Space Communication and Navigation Testbed
Communications Technology for Exploration

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NASA Glenn Research Center
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Sponsored by Space Communication and Navigation Program
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
- **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**
Pictures of Installation and First Operations

Launched: July 20, 2012
SCaN Testbed aboard International Space Station
SCAN Testbed System Architecture

- Tracking and data relay system (TDRS)
- TDRS-W
- TDRS K/L
- TDRS-E
- Global Positioning System (GPS) Constellation
- S/L-band
- Ka-band
- S-band
- L-band
- TDRS Space-to-ground links
- White Sands ground station
- Control Center Glenn Research Center
- Wallops/other ground station

Telemetry and control data path
Experiment data path

(Commercial/International)
Scan Testbed Mission Objectives

• **Maturing Software Defined Radio (SDR) technologies and infrastructure for future SCaN architecture and NASA Missions**
  – Development to TRL-7/verification/reconfiguration/operations/new sw aspects
  – Advance the understanding of STRS Standard, 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 of future missions; S, Ka, GPS
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., range Safety functions in launch phase, mission ops functions in mission phase
  - Technology upgrades can be made in flight
    - E.g., modulation methods, new coding schemes
  - Failure corrections can be effected 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**
  - Like different PCs running Word and Excel use an operating system, standardization 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;**
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

Software Defined Radio

Applications in Software (comm, networking, navigation)

STRS (Space Telecommunications Radio System)

Input

Processor
Memory
Science Instrument
Antenna

Output

digital ↔ RF conversion
Impact of SCaN Testbed Technology

- Reconfigurable components are a part of our infrastructure and our missions. Understanding their function both individually and within the system is critical.

- Open platform model to reduce developer dependence – platforms last for 10-15 years… opens software/firmware developers to NASA, universities and small business on space provider hardware.

- Standardization enables 3rd party software development on open platforms and formation of a software applications repository
  - Incentive to conform to standard architecture to reuse flight proven software/firmware and common understanding of radio architecture

- Challenging the culture associated with radio technology
  - Routine verification of new sw on ground hardware not the flight hardware
    - How much verification needed before new SDR software upload
    - Pioneering techniques for rapid turnaround of software for flight applications. We are unique to change functions often and intentionally…
  - Consider the platform along with the application
    - Requirements, test waveforms for sys verification, configuration options
Early 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

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

• Received GPS carrier signals; first civilian reception of L5 signals in space.

• Progress on waveform repository technical aspects and licensing issues – a key element of the SCaN Testbed
Experiment Program Goals

• Enable and encourage national participation with industry and academia to gain a broad level of ideas and concept

• Maximize use and usefulness of SCaN Testbed to meet NASA’s needs and interests
  – Guided by SCaN Integrated Architecture and Comm/Nav Roadmap
  – Innovative developments to advance new technologies and applications
  – Increase confidence in SDR technology and accelerate infusion

• Balance among different kinds of activities
  – TRL raising/flight validation (bandwidth efficient, cognitive, LDPC, DTN, GPS L5)
  – Mission concept demo (e.g. next gen relay, lander comm),
  – Supporting other NASA activities (e.g. TDRS-K, digital signal distribution)
  – Science experiments

DTN – Disruptive Tolerant Networking
GPS – Global Positioning System
LDPC – Low Density Parity Code
TRL – Technology Readiness Level
Advancing SDRs in space aboard ISS

• Experiment Program is ideal for high TRL demonstrations by industry, academia, NASA and OGA

• Broad, national participation will create a forum to exchange ideas and results, advance technology solutions, create new experiments, and new partnerships

• Increase the base of STRS experts—Agency personnel, sw and hw providers, researchers, and the user and operations communities—all knowledgeable of the common standard

• Publish understanding of system performance and SDR operations in a mission context → TRL-7/8 advancement

• Reduce the (perceived?) risk of infusing SDRs and their applications (comm, nav, networking) into NASA missions
What Experiment Can I Do?

- **Research or New Product Developments & Technology:**
  - Spectrum Efficient Techniques (new modulations and coding)
  - Adaptive Waveforms and Cognitive Radio Applications
  - GPS enhancement demonstrations (L1/L2, L5, comm signal augmentation)
  - Networking including DTN (store/forward), adaptive routing, new routing protocols, sensor web applications, formation flying, relative comm/nav

- **Architecture**
  - Unique system access in space with compatible ground station and Space Network

- **Conops**
  - Use on-orbit processing capacity in new and different ways
## Ways to Start the Experiment Process

<table>
<thead>
<tr>
<th>Intended Org</th>
<th>Call</th>
<th>Proposal</th>
<th>Evaluation</th>
<th>Agreement</th>
<th>Available Funding</th>
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<td>University</td>
<td>Cooperative Agreement Notice (CAN)</td>
<td>Submitted via NSPIRES to Principal Investigator</td>
<td>Three review periods (proposal due dates): Sept, Jan, May</td>
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<td>Commercial</td>
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<td>Ongoing—synch-up with CAN Review cycle or call Experiment Board as-needed</td>
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<td>EO, SCaN Program</td>
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<td>MOU</td>
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<td>Commercial (small)</td>
<td>SBIR</td>
<td>Submitted to NASA SBIR annual call</td>
<td>NASA review, per SBIR process</td>
<td>Contract</td>
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Sample of Proposed Experiments

