Space Communication and Navigation Testbed Communications Technology for Exploration

Richard Reinhart
NASA Glenn Research Center
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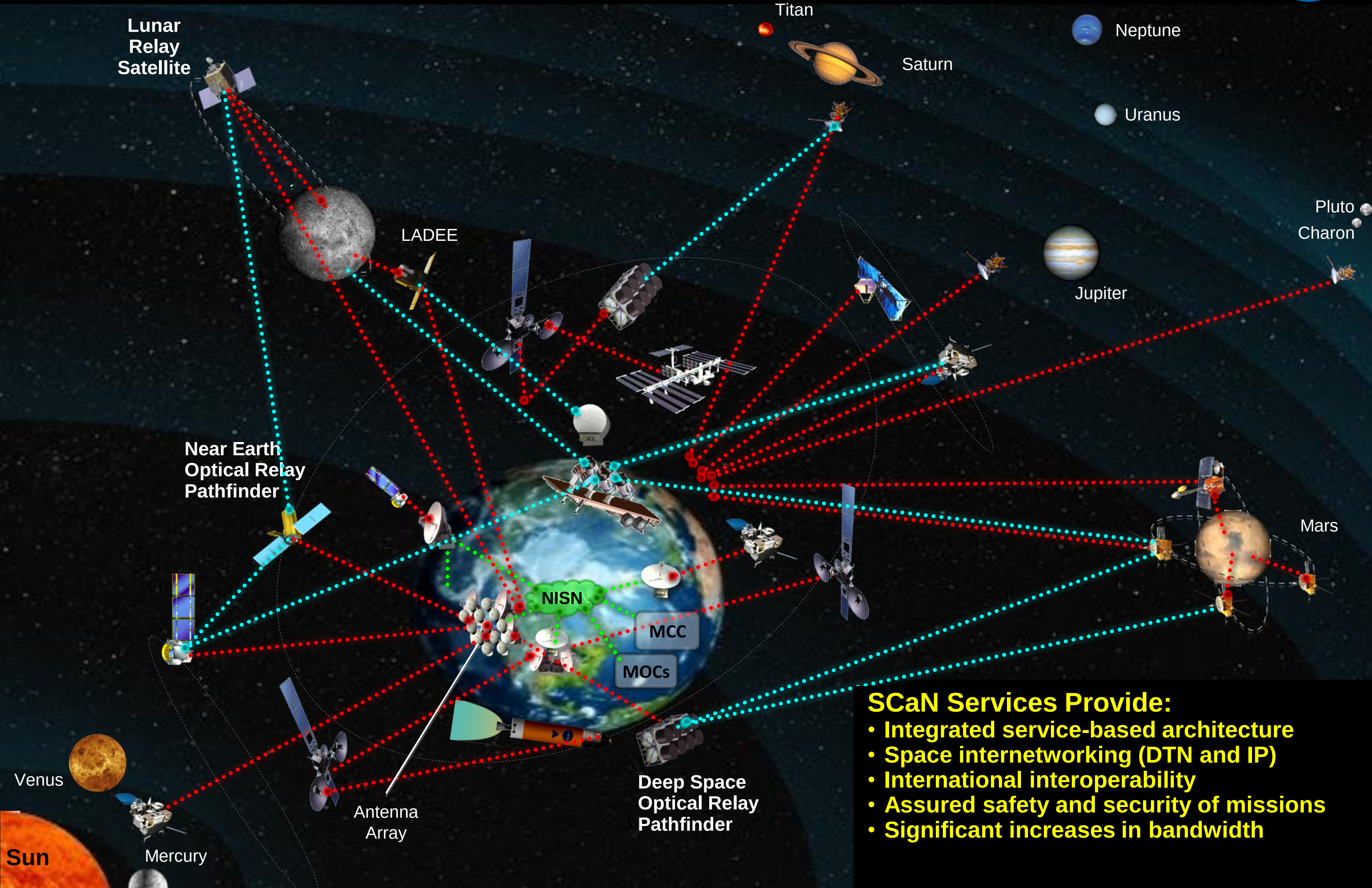
Sponsored by Space Communication and Navigation Program

