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

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Overview

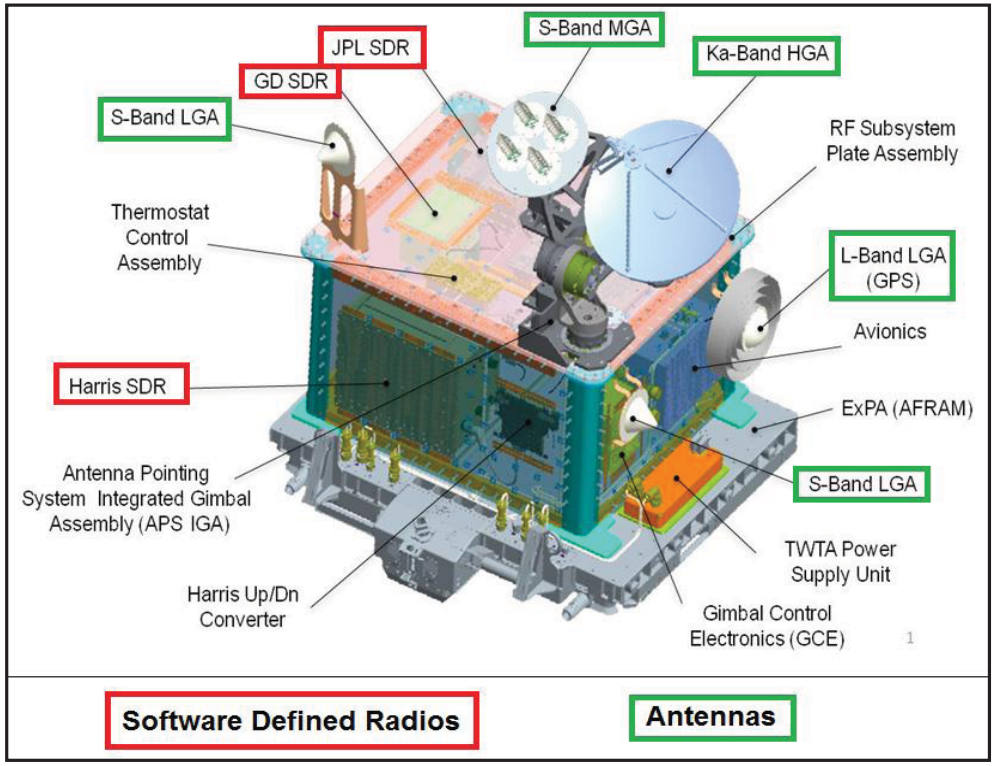
- **SCaN Testbed and Software Defined Radio**
  - SCaN Testbed SDRs
  - SCaN Testbed Communications Paths

