Lessons Learned
in the
First Year Operating
Software Defined Radios in Space

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Overview

♦ SCaN Testbed and Software Defined Radio
  • SCaN Testbed SDRs
  • SCaN Testbed Communications Paths

♦ Lessons Learned
  • Characterize the Platform
  • Mitigate Old Hardware
  • Flexible Commands
  • Flexible Telemetry
  • Great Engineering Models
  • Help Third-Party Developers

♦ STRS & SCaN Testbed Solicitations
SCaN Testbed

- **Space Communications and Navigation (SCaN) Testbed**
  - Software-defined radio (SDR) research testbed
  - Launched July 2012 to the International Space Station (ISS)
  - Space Telecommunications Radio System (STRS) architecture

*Above: SCaN Testbed*

*Left: SDRs and subsystems*
SCaN Testbed SDRs

- **General Dynamics (GD) SDR**
  - 60 MIPS Coldfire (VxWorks) and (1) QPRO FPGA
  - S-Band transceiver (2.0 – 2.3 GHz) with 8W amp
  - 1M chalcogenide non-volatile phase-change memory

- **Jet Propulsion Laboratory (JPL) / L3-CE SDR**
  - 66 MHz SPARC (RTEMS) and (2) Virtex2 FPGAs
  - S-Band transceiver (2.0 – 2.3 GHz) with 7W amp
  - L-Band receiver at L1, L2, and L5 GPS frequencies

- **Harris Corporation SDR**
  - 700 MIPS PowerPC (VxWorks) and (4) Virtex4 FPGAs
  - Ka-Band transceiver (22 – 26 GHz) with 40W TWTA
  - Texas Instruments digital signal processor (DSP)
Payload control via ISS primary path
LESSONS LEARNED
Characterize the Platform

- Test the SDR hardware independent of the waveform (software)
  - Development of a new waveform requires knowing platform performance.
  - Low-level test waveforms are necessary for platform characterization.
    - Store samples from the analog-to-digital converter
    - Transmit samples out the digital-to-analog converter

- The operational waveform often is not the best tool for platform characterization
  - Small subset of potential frequencies, modulations, and data rates
  - Performance depends on waveform implementation

Require delivery of test waveforms to aid platform characterization
SCaN Testbed has several Xilinx Virtex 2 FPGAs

- Virtex 2 was last supported by Xilinx ISE 10.1 (~2008)
- Increasingly challenging for present-day developers
  - Old software libraries; vendors are less willing to fix bugs in old software
  - Development boards are difficult to locate and buy

Two perspectives

- **Fly newer hardware** – added risk due to unproven technology, but lower size/weight/power and enhanced functionality with slower obsolescence.
- **Stay the course** – use proven, low-cost, low-risk technology and find ways to accommodate future development without limiting mission duration.

**Fly both new and proven hardware to mix functionality with reliability**
SDRs provide more command flexibility than traditional radios.

- How to effectively control and command SDRs?
- Commands – single operation, multiple operation, or scripts

Flexibility requires an operations team with some radio knowledge

- Pre-defined command lists will grow over time, but fewer typos
- Effects of a “wrong command” can be larger with SDRs

Minimize the amount of “Human-in-the-Loop” to reduce mistakes.
Cost of flexibility is increased knowledge or training.
Flexible Telemetry

- Telemetry can change with each waveform update
  - Pre-defined fields are rigid – use name/value pairs or generic strings.
  - Options to vary telemetry size, rate, contents, etc. on demand.

### GD SDR 1553 data
- Fixed size, rate, message
- “Bit positions” and “Words”

### Harris SDR name-value pairs
- Fixed rate, variable size/message
- Defined by XML.

### JPL SDR 1553 “serial” data
- Variable size, rate, message
- Text-over-1553 telemetry

Complexity (and usefulness) increases as telemetry becomes free-form
Great Engineering Models

♦ High fidelity SDR engineering models (EMs) -> future waveforms
  • Cost tradeoff: space-rated components vs commercial components
  • Fidelity tradeoff: amplifiers/up-converters vs low-power baseband
  • Performance tradeoff: antennas vs terminated test ports

♦ Case study – New Ka-band waveform
  • Successful verification of command sequences on the ground
  • Waveform worked half of the time on-orbit; otherwise, it crashed
  • Traced issue to radio signal timing at temperatures below 14C

Invest in quality engineering models, but know differences/limitations
Help Third Party Developers

- Waveform software should not depend on a specific platform
  - STRS platforms come with an abstraction layer
  - Why should a platform provider support a developer?
  - Show that radio documentation is sufficient for 3rd party software

- Platform developers are still involved as a service provider
  - Proprietary documentation/code requires non-disclosure agreement
  - Offer service/support agreements for 3rd party development

- Is it possible for third party developers to write effective waveform code? Can they ever match/exceed what the platform manufacturer could have delivered?

Require delivery of open sample code that exercises all platform interfaces
OPPORTUNITIES
STRS & SCaN Testbed Solicitations

♦ SDR Technology Request for Information
  - Investigate the state-of-the-art of near-term and long-term, space-applicable SDR technology and concepts
  - Understand the barriers to establishing a developer community to create or reuse applications for NASA communication systems
  - Recommended updates to the STRS architecture: NASA-STD-4009.
  - [http://www.fbo.gov/](http://www.fbo.gov/) (NNC14ZRH014L, or search “STRS”)

♦ SCaN Testbed Experiment Opportunities
  - Focus on cognitive concepts for system efficiency (data throughput, power, and spectrum)
  - Funded call for university experiments
  - Unfunded call for Space Act Agreements
    - [http://www.fbo.gov](http://www.fbo.gov) (Search “SCaNTestbed2014” posted in the last 365 days)