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

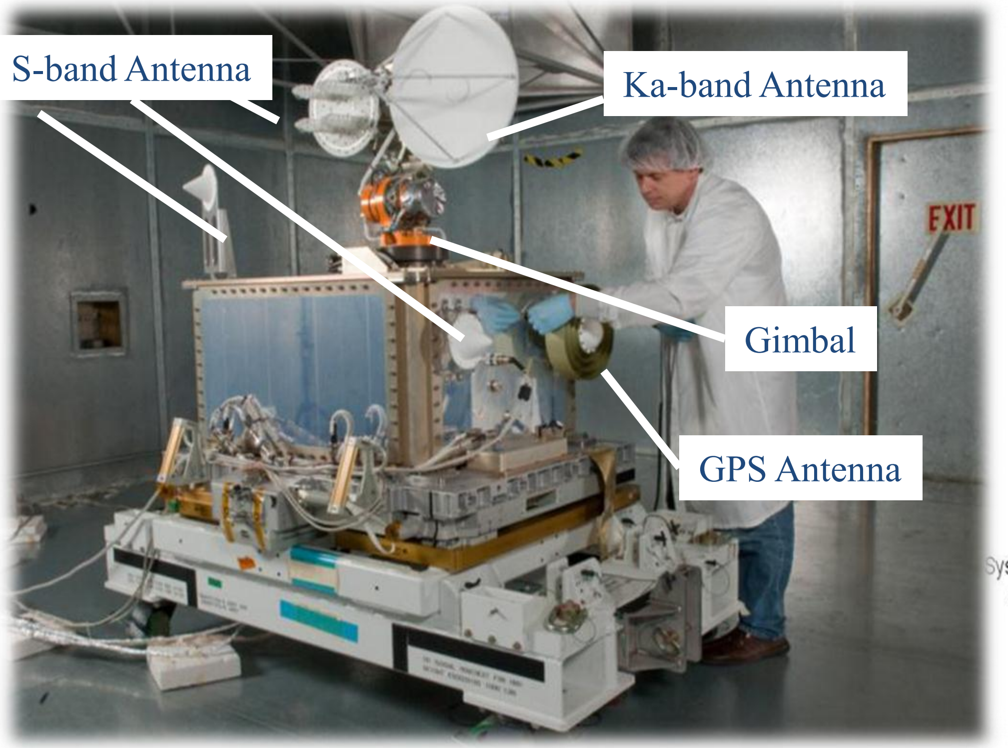
Microwave Links | Optical Links | NISN

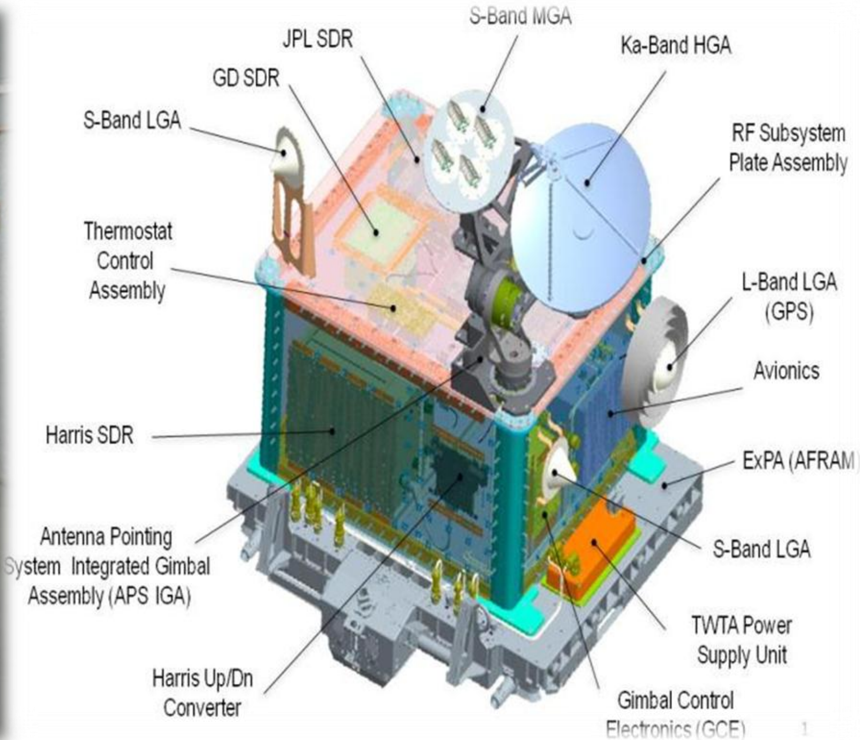
Next Generation Communication and Navigation Technology

