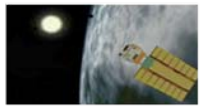
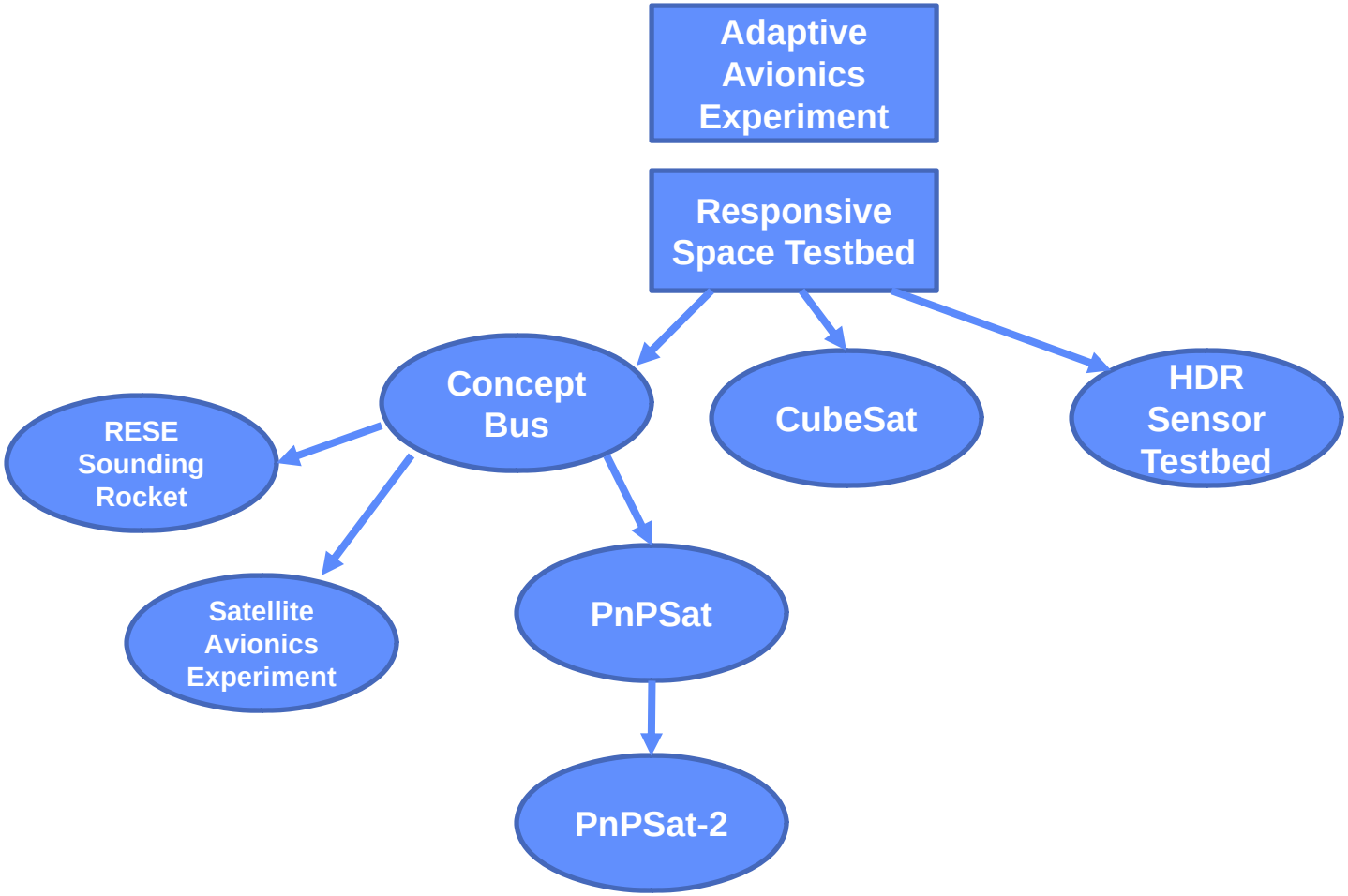
Plug and Play Satellite Evolution

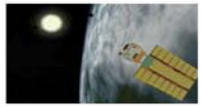
AIAA/USU Conference On Small Satellites
August, 2009
SSC09-VI-4

