ABSTRACT

This Paper is a Case Study Describing the Adaptation of Spectrum Astro’s SA-200HP (High Performance) RSDO Catalog Spacecraft Bus to Two Very Different Low Earth Orbiting (LEO) Science Missions, Coriolis and Swift

Coriolis is a Department-of-Defense-Sponsored Sun Synchronous Earth Observation Satellite Whose Primary Instrument, WindSat, Precisely Measures the Ocean Surface Wind Vector

Swift is a Low Inclination NASA Medium Explorer (MIDEX) Mission to Detect and Characterize Gamma Ray Bursts (GRBs). The Swift Observatory Carries Three Separate Telescopes: a Gamma Ray Burst Alert Telescope (BAT), an X-Ray Telescope (XRT), and a UV/Optical Telescope (UVOT)

In Addition to Describing How the Catalog Spacecraft Bus Was Applied to These Missions, This Paper Discusses the Unique Features and Benefits of the Catalog Bus Approach to Both the Procuring Agency and the Industry Bus Provider. Misconceptions Associated With the Use of the Catalog Bus Approach Are Also Discussed
Goddard Rapid Spacecraft Development Office (RSDO) Catalog Spacecraft Bus Approach

Flight Qualified Spacecraft Buses Are Eligible Core Buses

Approved Vendors
- Lockheed Martin
- Ball
- Astrium

Core Buses
- SA200-HP
- SA200-S
- SA200-B

Approved Vendors
- TRW Northrop Grumman
- Surrey
- Swales
- Orbital

Observatory Designs Based On Core Bus Architectures

NASA & External Customers
- Swift
- Coriolis

Specs
- RFOs
- Procurement Req'ts
GODDARD RAPID SPACECRAFT DEVELOPMENT OFFICE (RSDO) 
CATALOG REQUIREMENTS AND FEATURES

• Core Spacecraft Bus Entries Must Demonstrate Flight Qualification By Showing Direct Heritage to a Spacecraft That, At Minimum, Has Been Integrated to a Launch Vehicle

• Each Vendor Can Submit Multiple Core Buses Based on Different Architectures

• Core Bus Entries Can Have Options That Enhance or Tailor the Bus Capabilities

• Each Spacecraft Vendor That Has Received Approval of Their Core Bus Entry (or Entries) Holds an Indefinite Delivery Indefinite Quantity (IDIQ) Contract with GSFC/RSDO

• Each IDIQ Contract Spans a Five-Year Period and Includes Not-to-Exceed Prices Valid for the Contract Period

• IDIQ Contract Includes Services Clauses That Allow for Study Contracts to Evaluate and Assess Core Bus Applicability to Mission Requirements

• IDIQ Contract Enables Rapid Start by Issuance of a Delivery Order

• RSDO Catalog Provides for Semi-Annual Updates to Existing Catalog Entries and Offers Opportunity for New Vendors to Join
# Spectrum Astro RSDO Catalog Spacecraft Buses

## Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SA-200B</th>
<th>SA-200S</th>
<th>SA-200HP w/Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Mass</td>
<td>200 kg</td>
<td>350 kg</td>
<td>Up to 1220 kg</td>
</tr>
<tr>
<td>Payload Power</td>
<td>Up to 100 kg</td>
<td>Up to 200 kg</td>
<td>Up to 800 kg</td>
</tr>
<tr>
<td>Sunlit Array Power</td>
<td>Up to 200 W</td>
<td>Up to 300 W</td>
<td>Up to 2021 W</td>
</tr>
<tr>
<td>Payload Power</td>
<td>Up to 150 W</td>
<td>Up to 225 W</td>
<td>Up to 650 W OAP, 2300 W</td>
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<tr>
<td>Payload Accommodation</td>
<td>Science, Experimental, Imaging, LEO</td>
<td>Science, Experimental, Imaging, LEO</td>
<td>Science, Experimental, Imaging, Communications, LEO, MEO, GEO, Deep Space</td>
</tr>
<tr>
<td>Lifetime</td>
<td>1 to 3 years</td>
<td>1 to 3 years</td>
<td>6 years</td>
</tr>
<tr>
<td>Redundancy</td>
<td>Single String</td>
<td>Single String</td>
<td>Fully Redundant</td>
</tr>
<tr>
<td>Architecture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pointing Control/ Stability</td>
<td>0.25 deg &amp; 0.1 deg/sec</td>
<td>38 arcsec &amp; 0.1 arcsec/sec</td>
<td>16 arcsec &amp; 0.1 arcsec/sec</td>
</tr>
<tr>
<td>Orbit Control</td>
<td>None</td>
<td>± 0.5 km cross track/in-track</td>
<td>± 0.5 km cross track/in-track</td>
</tr>
<tr>
<td>Propulsion</td>
<td>None</td>
<td>Blow-Down Hydrazine</td>
<td>Blow-Down Hydrazine, Xenon Ion Option</td>
</tr>
</tbody>
</table>