- 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

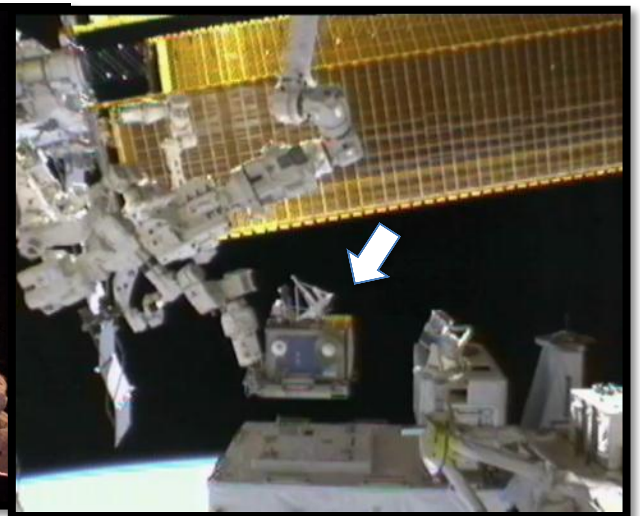
SDR Testbed - Communication System



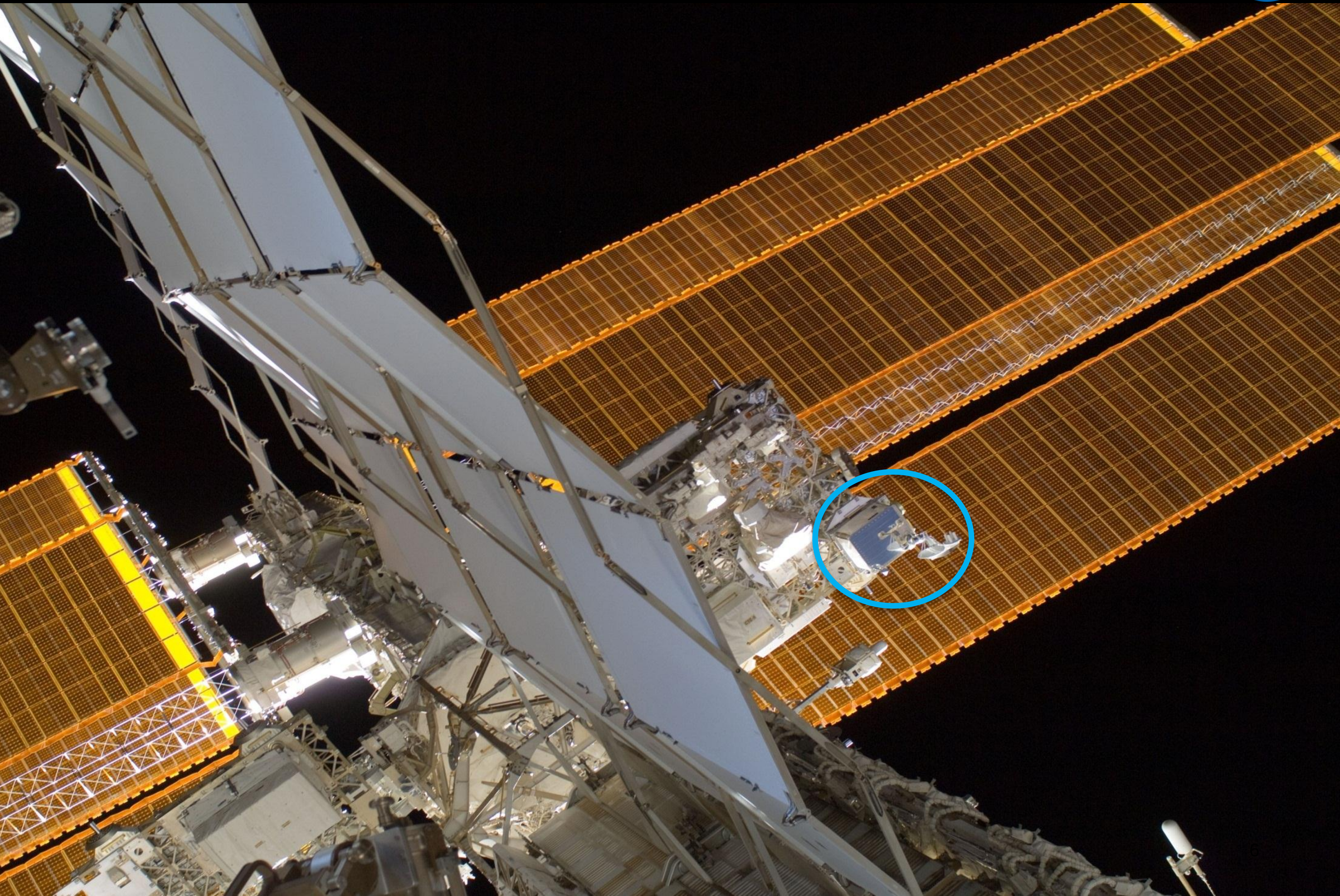


- **SDRs - Two S-band SDRs (One with GPS), One Ka-band SDR**
- **RF - Ka-band TWTA, S-band switch network**
- **Antennas - Two low gain S-band antennas, One - L-band GPS antenna, Medium gain S-band and Ka-band antenna on antenna pointing subsystem.**
- **Antenna pointing system - Two gimbals, Control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

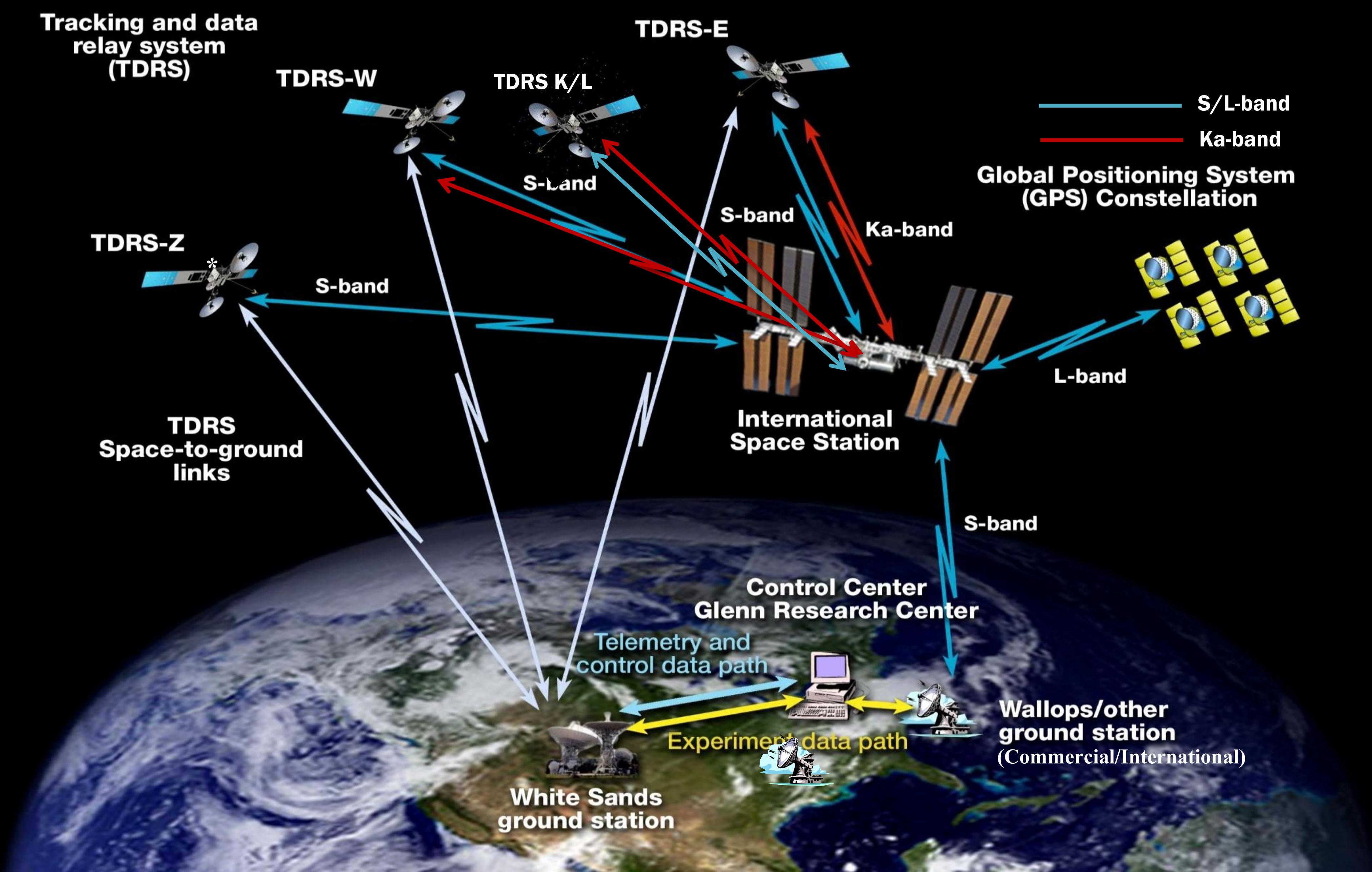
Pictures of Installation and First Operations



