RECENT SUCCESSES AND FUTURE PLANS FOR NASA’S SPACE COMMUNICATIONS AND NAVIGATION TESTBED ON THE INTERNATIONAL SPACE STATION

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SCaN Notional Integrated Communication Architecture

SCaN Services Provide:
- Integrated service-based architecture
- Space internetworking (DTN and IP)
- International interoperability
- Assured safety and security of missions
- Significant increases in bandwidth
Next Generation Communication and Navigation Technology

- Optical Communications
- Antenna Arraying Technology – Receive and Transmit
- Software Defined Radio
- Advanced Antenna Technology
- Spacecraft RF Transmitter/Receiver Technology
- Advanced Networking Technology
- Spacecraft Antenna Technology
- Spectrum Efficient Technology
- Ka-band Atmospheric Calibration
- Position, Navigation, and Time
- Space-Based Range Technology
- Uplink Arraying

SCaN Testbed Technologies
SCAN Testbed Mission Objectives

- **Mature Software Defined Radio (SDR) technologies and infrastructure for future SCaN architecture and NASA Missions**
  - Ready for space use/verification/reconfiguration/operations/new software aspects
  - Advance the understanding of SDR Standard, waveform repository, design references, tools, etc for NASA missions

- **Conduct Experiment’s Program**
  - Portfolio of experiments across different technologies; communication, navigation, and networking
  - Build/educate a group of waveform developers and assemble repository of waveforms

- **Validate Future Mission Capabilities**
  - Representative capabilities; S-band, Ka-band, GNSS
SCaN Testbed – Software Defined Radio-based Communication System

- **SDRs** - Two S-band SDRs (One with GPS), One Ka-band SDR
- **RF** - Ka-band TWTA, S-band switch network
- **Antennas** - Two low gain S-band antennas, One - L-band GPS antenna, Medium gain S-band and Ka-band antenna on antenna pointing subsystem.
- **Antenna pointing system** - Two gimbals, Control electronics
- **Flight Computer/Avionics**
SCAN Testbed System Architecture

Tracking and data relay satellite (TDRS)

TDRS-W

TDRS K/L

S-band

Ka-band

International Space Station

Global Positioning System (GPS) Constellation

S/L-band

L-band

S-band

Telemetry and control data path

Experiment data path

White Sands ground station

Control Center
Glenn Research Center

Wallops/other ground station
(Commercial/International)
Why Use Software Defined Radios?

- **SDRs provide unprecedented operational flexibility that allows communications functions in software to be updated in development or flight**
  - Functions can be changed within the same SDR across mission phases
    - E.g., launch phase, mission ops functions in mission phase, technology upgrades
  - Failure corrections can be implemented in flight
    - E.g., a Mars satellite corrected interference problem with software update in transit using an SDR

- **Software defined functionality enables standard radios to be tailored for specific missions with reusable software**
  - PCs use an operating system to abstract application software e.g. Word, Excel,
  - Standardization such as Space Telecommunications Radio System (STRS) enables different radio platforms to run common, reusable software across many missions
  - Cost reductions possible with common architecture, reusable software and risk avoidance

- **Software Defined Radios are the “instruments” of the SCaN Testbed;**
Research & Technology On-orbit Accomplishments

• STRS-compliant SDRs successfully implemented and operational in space - NASA’s new standard for SDRs

• Independent 3rd party developed waveform operating on another provider’s SDR, according to STRS Architecture

• Operated NASA’s first Ka-band mission with TDRSS. Many lessons both for project team and Space Network Ka-band system

• Routine SDR reconfigurations. Demonstrated new software verification and new capability added on-orbit

• Processed GPS & Galileo carrier signals; first civilian reception of new L5 signals in space. Conducting tests with the newest GPS satellites.

• New waveforms under development for bandwidth efficient modulation (up to 600 Mbps), DTN, and on-board networking
Experiments

• Enable and encourage national participation with industry and academia to gain a broad level of ideas and concept
  – Increase the base of STRS experts

• Align with NASA’s objectives in developments & technology:
  – Cognitive Radio Applications and Adaptive Waveforms
    • Signal sensing, environment awareness, & interference mitigation
  – Spectrum/power efficient techniques (new modulations and coding)
  – GPS/GNSS demonstrations (L1/L2, L5, GPS corrections/augmentation), jammer detectors, scintillation (e.g. solar flares)
  – Networking including disruptive tolerant networking (store/forward), adaptive routing, secure routing, formation flying