Don Fronterhouse
PnP Innovations, Inc



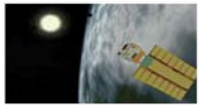
SPA Genealogical Tree





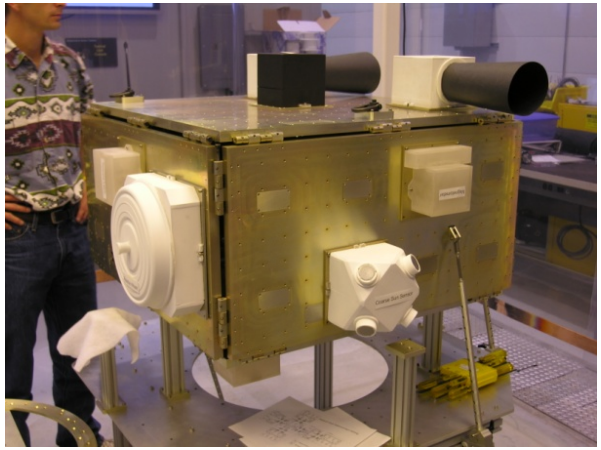
Responsive Space Testbed

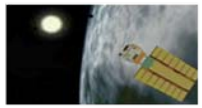
- The Responsive Space Testbed was built to –
  - Focus the development of SPA technologies
  - Provide a place for researchers to collaborate in SPA technologies
  - Demonstrate the current state of SPA technologies
    - Average 2-3 tours per week
- Built and tested the Concept Bus
- Built and tested PnPSat in the RST clean room
- Are building PnPSat-2 in the RST clean room



Concept Bus

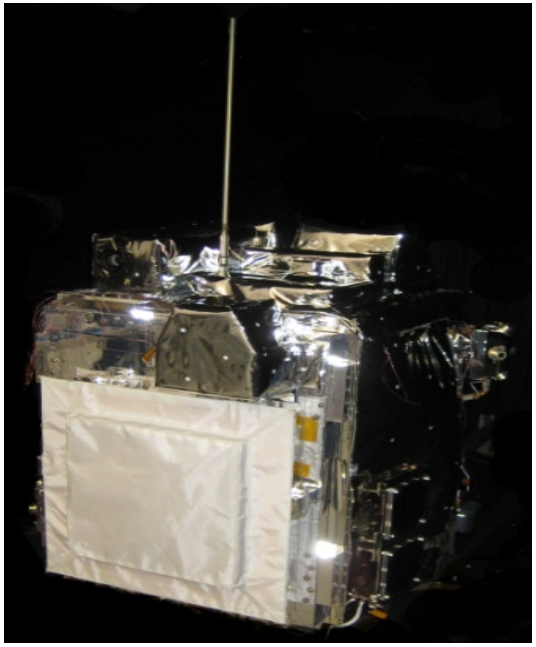
- Concept Bus was the first complete system based upon SPA technologies
- Provided a testbed for refining SPA software
- Used to develop ASIM based HWIL testing
- Demonstrated that rapid assembly was indeed possible
- Helped others to understand this radical new technology

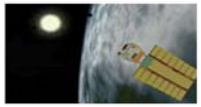




PnPSat

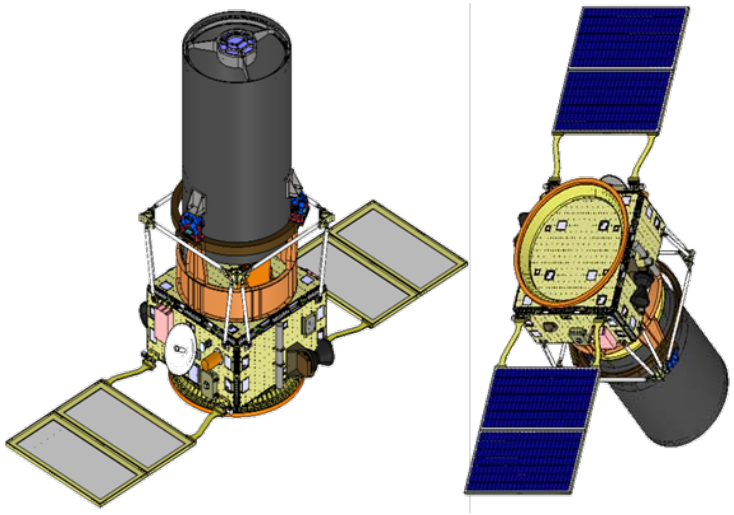
- First complete satellite based upon SPA technologies
- ESPA class, 120 Kg, 300 W
- True research spacecraft with many new technologies
- Rapid Assembly Test demonstrated 4 hours from components to a fully assembled satellite
- ORS is using it for rapid assembly tests