SCaN Testbed aboard International Space Station



SCAN Testbed System Architecture

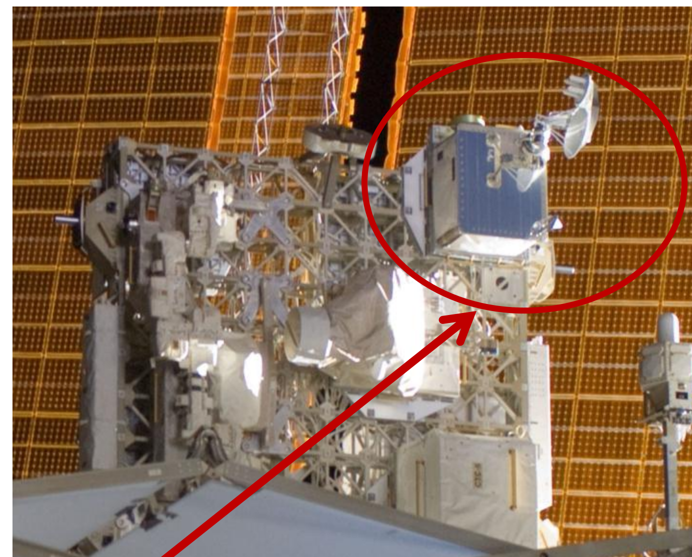


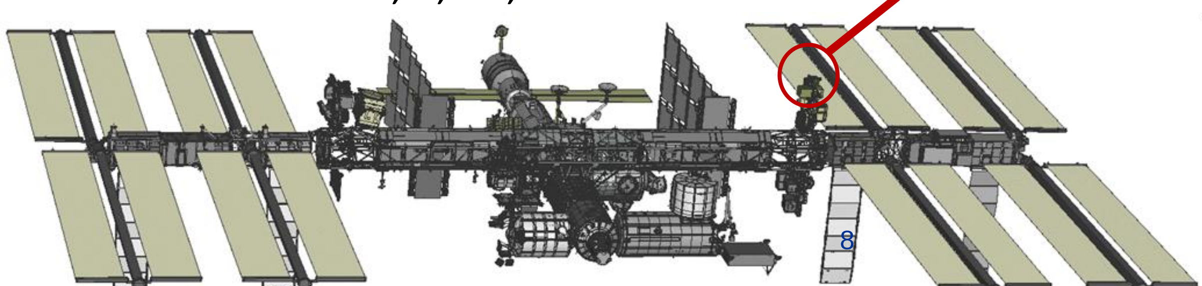
SCAN Testbed Mission Objectives

- **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?

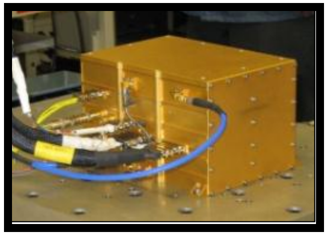
- **SDRs provide <u>unprecedented operational flexibility</u> that allows communications functions in software to be updated in development or flight**
  - Functions can be changed within the same SDR across mission phases
    - E.g., range Safety functions in launch phase, mission ops functions in mission 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 <u>tailored for specific missions with reusable software</u>**
  - 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;**

Jet Propulsion Lab

Harris Corp.



General Dynamics Corp.

