable Tasking
- Focused Real-time Products For Individual Tactical Units
- High Bandwidth Theater Downlink
- Tactical Terminal
Space Plug-and-Play Avionics (SPA)

• Plug – Hardware
  – Data Network
    ➢ USB 1.1 12 Mbps
    ➢ SpaceWire 625 Mbps
  – Power Distribution
    ➢ 4.5 amp monitored with breaker
  – Time Synchronization
    ➢ 1 Hz
    ➢ Accurate clocks
  – Single Point Ground

• Play – Software
  – Self-Forming Networks
    ➢ Spacecraft as a robust network
  – Self-describing components
    ➢ Extensible Markup Language (XML) Transducer Electronic Data Sheet (xTEDS)
      ▪ Data outputs
      ▪ Command inputs
      ▪ Interfaces supported
      ▪ Services provided
  – Machine-Negotiated Interfaces
    ➢ Satellite Data Model (SDM)
      ▪ Query and discovery
      ▪ Distributed processing
      ▪ Peer to peer messaging
      ▪ Help desk for applications
    ➢ Appliqué Sensor Interface (ASI)
Appliqué Sensor Interface Module (ASIM)

SPA Component

Legacy Component

SPA Interface Module (ASIM)

SPA Robust Hub

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Self-Defining Data Sheet (xTEDS)
- Data Products
- Commands
- Interfaces
- Services

Common Data Dictionary (CDD)
- Standard data meaning
- Distributed to all interested parties
- Extensible

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Component

xTEDS

Satellite Data Model

Data Manager

Application

Self-defining – Data, Commands, Services, & Interfaces
Sidewide to implement the Play side of SPA
Query and Discovery for software that can adjust to differing configurations
"Help Desk" for flight application software
ASIM Capabilities

• Care and feeding of attached device
  – Native commanding – implementation of SPA command
  – Health and status monitoring
  – Thermal control – under limit and over limit

• SPA data interface
  – Data messages
  – Command messages
  – Services

• System interfaces
  – Power
  – Safety

• Hardware In-the-loop (HWIL) interface
  – Initialization message
  – Test Bypass Protocol
Incorporate signal injection capabilities into the core of the ASIM.
Current ASIM Status

- Component style part with small footprint
- Module mounts on a carrier board with instrument specific electronics
- Gen 1 design based primarily on SPA-U although much work is being done to incorporate SPA-S capability
- Core design is intended to serve as a model for a future rad-hard ASIC
Gen 1 ASIM Baseline Code

- USB and SpaceWire Communications modules
- New subscription driver
- ASIM hardware drivers and application code remain relatively unchanged

![Diagram of ASIM Communication Modules]

<table>
<thead>
<tr>
<th>Main Executive (ASIMFW.C / GLOBAL.H)</th>
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<tbody>
<tr>
<td>SPA Communication Tasks: USB.C and SDM.C</td>
</tr>
<tr>
<td>Performs all SPA communication. Requests data from the application task.</td>
</tr>
<tr>
<td>Application Task (ASIMAPP.C): Performs sensor specific tasks. Uses communication task exports for communication.</td>
</tr>
<tr>
<td>Debug Task (DEBUG.C): Uses the serial port for printf debugging. Can be removed when not needed.</td>
</tr>
</tbody>
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<th>Communication Driver Modules</th>
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<tr>
<td>USB Device Definitions (UDC.H)</td>
</tr>
<tr>
<td>Spacewire Device Definitions (SDC.H)</td>
</tr>
<tr>
<td>Spacewire Driver (SPACEWIRE.C)</td>
</tr>
<tr>
<td>Subscription Driver (SUB.C)</td>
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<table>
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<tr>
<th>Application Driver Modules</th>
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<td>Sample Application (LCD.C)</td>
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<tr>
<th>Hardware Driver Modules</th>
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<tr>
<td>Serial Port (SERIAL.C)</td>
</tr>
<tr>
<td>Analog Input (ADC.C)</td>
</tr>
<tr>
<td>Analog Output (DAC.C)</td>
</tr>
<tr>
<td>Digital I/O and Power Relay (DIO.C)</td>
</tr>
<tr>
<td>Test Bypass Register File (REGFILE.C)</td>
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</tbody>
</table>
Re-Entry Structures Experiment I (RESE-1) Suborbital Flight

RESE-1 Suborbital Flight Experiment
- Sounding Rocket: Single-stage Terrier
- Launch Site: White Sands Missile Range, N.M.
- Launch Date: ~ September 2007
- Max Altitude: ~ 200,000 to 250,000 ft
- Duration above 90,000 ft: ~100 sec

RESE-1 Plug-and-Play Experiment on dedicated composite deck with 4 SPA-U spacecraft sensors:

- SPA hardware integrated into controller cards and configured for space in 4 months

SPA hardware:
- Magnetometer
- Tri-axial Accelerometer
- Strain Gauges
- Thermistors

Two controller cards with integrated SPA-U hub and ASIMs integrated on bottom of composite deck
TacSat-3: Spacecraft Avionics Experiment (SAE)

- Launch on TacSat-3 in early 2008
  - Smart Deck with SPA-U host, 4 SPA-U ports, and data handling system
  - MSI’s Intelligent Power & Data Ring (IPDR) with multiple processing nodes
    - SpaceWire/SPA-S link between Sensor Processor and C&DH for backup downlink capability of HSI data
  - SPA-U PnP experiments (2 via Smart Deck, 2 via IPDR): Sun sensor, rate sensor, temperature sensors, AC coupled interconnect
  - Mass: 8.3 kg, Orbital average power: 10W, Dimensions: 10.2” x 9.2” x 5.75”
Plug-and-Play Satellite (PnPSat)