**Launch Vehicles:**
- SA-200B: MightySat II Derivative
- SA-200S: MSTI-3 Derivative
- SA-200HP w/Options: Deep Space 1 Derivative

**Launch Vehicles (continued):**
- SA-200B: Pegasus, Shuttle Hitchhiker, OSP, Taurus
- SA-200S: Pegasus, Taurus, Athena, Delta, Atlas
- SA-200HP w/Options: Taurus XL, Delta, Atlas, Titan II, Athena, Ariane 4, Ariane 5

**Propulsion Options:**
- Blow-Down Hydrazine
- Xenon Ion Option
SA-200HP CORE BUS HERITAGE
NEW MILLENNIUM PROGRAM – DEEP SPACE 1

• Deep Space 1 - Advanced Technology Demonstration and Asteroid Braille and Comet Borrelly Flyby

• Spectrum Astro Teamed With JPL to Provide the Spacecraft Bus in Response to the New Millennium Program

• Technology Payloads Included:
  – Xenon Ion Propulsion System
  – Solar Concentrator Array
  – Autonomous On-Board Optical Navigation
  – Autonomous Remote Agent
  – Miniature Integrated Camera Spectrometer

• Orbit: Heliocentric

• Mass: 486.3 kg, Including 81.5 kg of Xenon and 31.5 kg of Hydrazine

• 2500 W Solar Array; Separate High Voltage Power Bus for Efficient Ion Engine Operation

• Launched October 24, 1998 on Delta 7326-9.5

• Mission Intentionally Terminated December 2001 With Xenon Propellant Depleted
SA-200HP CORE BUS HERITAGE
NEW MILLENNIUM PROGRAM – DEEP SPACE 1

Fully Integrated Observatory

Spacecraft In Inverting Fixture, Showing Ion Engine
CORIOLIS MISSION DESCRIPTION

- CORIOLIS is a US Air Force, Space and Missile Center Mission Providing Instrument Risk Reduction for the NPOESS Program
- Program Initiated April 1999; Launched January 06, 2003 on Titan II to 830 km, Sun Synchronous Orbit
- Instrument Complement:
  - WindSat: 30 rpm Passive Microwave Radiometer Measuring Ocean Surface Winds
  - SMEI: Solar Mass Ejection Imager (3 Cameras)
- 818 kg Total Launch Mass (incl. LV Adapter)
- Near Fully Redundant Spacecraft Bus – 3 Year Mission Life ~ 80% Reliability @ 5 years
- Three-Axis Stabilized, Stellar-Inertial Attitude Determination and Wheel Based Control
- VME Based RAD6000 Computer
- AFSCN/SGLS S-Band Command & Telemetry; User Selectable Rate of 51.2 or 25.6 Mbps X-Band Downlink
CORIOLIS MISSION DESCRIPTION

Fully Integrated Observatory

Titan II Launch of Coriolis
January 6, 2003

Pre-Launch Testing
CORMOLIS MISSION DESCRIPTION - STATUS

- Launch, separation, deployment, initial bus checkout 6 – 7 Jan 03
- Perigee raising completed from 8 Jan 03 thru 17 Jan 03, 16 burns total
- High rate X-band data downlink initiated 17 Jan 03
- WindSat nominally spun-up to 31.6 RPM on 19 – 20 Jan 03
- Radiometers activated and operating on 24 Jan 03
- SMEI camera baffle doors deployed and cameras operating 1 Feb 03
- Final acceptance and transition to payload operations 7 Feb 03

- WindSat pre-calibration results (1 Feb 03, 37 GHz horizontally polarized channel data comparison shown) compared favorably with existing systems
- SMEI observed its first Earth directed coronal mass ejection in May (major milestone)
CORIOLIS SPACECRAFT LAYOUT

