National Aeronautics and Space Administration

Space Communication and Navigation Testbed: Communications Technology for Exploration

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NASA Glenn Research Center

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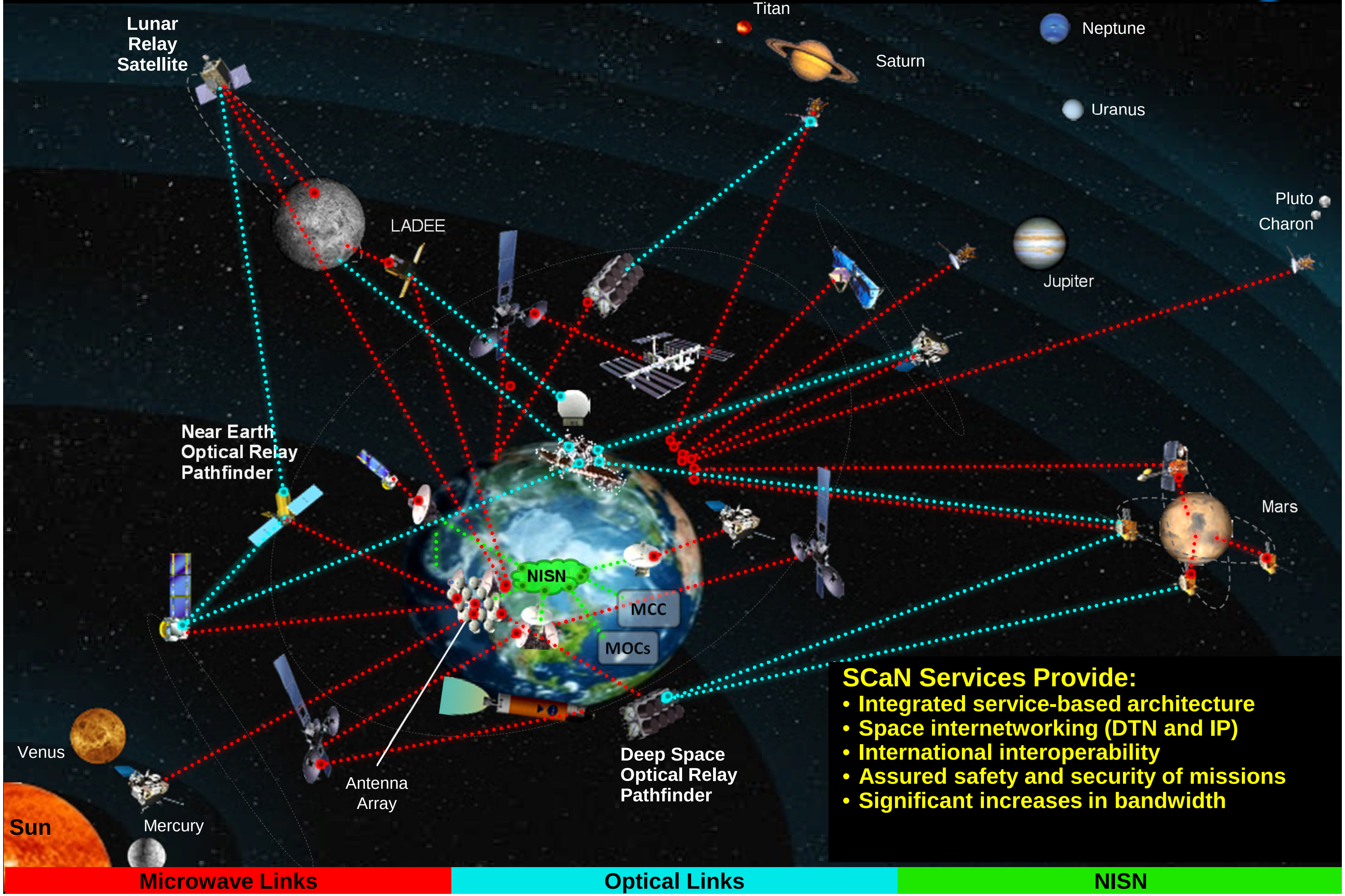
Sponsored by Space Communication and Navigation Program