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

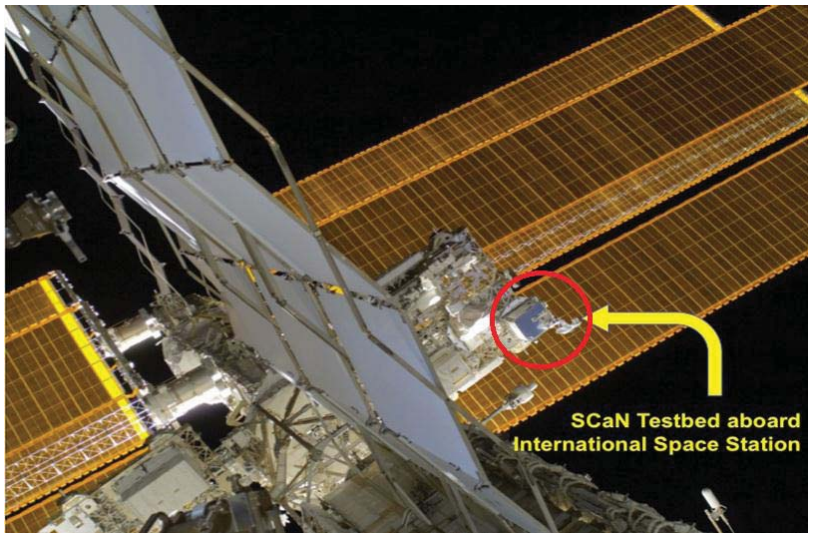
- **STRS & SCaN Testbed Solicitations**

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



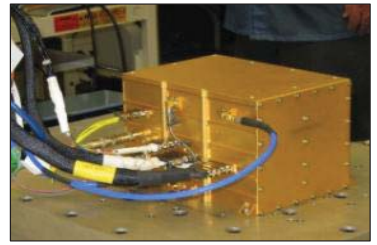
Left: SDRs and subsystems



Above: SCaN Testbed

SCaN Testbed SDRs

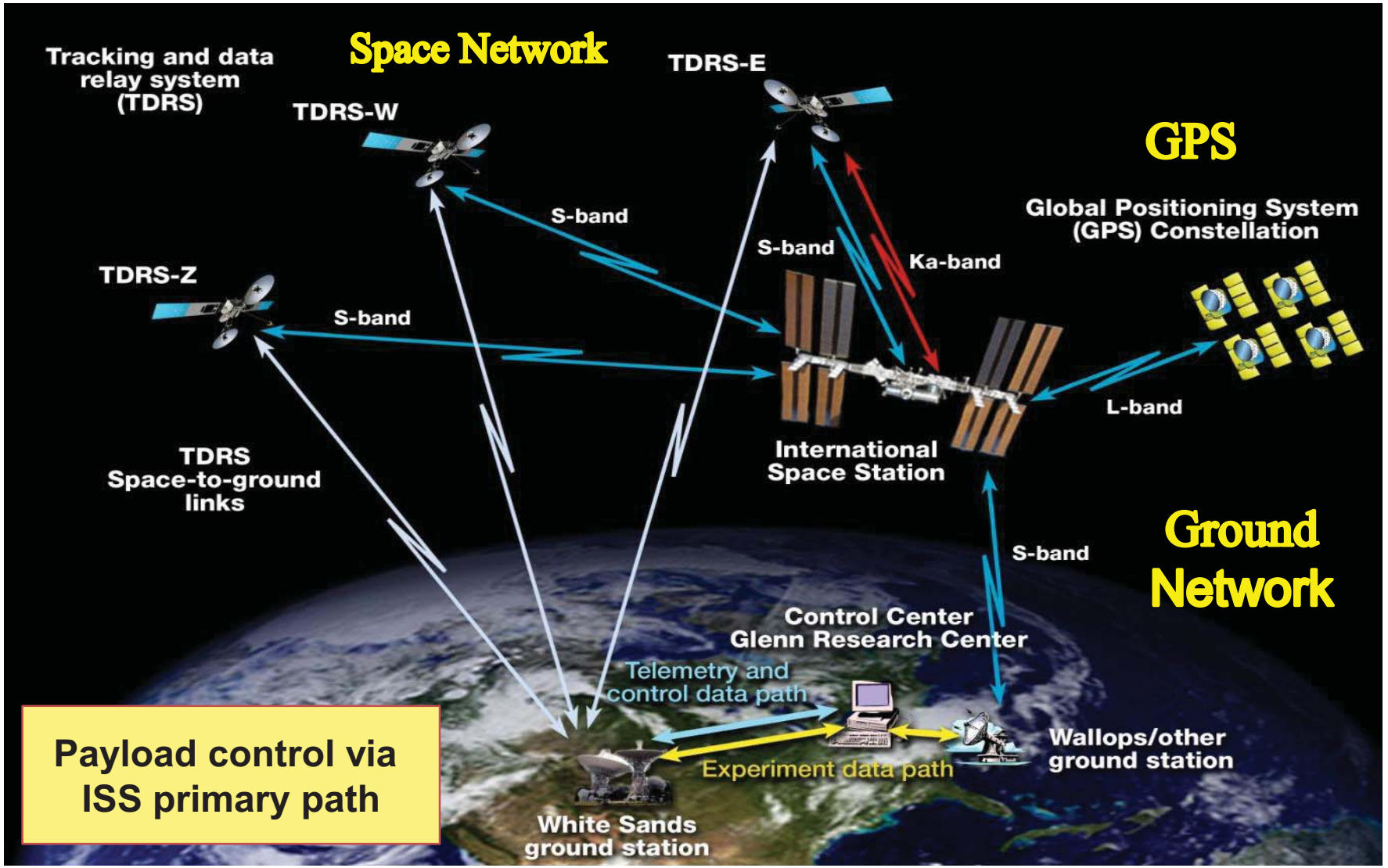
- **General Dynamics (GD) SDR**
  - 60 MIPS Coldfire (VxWorks) and (1) QPRO FPGA
  - S-Band transceiver (2.0 – 2.3 GHz) with 8W amp
  - 1M chalcogenide non-volatile phase-change memory



- **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)