- X-Band Transmitter
- Radiator
- PDU & SSR
- Radiator
- SMEI DHU
- SMEI Camera #3
- GPS
- Radiator Panel
- SMEI Camera #2
- X-Band Antenna
- WindSat Radiometer
- Star Trackers (2)
- IMUs (2)
- Integrated Electronics Module
- SMEI Camera #1
- Propulsion Service Boom
- 50 A-hr SPV Battery
- Fixed Solar Array
- SGLS Antennas
- Charge Control Unit
- SGLS Antenna
- GPS Antenna
- SGLS Transponder Radiator
CORIOLIS ADAPTATION OF SA-200HP – BLOCK DIAGRAM

Command & Data Handling
- Autonomous Redundancy Manager
- 34-Gbit Solid State Recorder
  - To Mission Instruments

Integrated Electronics Module
- RAD-6000 Central Processing Unit
  - Interfaces for: Propulsion, Attitude Control Devices, Uplink Downlink, Instruments (RS-422 & Mil-Std-1553), and Miscellaneous Analog and Digital Signals

Propulsion
- Hydrazine Valve & Feed System
  - Hydrazine
  - Propulsion

Electrical Power
- Solar Array
  - Charge Control Unit
    - 50 A-hr Battery

Attitude Control & Determination
- Reaction Wheel Electronics
  - Star Tracker
  - GPS Receiver & Antennas

RF Network
- S-Band Trans - Receiver
  - S-Band Communications Antennas

Legend:
- SA-200HP
  - w/Redundancy & GPS/Magnetics
- Removed For Coriolis
- Added For Coriolis
- Modified For Coriolis

* Internally Redundant

* Magnetic Torquer Bars

* Inertial Measurement Unit - IMU

* Coarse Sun Sensors

* Fine Sun Sensor Assembly

To Essential & Non Essential Power Loads
• Swift is a NASA MIDEX Mission to Detect and Characterize Gamma Ray Bursts (GRBs)
• Program Initiated November 1999; Scheduled to Launch December 2003 on Delta 2420 – 600 km, 22° Orbit
• 1455 kg Total Launch Mass
• Near Fully Redundant Spacecraft Bus ~87% Reliability @ 5 years
• Three-Axis Stabilized; Autonomous Rapid Slewing (50° in 75 sec) to Instrument-Detected GRB Coordinates
• S-Band Command and Telemetry, STDN and TDRSS Compatible; Continuous TDRSS Access for Immediate Ground Notification of GRB Activity/Coordinates
• RAD6000 Computer with 1553 Science Data Bus

Instrument Complement:
• Burst Alert Telescope – BAT
• X-Ray Telescope – XRT
• Ultraviolet/Optical Telescope – UVOT
SWIFT MISSION DESCRIPTION