SCaN Notional Integrated Communication Architecture

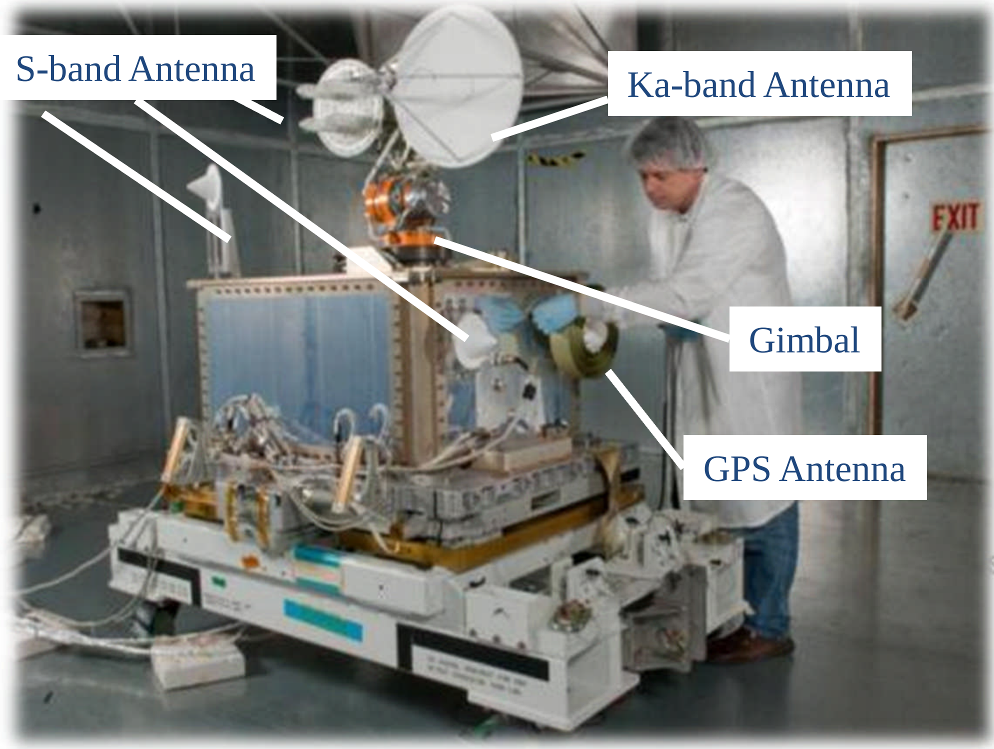


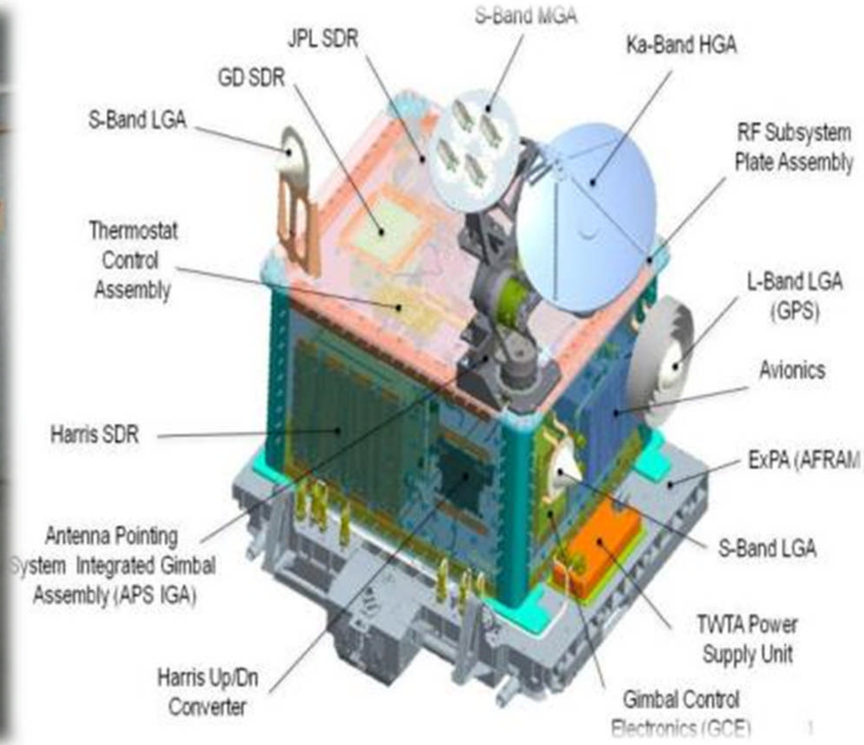
Next Generation Communication and Navigation Technology

- 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 – Software Defined Radio-based Communication System