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
Hard Drive
Keyboard
Video /Monitor

Input Output

Software Defined Radio

Applications in Software
(comm, networking, navigation) ← New

STRS
(Space Telecommunications Radio System) ← New

Processor
Digital Signal Processing HW (e.g. FPGA, DSP) ← Validate
Memory
digital ⇔ RF conversion
Science Instrument
Antenna

Input Output

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**

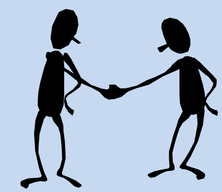
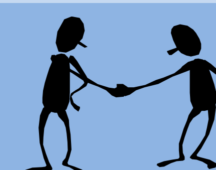
What Experiment Can I Do?

- **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

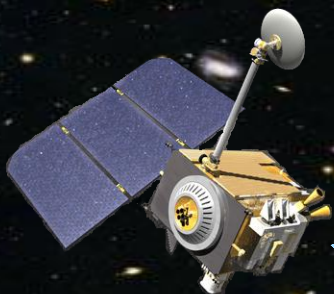
Intended Org	Call	Proposal	Evaluation	Agreement	Available Funding
University	Cooperative Agreement Notice (CAN)	Submitted via NSPIRES to Principal Investigator	Three review periods (proposal due dates): Sept, Jan, May	Cooperative Agreement	
Commercial	Experiment Opportunity (EO)	Submitted to Project Principal Investigator	Ongoing–synch-up with CAN Review cycle or call Experiment Board as-needed	Space Act Agreement	
NASA/ OGA	EO, SCaN Program,	Submit to Principal Investigator		MOU	
Commercial (small)	SBIR	Submitted to NASA SBIR annual call	NASA review, per SBIR process	Contract	

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

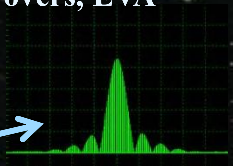
• GPS L1, L2c, L5 orbit (PVT) and validation
• Improved GPS solutions with comm link data fusion

• Space based networking, including DTN

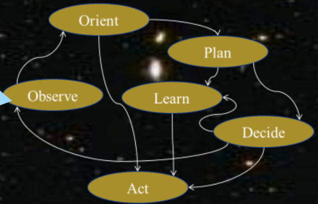
• Potential SDRs for lunar landers, rovers, EVA

• SDRs for future TDRS Transponders

• Ka/S System for TDRSS K,/ L function, performance validation



•Bandwidth efficient waveforms reduce spectrum use

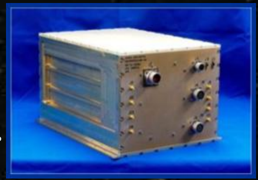


•Cognitive applications enable next generation comm

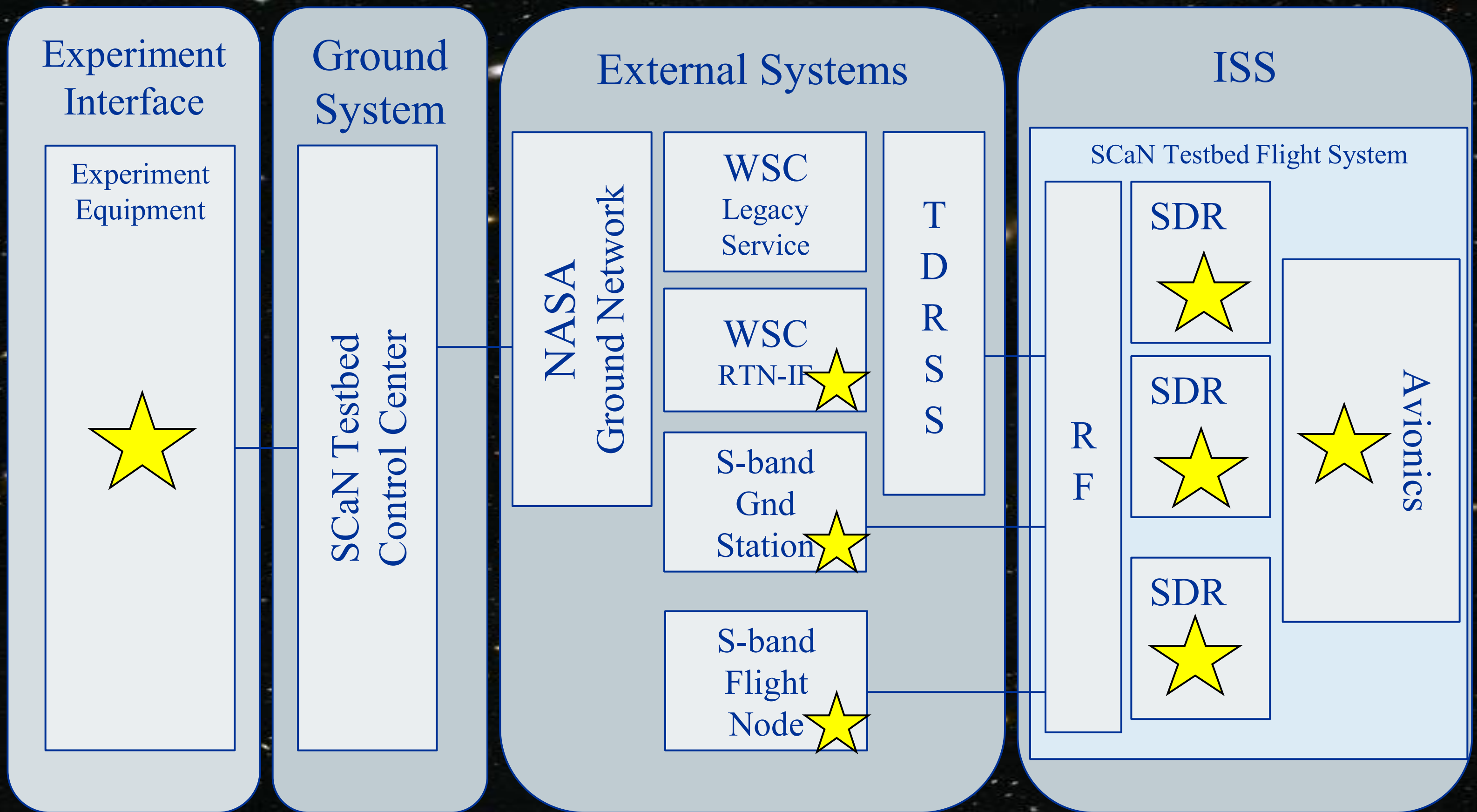
•Validation and on-orbit user for WSC testing