- Modular structure incorporates
  - Locking hinge joints allow panels to rotate about hinge line for easy access
  - Standardized mounting grid (5 cm)
  - SPA mechanical and electrical interfaces for 48 components/payloads on interior/exterior
  - Connectors and harness recessed in panels
  - Inter-panel harness keep electrical network intact throughout assembly, integration and test

- Higher performance PnP components incorporated in successive upgrades

- Payloads will be STP exp’ts that match bus capability

- Planned launch in Oct 2009 as co-manifest with SIV-1 on Minotaur IV

- Spacecraft configuration to be frozen ~6 months prior to launch to complete final integration and test
Interior of Panel

- Electronics infrastructure is internal to panel
  - Electronics boards and inter-board harnessing
  - Provides power and data services to each of eight payload endpoints per panel
  - Networked to all panels through inter-panel harnessing across specific joints
Future ASIM Work

• Small number of very high performance ASIMs (Tier 4)

• Current implementation includes the middle two Tiers: SPA-S for high data rate components, and SPA-U for low data rate components

• Tier 1 may include the largest number of components, but has the lowest data rate
Roadmap for Future ASIM Work

<table>
<thead>
<tr>
<th>Year</th>
<th>SPA-1</th>
<th>SPA-U</th>
<th>SPA-S</th>
<th>SPA-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>&lt;10kbps</td>
<td>&lt;1Mbps</td>
<td>&lt;1Gbps &lt;150Mbps (Lite)</td>
<td>&lt;10Gbps</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>Gen 1.2b 8-bit</td>
<td>Gen 1.3b 32-bit</td>
<td>Gen 2.4a HiPer-CASM</td>
</tr>
<tr>
<td>2009</td>
<td>Gen 2.1a ASIM</td>
<td>Gen 1.2c 8-bit</td>
<td>Gen 1.3c 8-bit</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Gen 2.1b ASIM</td>
<td>Gen 1.2d 8-bit (Lite)</td>
<td>Gen 1.3d 8-bit (Lite)</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>0.1mw, 1 cm²</td>
<td>10mw, 2.5 cm²</td>
<td>10mw, 2.5 cm²</td>
<td>&lt;5W, 12cm²</td>
</tr>
<tr>
<td>future</td>
<td>~1W, 6.5cm²</td>
<td>500mw, 6.5cm²</td>
<td>50mw, 2.5 cm²</td>
<td>&lt;5W, 12cm²</td>
</tr>
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Conclusion

• Plug-and-play modularity can dramatically cut cost and schedule, insert latest technology, and increase mission flexibility

• Appliqué Sensor Interface Modules (ASIMs) are simplifying the transition from legacy to plug-and-play components and enable successful implementation of SPA by providing:
  – Single point/standard electrical interface
  – Self-describing components
  – Machine negotiated interfaces

• Series of flight demonstrations are proving out the technology

• Family of ASIMs envisioned to meet various power and performance requirements
Questions?
Standardization of Hardware and Software Interfaces

- Work proceeding under an approved AIAA Committee on Standards (CoS)
- Documents under development
  - SPA-U standard (USB)*
  - SPA-U guideline (USB)*
  - SPA-S standard (SpaceWire)**
  - SPA-S guideline (SpaceWire)**
  - xTEDS schema standard**
  - xTEDS guideline**
  - Applique Sensor Interface Module (ASIM) guideline**
  - Satellite Data Model (SDM) guideline**
  - Push-button toolflow guidebook**
- Technical Committee (TC) with five working groups
  - Gen0 hardened parts
  - Gen1 Intellectual Property development
  - Software
  - Testbed
  - Technology
- Meetings Held 3-4 times/yr

*Drafts in coordination
**Drafts in work
Vertically Layered Software Model

Satellite Data Model (SDM)
- Enables flight software to be plug-and-play aware

Flight Software
- Modular and adaptable
- Reusable modules
- Autonomous
- Smart and fault tolerant
- Written prior to s/c design

Mission Code / Scripts
- Application #1
- Application #2
- Application #i
- Application #N

Task Manager
Data Manager
Sensor Manager (SM)

Processor Manager

RF

CPU
Automated Mission and Spacecraft Design

- Type of sensor
- Target locations
- Collection duty cycle
- Theater downlink

Mission Capture → Orbit Design → Spacecraft Design → Design Verification

Configurability + Design Automation = Speed

3D Design → Flight Verification

- Bill of materials
- Assembly instructions
- Software load
- Ground console

Hardware-in-the-loop testbed with full 6 degrees of freedom physics simulation
Space Plug-n-Play USB & SpaceWire (SPA-U & SPA-S)

- Take standard USB & SpaceWire and add:
  - 28V DC s/c power & ground (power return)
  - +/- Synch pulses (RS-422, 1 pps)
  - User-definable chassis or single-point ground

- SPA-U
  - 9-pin single point connector
  - 12 Mbps, to 3 Amps 28V DC
  - USB (1.1 or 2.0) for data transport
    - USB Lines: +/- Data, 5V DC, Ground

- SPA-S
  - 13-pin single point connector
  - 675 Mbps, to 20 Amps 28V DC
  - SpaceWire for data transport
    - SpaceWire Lines: +/- Xmit Data, +/- Xmit Clock, +/- Rx Data, +/- Rx Clock, Ground