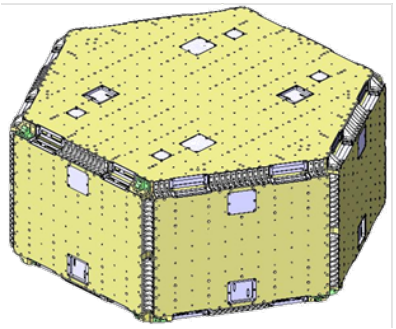


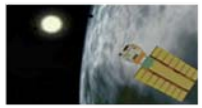


PnPSat-2

- Leveraging PnPSat lessons learned
- PnPSat-2 is evolving the PnPSat legacy
  - Next Generation of SPA infrastructure components and software
  - Transition technology to the broader commercial community
- Program is managed to a standard flight WBS to insure technologies are integrated in the proper context





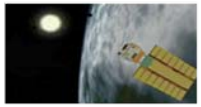


xTEDS Evolution

- xTEDS are used by on-board components to discover available data, commands, and services
  - SDM Data Manager collects and makes available via query
- Current versions offer
  - Standardized interfaces (e.g. power, attitude, torque, etc.)
  - Support for diagnostic data outside of Data Manager

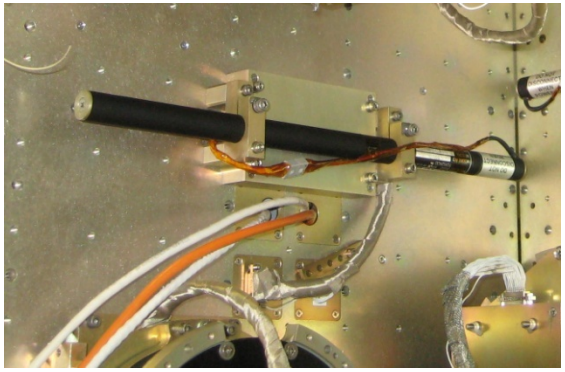
Gen 0	Initial version
Gen 1	Focussed on flight functionality
Gen 2	Standardized for broader use

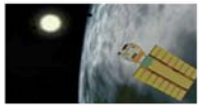
xTEDS	Gen 0	Gen 1	Gen 2
Schema	v1.2	2.5	2.5
Organization	Message	Interface	Std Interface
CDD	v0.1	v1.0	v2.0
Diagnostic Support	None	Limited	Yes
Mission Sensors	None	Simple	Tactical



Gen1 vs Gen2 ASIM

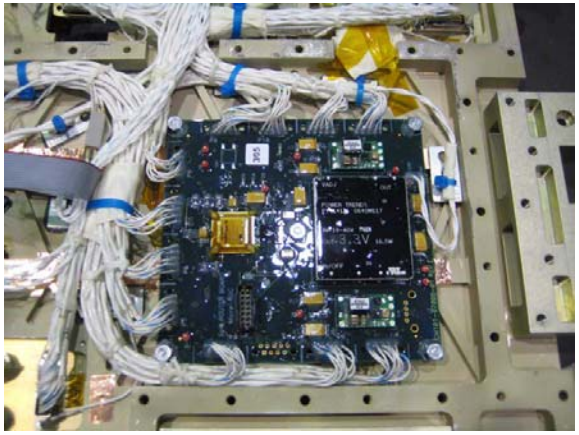
	Gen1	Gen2
ASIM		
Program Code Memory	32kB	64kB
Electronic Parts Selection	COTS	Rad-tolerant components suitable for NASA Class C missions or better.
Program Code Updates	Requires JTAG cable connection	In situ updates possible through normal spacecraft network connection
Front End +28V Converter Type	Non-isolating step-down	Isolating converter
Low Level Command Processor	Supported in software	Done in hardware
Peripheral Set	Baseline	3 RS-422 serial port, CRC peripheral, PWM capability, async & synchronous serial hardware buffers
SPA-S	50 Mbps	50 Mbps
Hardware debugger	No	Yes
Power Consumption	1.2 – 1.5 Watts	Est. 0.8 – 1.0 Watt
FPGA	Virtex 4	ProASIC, >30 kRad
Non-volatile Memory	None	8 kBytes