Partially Integrated Observatory
Showing XRT, UVOT and Six Reaction Wheels

Integration of XRT in Hubble Space Telescope Clean Room at NASA GSFC

Full Observatory Showing XRT, UVOT, and BAT
SWIFT SPACECRAFT LAYOUT

- BAT Image Processors
- Star Trackers (2)
- Reaction Wheels (6) Torque Rods
- Transponders
- BAT Image
- Processors
- XRT Electronics
- -X S-Band Antennas
- XRT Radiator
- BAT
- NiH₂ Battery
- Power Distribution Unit (PDU)
- Integrated Electronics Module (IEM)
- Solid State Recorder
- UVOT
- XRT
- Coarse Sun Sensors
- Solar Array Wings
- Sun Shade
- +X S-Band Antennas
- BAT Power Supply
- Solid State Recorder
- UVOT
- XRT
- Coarse Sun Sensors
- Solar Array Wings
- Sun Shade
- +X S-Band Antennas
- BAT Power Supply
- Solid State Recorder
- UVOT
- XRT
- Coarse Sun Sensors
- Solar Array Wings
- Sun Shade
- +X S-Band Antennas
## COMPARISON OF PERFORMANCE CHARACTERISTICS
### SA-200HP CORE, CORIOLIS, and SWIFT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SA-200HP Core</th>
<th>SA-200HP With Full Redundancy &amp; GPS/Magnetics Options</th>
<th>Coriolis</th>
<th>Swift</th>
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<tbody>
<tr>
<td>Mission Orbit &amp; Inclination</td>
<td>600 x 600 km; 28.5°</td>
<td>830 x 830 km; 98.7°</td>
<td>600 x 600 km; 22°</td>
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<tr>
<td>Launch Date</td>
<td>N/A</td>
<td>N/A</td>
<td>6-Jan-03</td>
<td>5-Dec-03</td>
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<td>ACS Type</td>
<td>4-Wheel Zero Momentum Bias With Single Star Tracker &amp; GPS Receiver</td>
<td>4-Wheel Zero Momentum Bias With Dual Star Trackers &amp; GPS Receivers</td>
<td>4-Wheel Pitch Momentum Bias With Dual Star Trackers &amp; GPS Receiver</td>
<td>6-Wheel Zero Momentum Bias With Dual Star Trackers (No GPS)</td>
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<tr>
<td>SC Bus Dry Mass (kg)</td>
<td>354</td>
<td>374</td>
<td>354</td>
<td>613</td>
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<tr>
<td>Payload/Instrument Mass (kg)</td>
<td>666</td>
<td>646</td>
<td>339</td>
<td>843</td>
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<td>Observatory Dry Mass (kg)</td>
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<td>1020</td>
<td>693</td>
<td>1456</td>
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<td>Propellant Mass (kg)</td>
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<td>Observatory Wet Mass (kg)</td>
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<td>1087</td>
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<td>Delta V Capability (m/s)</td>
<td>137</td>
<td>137</td>
<td>228</td>
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<td>Bus Power (W OAP)</td>
<td>356</td>
<td>367</td>
<td>251</td>
<td>353</td>
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<tr>
<td>Payload Power (W OAP)</td>
<td>650</td>
<td>639</td>
<td>421</td>
<td>695</td>
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<td>Total Power (W OAP)</td>
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<td>1006</td>
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<td>Solar Array Output (W EOL)</td>
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<td>2000</td>
<td>1174</td>
<td>2215</td>
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<td>Battery Type</td>
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<td>NiH₂ / SPV</td>
<td>NiH₂ / SPV</td>
<td>NiH₂ / IPV</td>
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<tr>
<td>Battery Size</td>
<td>Two @ 50 Ahr</td>
<td>Two @ 50 Ahr</td>
<td>One @ 50 Ahr</td>
<td>One @ 80 Ahr</td>
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<tr>
<td>Uplink Rate (kbps)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2.125 (TDRSS)</td>
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<tr>
<td>Science D/L Rate</td>
<td>80 Mbps 2.5 Mbps Backup</td>
<td>80 Mbps 2.5 Mbps Backup</td>
<td>25.6 / 51.2 Mbps 256 kbps Real-Time</td>
<td>2.25 Mbps 1 kbps TDRSS</td>
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<tr>
<td>Telemetry D/L Rate (kbps)</td>
<td>128</td>
<td>128</td>
<td>128</td>
<td>in 2.25 Mbps link</td>
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<tr>
<td>Data Storage (Gbits EOL)</td>
<td>100</td>
<td>100</td>
<td>34</td>
<td>32</td>
</tr>
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</table>
BUYER'S GUIDE TO RSDO CATALOG BUSES

• Don’t Assume Catalog Bus Designs are Static
• Bus Designs in Catalog Serve as a Reasonable Starting Point
• Catalog Serves to Demonstrate Vendor Capabilities, Not Just Point Designs
• Modest Modifications to Subsystems are Typical and Expected
• Discuss/Convey Subsystem Requirements that are Not Met or Significantly Exceeded by the Core Bus Specifications; Heritage, Compatible Substitutions May be Available With No Risk and Possibly Lower Cost
• Retaining Some Excess Capability May Result in Cost Benefits
• Most Bus Providers Have a Family of Products That Represent a “Continuum” of Designs; View the Catalog as a Range of Performance
• RSDO Offerings Contains “Standard” Deliverables and Contract Terms/Conditions – These Items Can Be Tailored to Each Buyer’s Needs and Must be Assessed to meet the Performance and Cost Goals of a Given Program
SUMMARY

• “Standard” Core Spacecraft Bus Designs (Such as Found in the RSDO Rapid Catalog) Can Offer Science and Technology Developers Technically Responsive Missions With Broad Benefits
  – Low Risk Due to Common Design/Heritage Basis
  – Demonstrated Performance
  – Reduced Cost and Stable Schedules

• RSDO Standardized, Yet Tailorable, Deliverables, and Contract Terms Offer a Streamlined Procurement Process that Complements the Technical Benefits of a Catalog

• Build-to-Print Procurement Highly Unlikely, Especially for Science Missions With Their Unique Instruments
  – Buyers Must Allow for Reasonable Modifications
  – Buyers Should Use the Catalog to Assess and Evaluate Vendor Capabilities, Not Simply as a Listing of Products
  – This Paper Gives Good Examples of Reasonable Modifications That Retain a Baseline Architecture, While Resulting in Significantly Different Appearances

• Catalog is a Mission Design Tool as Well as a Procurement Vehicle
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