## SCaN Testbed Planned Experiments

### Communications/Cognitive
- Bandwidth Efficient 8-PSK/16APSK & LDPC
- Integrating GMSK, LDPC, and DTN
- Signal sensing and classification - University
- Adaptive data rate, modulation, coding
- Single Carrier FDMA Modulation - University

### Navigation
- GPS L1, L2, L5
- CNAV Test of L2c, L5
- GPS Scintillation-SBIR
- GPS/Galileo Receiver

### Space Internetworking & Protocols
- IP On-board Routing
- DTN on a radio (network appliance)
- Secure DTN Links - SBIR
- DTN Interoperability (CNES)
- CCSDS Protocol Standards Validation

### NASA Network Services Support
- TDRS-K/L Acceptance and Operation Testing
  - TDRS 8/9/10 Autotrack Testing
- New Receiver/Ground Station Testing
## Experiment Waveform Examples

<table>
<thead>
<tr>
<th>TDRSS Mode</th>
<th>Modulation</th>
<th>Data Rate (kbps)</th>
</tr>
</thead>
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<tr>
<td><strong>Tx - S-band</strong></td>
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<td></td>
</tr>
<tr>
<td>DG1, Mode 1</td>
<td>SQPN</td>
<td>24, 192</td>
</tr>
<tr>
<td>DG1, Mode 2</td>
<td>SQPN</td>
<td>24, 192</td>
</tr>
<tr>
<td>DG1, Mode 2</td>
<td>SS-BPSK</td>
<td>24</td>
</tr>
<tr>
<td>DG1, Mode 3</td>
<td>QPSK</td>
<td>Q: 1000 I: 1 kbps</td>
</tr>
<tr>
<td>DG2</td>
<td>SQPSK</td>
<td>1000</td>
</tr>
<tr>
<td>DG2</td>
<td>BPSK</td>
<td>192, 769</td>
</tr>
<tr>
<td><strong>S-band</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KA-band</td>
<td>OQPSK</td>
<td>1000-100K</td>
</tr>
<tr>
<td>KA-band</td>
<td>OQPSK, 8PSK, 16APSK, GMSK</td>
<td>100-600 Mbps</td>
</tr>
<tr>
<td><strong>S-band</strong></td>
<td></td>
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</tr>
<tr>
<td>S-band</td>
<td>QPSK. (PN spread)</td>
<td>18, 72</td>
</tr>
<tr>
<td><strong>Ka-band</strong></td>
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<td></td>
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<tr>
<td>S-band</td>
<td>BPSK (PN spread)</td>
<td>18</td>
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<tr>
<td>S-band</td>
<td>BPSK (non-PN spread)</td>
<td>155, 769</td>
</tr>
<tr>
<td>Ka-band</td>
<td>BPSK</td>
<td>1000-25K</td>
</tr>
</tbody>
</table>
Summary

- As a technology demonstration mission, SCAN Testbed is primarily a benefit to future missions
  - Greater science data return from future missions
  - Enable new science capability and/or extend mission life through adaptive platforms

- Reduces technology and development risks for new SDR-based systems
  - Reduce SDR vendor dependence for waveform development
  - Demonstrate new capability and concepts in space

- The STRS Architecture is a NASA-wide SDR Standard (NASA-STD-4009)

- Strong relevance to future Agency communication and navigation needs
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Or visit SCaN Testbed on-line:
http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed
STRS and SCaN Testbed References

- **Space Telecommunication Radio System NASA Standards and technical Assistance Resource Tool**
  - STRS Standard (NASA-STD-4009)
    - [https://standards.nasa.gov/documents/detail/3315911](https://standards.nasa.gov/documents/detail/3315911)
  - STRS Handbook (NASA-HDBK-4009)
    - [https://standards.nasa.gov/documents/detail/3315910](https://standards.nasa.gov/documents/detail/3315910)

- **SCaN Testbed Overview, Experimenter Documents**
  - [http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed/Candidate/](http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed/Candidate/)
Software makes it go…
Waveform Application and Hardware Interfaces

Reprogrammable Software is the key!

Desktop Computer

- Applications in Software (Word, Excel, Financial, Games)
- Hardware Abstraction Layer (e.g. Windows Operating System)
- Processor
- Memory
- Keyboard
- Hard Drive
- Video /Monitor

Software Defined Radio

- Applications in Software (comm, networking, navigation)
- STRS (Space Telecommunications Radio System)
- Processor
- Memory
- Science Instrument
- Digital Signal Processing HW (e.g. FPGA, DSP)
- Antenna
- Input (Data)
- Output (Signal)

New

Validate