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

2015 Add:
- Standard Services and Interfaces
- Delay Tolerant Networking
- Deep Space Antenna Array
- Lunar Optical Pathfinder (LADEE)
- TDRS K, L
- Increased microwave link data rates

2018 Add:
- Integrated Network Management (INM)
- Integrated Service Execution (ISE)
- Space Internetworking
- Optical Ground Terminal
- Near Earth Optical Initial Capability
- TDRS M, N
- Lunar Relay Payload (potential)

2023 Add:
- Enhanced Optical Initial Capability
- Deep Space Optical Relay Pathfinder
- Lunar Relay Satellite Initial Capability

2025 Add:
- Deep Space Optical Initial Capability
- Space Internetworking throughout Solar System
- Significant Increases in Bandwidth
- Retirement of Aging RF Systems
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-Z

TDRS K/L

TDRS-E

S-band

Ka-band

Global Positioning System (GPS) Constellation

International Space Station

Telemetry and control data path

Telemetry and control data path

White Sands ground station

Control Center
Glenn Research Center

Wallops/other ground station
(Commercial/International)

Experiment data path

S-band

L-band

S/L-band

Ka-band
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

Enabling Infrastructure and Mission Capability

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>
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<tr>
<td><strong>Tx - S-band</strong></td>
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<td></td>
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<tr>
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<td>SQPN</td>
<td>24, 192</td>
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<tr>
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<td>SQPN</td>
<td>24, 192</td>
</tr>
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<td>DG1, Mode 2</td>
<td>SS-BPSK</td>
<td>24</td>
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<tr>
<td>DG1, Mode 3</td>
<td>QPSK</td>
<td>Q: 1000</td>
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<tr>
<td></td>
<td></td>
<td>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>Tx</strong></td>
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<td>Ka-band</td>
<td>OQPSK</td>
<td>1000-100K</td>
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<tr>
<td>Ka-band</td>
<td>OQPSK, 8PSK, 16APSK, GMSK</td>
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<td><strong>Rx</strong></td>
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<td>S-band</td>
<td>QPSK. (PN spread)</td>
<td>18, 72</td>
</tr>
<tr>
<td>S-band</td>
<td>BPSK (PN spread)</td>
<td>18</td>
</tr>
<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
For more information

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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
  - STRS Handbook (NASA-HDBK-4009)
    - https://standards.nasa.gov/documents/detail/3315910

- **SCaN Testbed Overview, Experimenter Documents**
  - 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)

Input

Processor
Memory
Keyboard
Video /Monitor

Output

Hard Drive

Software Defined Radio

Applications in Software
(comm, networking, navigation)

STRS
(Space Telecommunications Radio System)

Input
(Data)

Digital Signal Processing HW
(e.g. FPGA, DSP)

digital ↔ RF conversion

Output
(Signal)

Processor
Memory
Science Instrument
Antenna