High Speed, Low Cost Telemetry Access from Space Development Update on Programmable Ultra Lightweight System Adaptable Radio (PULSAR)

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What is PULSAR

- PULSAR
  - Software Defined Radio
  - Flexible System
  - Modular
  - Adaptive to Mission Requirements
  - Optimized SWaP
  - Address NASA Roadmap Objectives
    - Communications and Navigation
    - Higher data rates
    - Information Technology

Software Defined Radio (SDR)

Description

- Software Defined Radio (SDR) concept uses a minimum amount of analog/RF front-end components to upconvert/downconvert the RF signal to and from a digital format

- Once in digital format, the SDR downconverts, samples, filters, and demodulates received signals and then modulates and upconverts the transmitted data stream to power amplifier RF Module using software algorithms or the fabric of a field programmable gate array (FPGA)

- Directly interfaces with the Command and Data Handling (C&DH) subsystem

Goal

- By leveraging existing designs and extensive experience with digital processor and FPGA design, software, and tools, as well as analog and RF expertise, Marshall is creating the next-generation of software defined radio transponders

Software Defined Radio (SDR)

Flight Heritage

- First generation telemetry module made for micro-satellites currently in orbit
- Uplink data — 50 kbps
- Downlink data rate — 1 Mbps
- Interfaces to the flight computer via a source synchronous 422 interface. This means, data, and clock are coming from the flight computer
- Power — ~200 mW
- Telemetry is CCSDS compatible
- Reed-Solomon encoding is done in an ASIC from GSFC
- FPGA handles all CCSDS encoding, decoding and bit-synchronization, as well as interfacing to flight computer
- On-board processor handles housekeeping and interfaces to flight computer through 422 interface
- Low cost
- First generation telemetry system licensed by Orbital Telemetry Systems
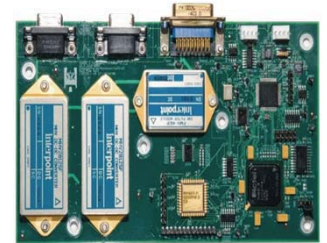
Software Defined Radio (SDR)

How Does PULSAR (4th Generation SDR) Compare?

Maker	Unit	Freq. Band	Downlink Data Rate, Msps	Mass, kg	Bench-mark, b/W
NASA-MSFC	PULSAR	S-, X-	150	2.1	10e6
L3 Comm	Cadet	S-	100	0.215	8.3e6
Innoflight	SCR-100	S-	4.5	0.25	3e6
L-3 TW	CTX-886	X-	400	3.85	66e6
Space Micro	µSTDN-100	S-	4	2.1	0.7e6
Harris Corporation	SCaN	Ka	100	19.2	2.5e6
General Dynamics	SCaN	S-	10	-	1.0e6
Jet Propulsion Laboratory	SCaN	S-	10	6.6	1.0e6

PULSAR exceeds most of the other units in term of the industry benchmark. The L-3 TW CTX-886 exceeds PULSAR in data rate, but PULSAR has less mass (2.1 versus 3.85 kg) and uses less power (42 versus 75 watts.

Software Defined Radio (SDR)

Current Design

- SDR is a modular design and is comprised of slices or decks.
    - S-Band Command Receiver
    - S-Band Telemetry Transmitter
    - X-Band Telemetry Transmitter
    - Processor
    - Power Supply

- Transponder can be built "al la cart" as missions requirements dictate.
    - Typical size is 4.25″ ´ 4.25″ ´ 3″ (L ´ W ´ H) for S-band command, telemetry, power supply, and processor slices
    - Add 0.75″ in height for each additional slice
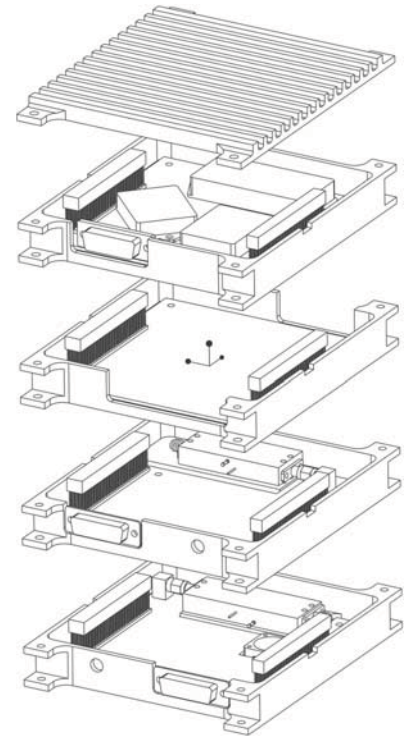
Software Defined Radio (SDR)