Connect Payload with Ka, S, L band, and JPL Electra, GD Starlite, and Harris SDRs

• SDR/STRS technology advancement to TRL-7
•1st NASA Ka TDRSS User



Experimenter Access Points within SCaN Testbed System

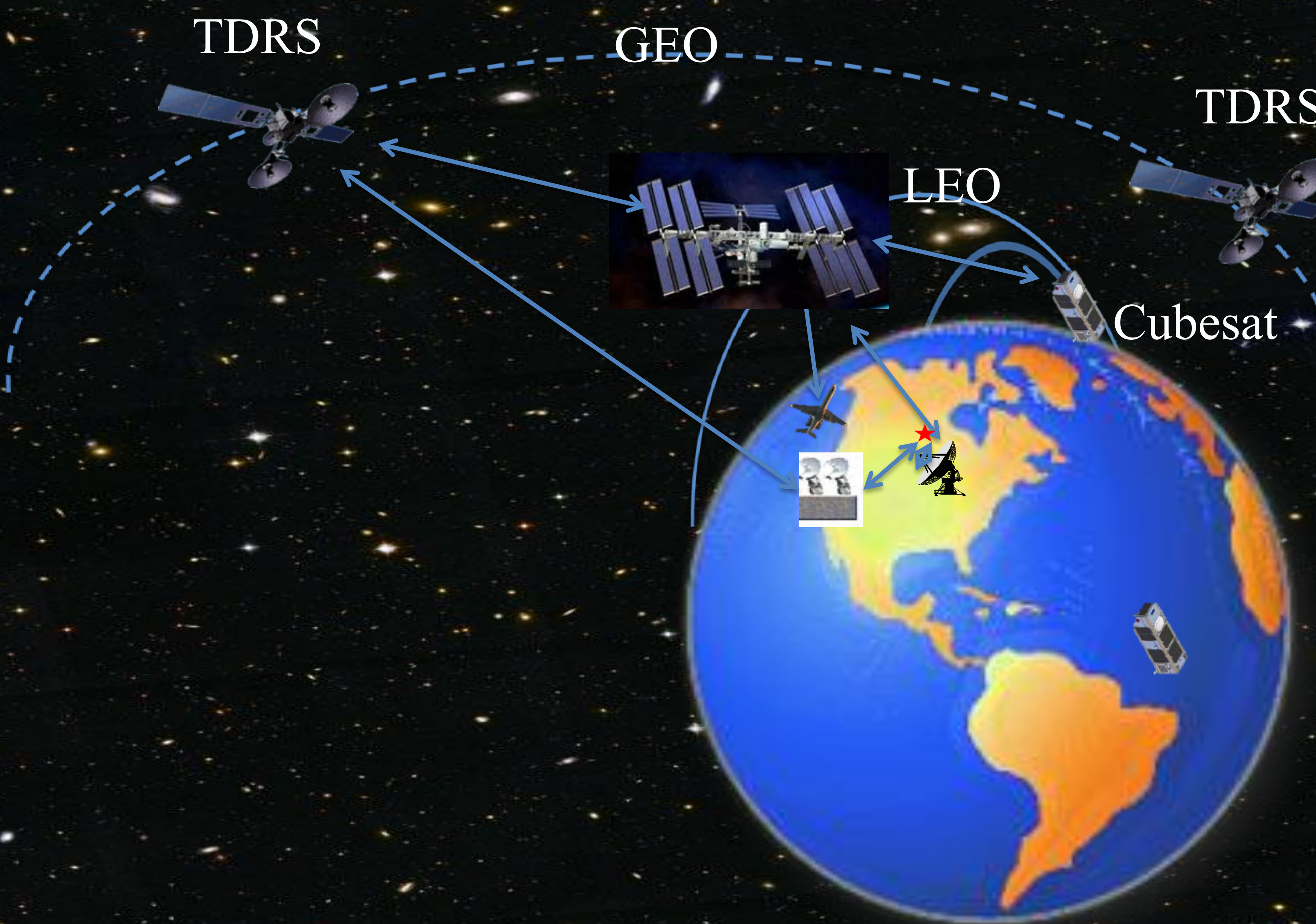


★ = Experiment Element (e.g. sw, fw, or hw component)