- **Communications/Cognitive**
  - Bandwidth Efficient Modulations and Coding 8-PSK/16APSK/GMSK & LDPC
  - Signal sensing and classification
  - Adaptive data rate, modulation, and coding
  - Power Efficient Modulation (Adaptive Continuous Phase)

- **Space Internetworking & Protocols**
  - IP On-board Routing
  - Disruptive Tolerant Networking (DTN) enabled platform (network appliance)
  - Secure DTN Links
  - CCSDS Protocol Standards Validation

- **Navigation**
  - GPS L1, L2, L5
  - Civil Navigation Test of L2c, L5
  - GPS Scintillation
  - GPS Jammer Detector
  - Improved Navigation through Nav and Comm data fusion

- **NASA/Space Network System Tests**
  - TDRSS Ka-band user validation tests
  - TDRS-K Acceptance and Operations
  - Next Gen Digital Signal Distribution
  - TDRS-L Acceptance and Operations
  - Next Generation ground infrastructure

CCSDS – The Consultative Committee for Space Data Standards
GPS – Global Positioning System
GMSK – Gaussian Minimum Shift Keying
LDPC – Low Density Parity Code
PSK – Phase Shift Keying
TDRS – Tracking and Data Relay Satellite
SCaN Testbed Experiment Benefits Validate Next Generation Capabilities

- Ka/S band System emulation for Space Based Relay
- SDRs for future TDRS Transponders
- Ka/S System for TDRSS K/L function, performance validation
- GPS L1, L2c, L5 orbit (PVT) and validation
- Improved GPS solutions with comm link data fusion
- Space based networking, including DTN
- Potential SDRs for lunar landers, rovers, EVA
- Bandwidth efficient waveforms reduce spectrum use
- Cognitive applications enable next generation comm
- Validation and on-orbit user for WSC testing
- SDR/STRS technology advancement to TRL-7
- 1st NASA Ka TDRSS User
Experimenter Access Points within SCaN Testbed System

- Experiment Interface
  - Experiment Equipment
- Ground System
  - SCaN Testbed Control Center
- External Systems
  - NASA Ground Network
  - WSC Legacy Service
  - WSC RTN-IF
  - S-band Gnd Station
  - S-band Flight Node
- ISS
  - SCaN Testbed Flight System
    - RF
    - SDR
    - SDR
    - SDR
  - Avionics

⭐ = Experiment Element (e.g. sw, fw, or hw component)

Experimenters have access to Flt SDRs, avionics, Gnd SDR, various ground points

WSC – White Sands Complex
Architecture Concept Example

TDRS

GEO

LEO

Cubesat
SCAN Testbed Benefits

• 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

• Enables greater capability and reduces technology and development risks for new SDR-based systems
  – Reduce SDR vendor dependence for waveform development

• The STRS SDR Standard has been referenced in SDR standards bodies for applicability to terrestrial resource constrained radio systems

• Strong relevance to future Agency communication and navigation needs
## NSPIRES Website

### Solicitations

**Open Solicitations**

<table>
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<tr>
<th>Solicitation Title</th>
<th>Solicitation #</th>
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<td><strong>Use of the Space Communications and Navigation (SCaN) Testbed:</strong> A Communications, Navigation and Networking Reconfigurable Testbed</td>
<td>NNN12ZEH002C</td>
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Summary

• SCaN Testbed launched, on-orbit and performing great!

• SCaN Testbed available to commercial, university, and other partners for experiments!

• Experiment proposals welcome!
For more information

Visit SCaN Testbed on-line:
http://spaceflightsystems.grc.nasa.gov/SPSO/SCO/
SCaNTesbed

or

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richard.c.reinhart@nasa.gov
Acknowledgements

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• Sandra Johnson¹, Thomas Kacpura¹, James Lux², Greg Heckler³, Oron Schmidt⁴, Jacqueline Myrann⁴

SCaN Testbed Glenn Research Center R&T Team
• Jennifer Nappier, Joe Downey, David Chelmins, Dan Bishop, Dale Mortensen, Mary Joe Shalkhauser, Steve Hall, Neil Adams, David Kifer, Jeff Glass, Janette Briones, David Brooks, Wes Eddy, Bryan Welch

1. NASA Glenn Research Center
2. Jet Propulsion Laboratory
3. NASA Goddard Space Flight Center
4. NASA Johnson Space Center
SCaN Testbed Point of Contacts

• **Project Website**
  – http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed

• **Technical Contacts**
  – Principal Investigator
    • Mr. Richard Reinhart
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  – Deputy Principal Investigator
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• **Programmatic Contact**
  – Project Manager
    • Mr. Dave Irimies
    • david.p.irimies@nasa.gov
    • 216-433-5979
STRS and SCaN Testbed References

• **Space Telecommunication Radio System Rel 1.02.1**
  – NASA/TM—2010-216809/REV1
  – http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110002806_2011001718.pdf

• **SCaN Testbed Overview, Documents, Links**
  – http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed/Candidate/
Call For Experiment Information

• University

• Commercial/Non-profit
  – FedBiz Ops: https://www.fbo.gov/

• Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR)
  – http://sbir.gsfc.nasa.gov/SBIR/SBIR.html