Current Modules

- SDR Command Receiver
  - 5W DC input power
  - Maximum uplink data rate is 300 Kbps (limitation due to ground station)
  - Receiver Front End — 0.6 dB Noise Figure
  - Capability of FM/BPSK/QPSK demodulation
  - Ranging tones not required — Doppler shift ranging
  - Advanced Encryption System (AES) Decryption Command Decoding

- Processor Slice
  - Advanced RISC Machine (ARM), ARM-M1 Processor running inside rad-tolerant, field programmable gate array (FPGA).
  - Uplink/downlink, encoding, and decoding can be done in high-speed logic inside the FPGA on this slice

Software Defined Radio (SDR)

Current Modules

- Telemetry Transmitter
  - BPSK/QPSK telemetry data stream
  - Maximum data rate 150 Msps (limit ground stations)
  - Low-Density Parity (LDPC) Forward Error Correcting (FEC)
    - Adds at least an order of magnitude increase in telemetry through-put due to improved coding gain
    - Reed-Solomon available
  - RF Output power can be tailored to mission
    - 0 – 2W RF output power
    - If higher power levels are required an external Solid State Power Amplifier (SSPA) can be added

- Power Slice
  - EMI/EMC compatibility
  - 28VDC +/– 4VDC input voltage, electrically isolated from satellite bus
 - Command ON/OFF, warm/soft reboots - external source

- "Hardware in the loop" bench test
  - August 2013
  - Good BW/Data Rate
- High Energy Replicated Optics to Explore the Sun (HEROES) Balloon Flight
  - September 2013
  - Fort Sumner, NM
  - Problems
    - S-Band Antenna Severed
    - X-Band Failure
      - Lightning Prior to Launch Day
      - Elevated Temperatures

- ## HEROES Outcomes
  - ### Redesigned Circuit Board
    - Move from Prototype to Flight
      - Planned but Additional Lessons Learned
  - ### Improved Thermal Management
    - Alodine to Black Anodized Coating
    - Significant Reduction in Maximum Board Temperatures
      - 82C (5 Hour Transient)
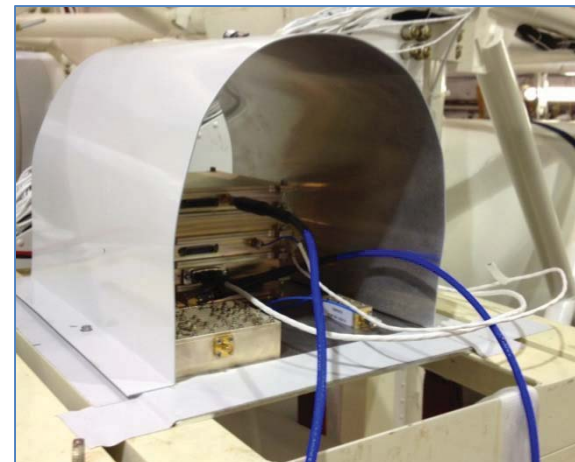
Current Status

- Preparing to Deliver Test/Eval Units to GSFC
  - Part of Interoperability Test Series
    - Validation of Integrated Power Avionics and Software (iPAS)
- Completing Flight Unit Design/Development
  - TVAC & Vibration Testing
    - Q4 CY 2014
- Balloon Test
  - Fall 2014
- Small 2 Stage Sounding Rocket Flight
  - February 2015
- Peregrine Sounding Rocket Demonstration
  - May 2015

- Evaluating Multiple Opportunities
  - Increase to TRL 8 or 9
- Development of Reduced Footprint Unit
- Additional Receiver/Transmitter Options
- Enabling Extended Capabilities
  - Flight Computer Backup/Operation Offload
  - Separate Sensor Deck
  - Image Processing
    - Autonomous Operation Support
  - AES256 Data Encryption
  - In Flight Reconfiguration
- Continued Ground Station/Relay Station Effort
- ?

Summary

- PULSAR
    - Progressing Well on Development Path
        - Failures = Lessons Learned & Improvements
        - Goals Met
    - Future is Very Promising
        - Significant Opportunities for Enhanced Capabilities
        - Evaluating/Determining the Roadmap
    - Supportive of LEO to Deep Space Missions
    - An Excellent System for NASA
        - And Other Government Users
        - And Commercial/Academic through Licensee
            - Orbital Telemetry
    - An Asset for Many Years

Questions?

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