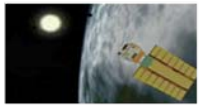




Gen1 vs Gen2 SpaceWire Router

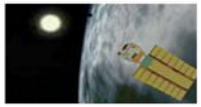
	Gen1	Gen2
SPACEWIRE ROUTER		
Maximum Link Speed	200 Mbps	300 Mbps
Electronic Parts Selection	COTS	Rad-tolerant components suitable for NASA Class C missions or better.
Number of supported endpoints	8	10
Port Configurability	Wormhole	Wormhole or Store & Forward
FPGA	Virtex 4	Virtex 4QV with Aeroflex Eclipse scrubber, 300 kRad
Stalled Message Handling	None	Provisions for Stalled Source / Stalled Destination
Radiation Tolerance	Unknown	Latchup immune, Less than 1 critical upset per year based on HEO orbit
Power	3.5 Watts	4 Watts





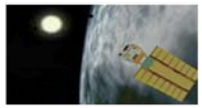
Gen1 vs Gen2 PowerHub

	Gen1	Gen2
POWER HUB		
Number of supported endpoints	8	10
Current measurement granularity	+/- 100 mA	+/- 25 mA
Electronic Parts Selection	COTS	Rad-tolerant components suitable for NASA Class C missions or better.
Support for High Power Endpoint	With external board	Yes, 1 30 Amp endpoint each power hub
Front end +28V Converter Type	Non-isolating	Isolating converter, with isolating current measurements
FPGA	Virtex 4	ProASIC 3, >30 kRad
Power Consumption	4 Watts	Est. 3 Watt
SPA-S	10 Mbps	50 Mbps
Test Bypass Router	External	10 port built-in



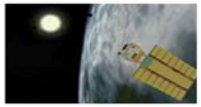
SPA Infrastructure Evolution

Gen 0	SPA-U	USB based focussed on SPA functionality			
Gen 1	SPA-S	Spacewire based focussed on flight functionality			
Gen 2	SPA-S	focussed on flight ready and radiation tolerance			
Power Distribution		**Gen 0**	**Gen 1**	**Gen 2**	
Current / Endpoint (A)		3.0	4.5	4.5/30.0	
Endpoints per panel		8	8	10	
Time Sync Pulse		RS-422	RS-422	RS-422	
Size (cm)		15x15	9x20	13x20	
Power (W)		4	4	3	
Data Network		**Gen 0**	**Gen 1**	**Gen 2**	
Transport		USB 1.1	SpaceWire	SpaceWire	
Speed (Mbps)		11	200	300	
Bus Type		Shared	Point - Point	Point - Point	
Bisection BW (Mpbs)		5.5	1600	3000	
Size (cm)		15x15	10x10	13X12	
Power (W)		5	3.5	4	
ASIM		**Gen 0**	**Gen 1**	**Gen 2**	
Data Network		USB 1.1	SpaceWire	SpaceWire	
Speed (Mbps)		11	50	100	
Interfaces		Serial	Serial	Serial	
		Digital	Digital	Digital	
		Analog	Analog		
Size (cm)		10x10	5 x 5	7x7	
Power (W)		3.5	1.3	0.8	



What is Next?

- Expand the satellite size envelope
  - CubeSats (1 Kg)
  - Small Sats (~50 Kg)
  - Tactical Satellite (~400 Kg)
  - Large Satellite (> 400 Kg)
- Expand the architecture
  - Internal SPA Panels
    - Flexibility in mounting
    - Standard architecture
    - Reduced complexity
  - External SPA
    - Flexibility in architecture
    - Integrate with existing processes



What is Next

- Expand the data network
  - SPA-10 – 10 Gbps optical network
  - SPA-E – Ethernet
  - SPA-1 – Low speed, low power 1 wire
  - SPA-W – Wireless data and power
- Expand the performance – Structured ASIC
  - Lower power
  - Faster schedule
  - Higher performance
  - Reduced cost and schedule
  - Increased radiation hardness