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

WSC – White Sands Complex

Architecture Concept Example



SCAN Testbed Benefits

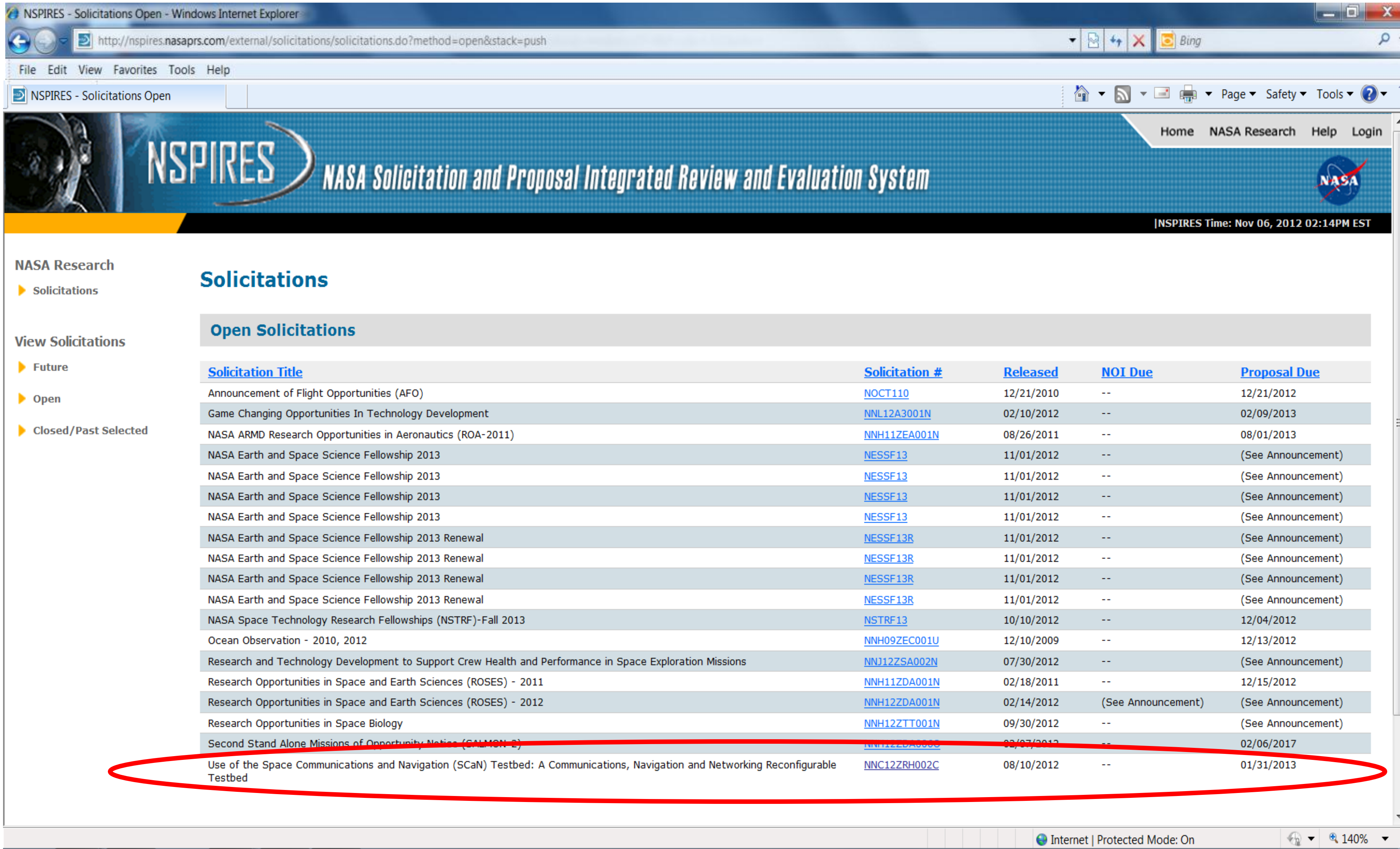
- **As a technology demonstration mission, SCAN Testbed is primarily a benefit to future missions**
  - Greater science data return from future missions
  - Enable new science capability and/or extend mission life through adaptive platforms

- **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



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NSPIRES Time: Nov 06, 2012 02:14PM EST