SCaN Testbed Communications Paths

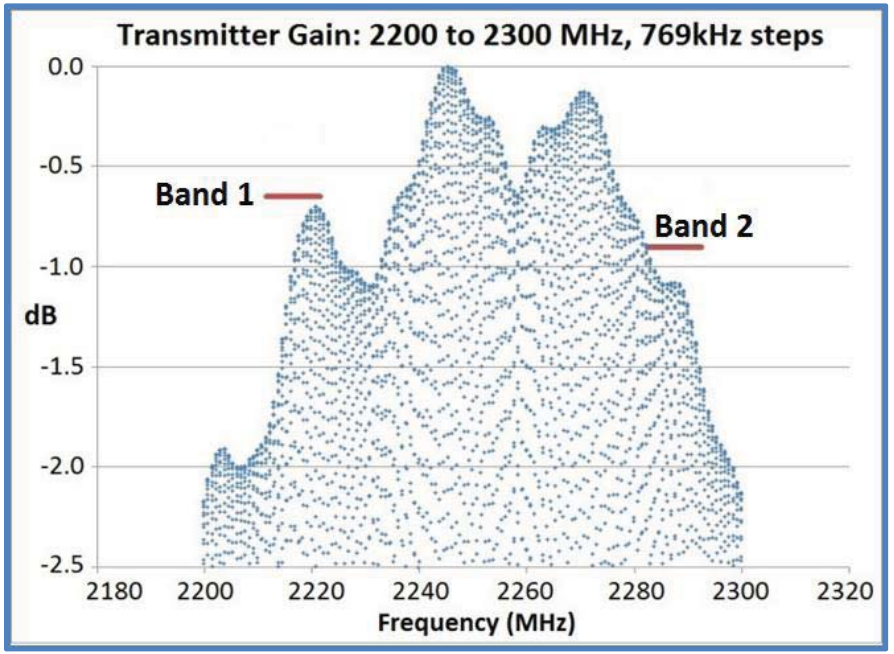


LESSONS LEARNED

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

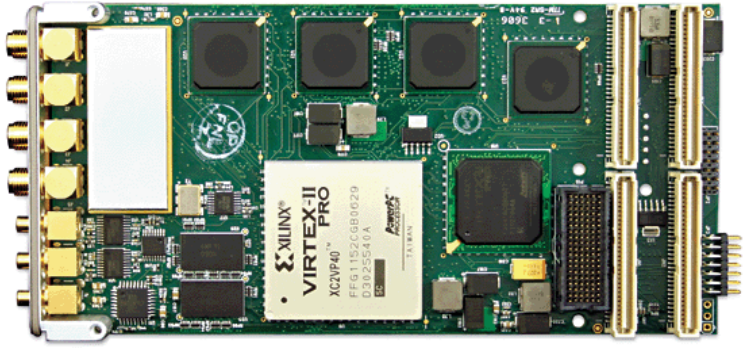


Require delivery of test waveforms to aid platform characterization

Mitigate Old Hardware

- **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

Flexible Commands

- **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.

Bit Position															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PRG EE ERR	PRG EE	RAM CS STS	RAM PWR STS	EE PWR STS	PRM PWR STS	NV CS STS	MEM DMP	FILE UPLD	FILE DNLD	FPGA STS	SP	SP	SP	SP	SP
MSB															LSB

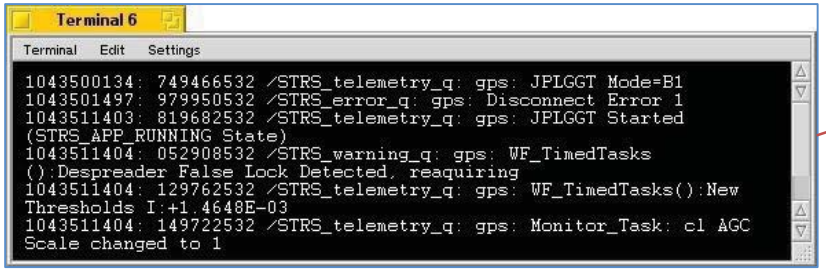
GD SDR 1553 data

- Fixed size, rate, message
- "Bit positions" and "Words"

```
<?xml version="1.0" ?>
<HarrisWaveFormPropertySettings>
  <Property name="STRS_APP_STATE" value="" />
  <Property name="APQM_DB" value="" />
  <Property name="RX_CENTER_FREQ" value="" />
  <Property name="RX_ATTEN_VAL" value="" />
  <Property name="USE_XML_DEFAULTS" value="" />
  <Property name="WF_GPP_INFO" value="" />
</HarrisWaveFormPropertySettings>
```

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/ (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
    - http://nspires.nasaprs.com/ (NNC12ZRH002C, or search "SCaN Testbed")
  - Unfunded call for Space Act Agreements
    - http://www.fbo.gov (Search "SCaNTestbed2014" posted in the last **365** days)