NASA Research
- Solicitations

View Solicitations
- Future
- Open
- Closed/Past Selected

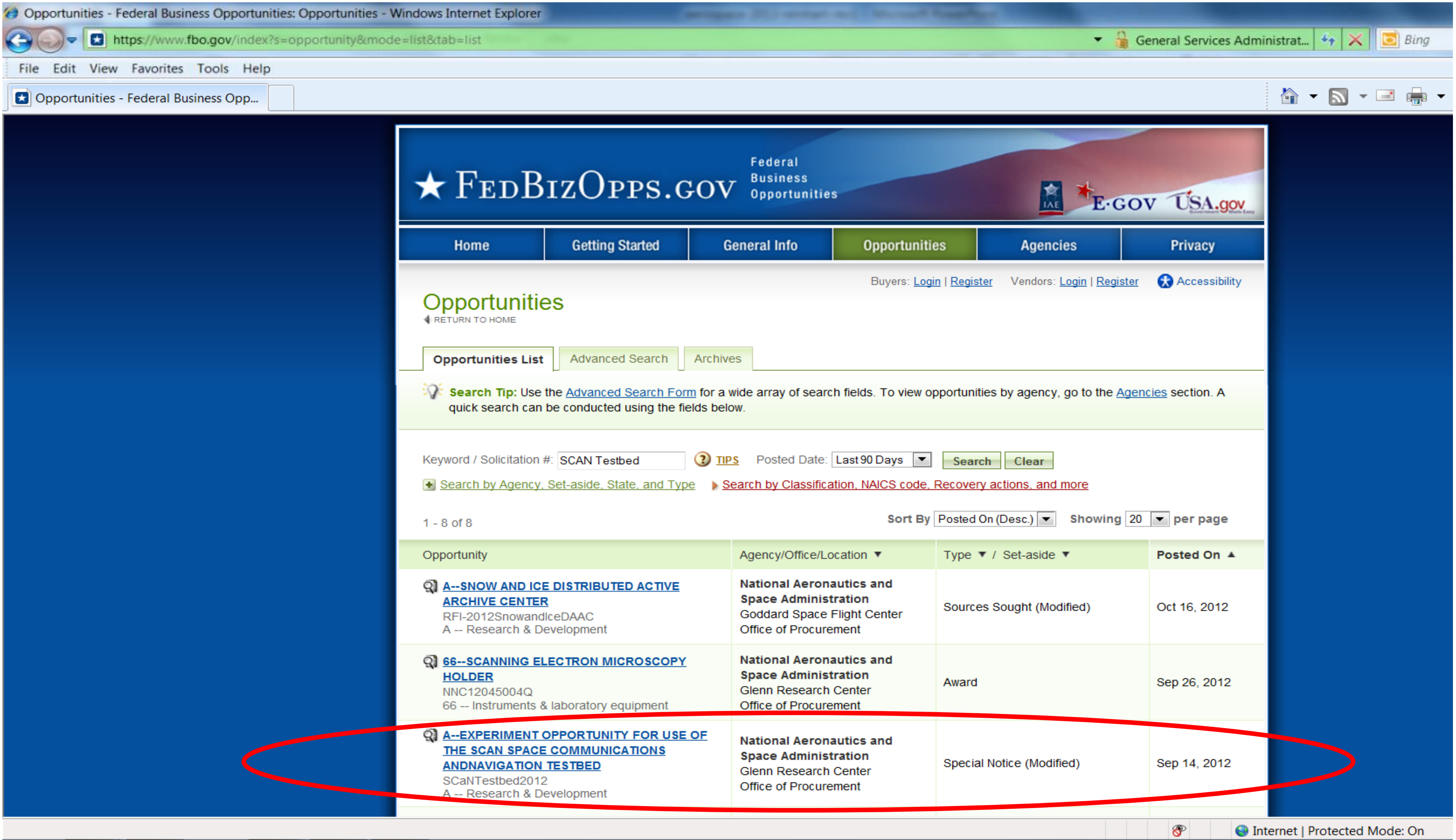
Solicitations

Open Solicitations

Solicitation Title	Solicitation #	Released	NOI Due	Proposal Due
Announcement of Flight Opportunities (AFO)	NOCT110	12/21/2010	--	12/21/2012
Game Changing Opportunities In Technology Development	NNL12A3001N	02/10/2012	--	02/09/2013
NASA ARMD Research Opportunities in Aeronautics (ROA-2011)	NNH11ZEA001N	08/26/2011	--	08/01/2013
NASA Earth and Space Science Fellowship 2013	NESSF13	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013	NESSF13	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013	NESSF13	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013	NESSF13	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013 Renewal	NESSF13R	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013 Renewal	NESSF13R	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013 Renewal	NESSF13R	11/01/2012	--	(See Announcement)
NASA Earth and Space Science Fellowship 2013 Renewal	NESSF13R	11/01/2012	--	(See Announcement)
NASA Space Technology Research Fellowships (NSTRF)-Fall 2013	NSTRF13	10/10/2012	--	12/04/2012
Ocean Observation - 2010, 2012	NNH09ZEC001U	12/10/2009	--	12/13/2012
Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions	NNJ12ZSA002N	07/30/2012	--	(See Announcement)
Research Opportunities in Space and Earth Sciences (ROSES) - 2011	NNH11ZDA001N	02/18/2011	--	12/15/2012
Research Opportunities in Space and Earth Sciences (ROSES) - 2012	NNH12ZDA001N	02/14/2012	(See Announcement)	(See Announcement)
Research Opportunities in Space Biology	NNH12ZTT001N	09/30/2012	--	(See Announcement)
Second Stand Alone Missions of Opportunity Notice (SALMON-2)	[illegible]	[illegible]	--	02/06/2017
Use of the Space Communications and Navigation (SCaN) Testbed: A Communications, Navigation and Networking Reconfigurable Testbed	NNC12ZRH002C	08/10/2012	--	01/31/2013

Internet | Protected Mode: On 140%

Federal Business Opportunity WebSite



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/SOPO/SCO/SCaNTestbed

or

Contact: Richard Reinhart

Principal Investigator, SCaN Tesbed

richard.c.reinhart@nasa.gov

Acknowledgements

SCaN Testbed Research & Technology (R&T) Leadership:

- **Sandra Johnson[1], Thomas Kacpura[1], James Lux[2], Greg Heckler[3], Oron Schmidt[4], Jacqueline Myrann[4]**

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
    - richard.c.reinhart@nasa.gov
    - 216-433-6588
  - Deputy Principal Investigator
    - Ms. Sandra Johnson
    - sandra.k.johnson@nasa.gov
    - 216-433-8016

- **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**
  - NSPIRES: http://nspires.nasaprs.com/external/index.do
- **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