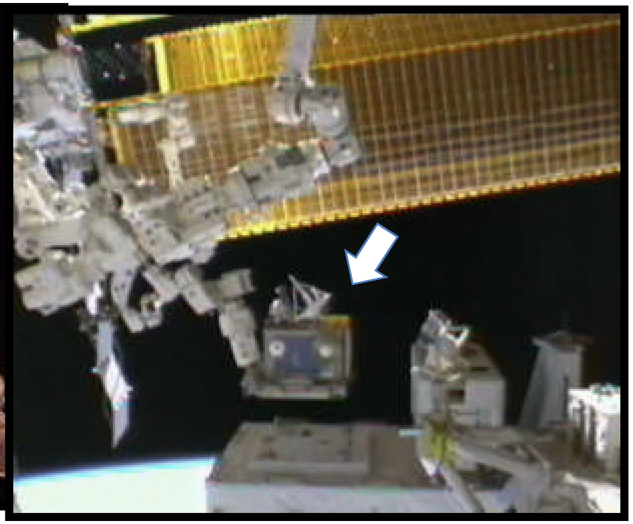


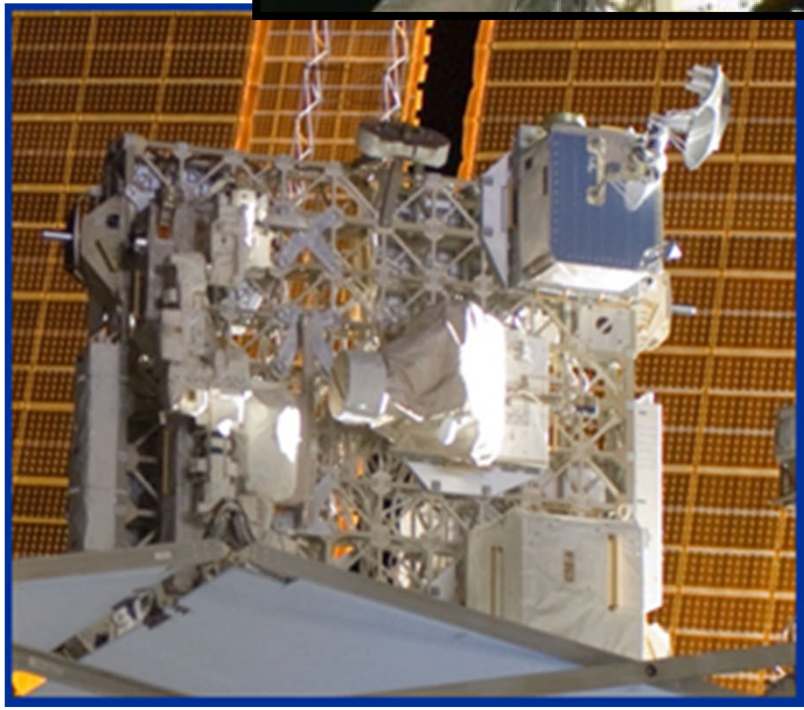


- **SDRs - Two S-band SDRs (One with GPS), One Ka-band SDR**
- **RF - Ka-band TWTA, S-band switch network**
- **Antennas - Two low gain S-band antennas, One - L-band GPS antenna, Medium gain S-band and Ka-band antenna on antenna pointing subsystem.**
- **Antenna pointing system - Two gimbals, Control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

Pictures of Installation and First Operations

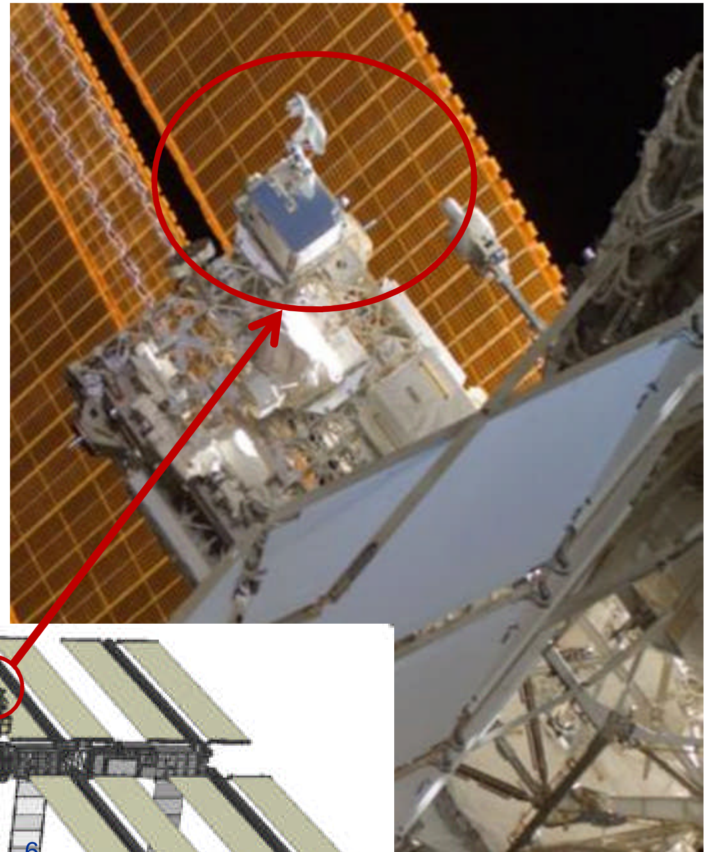
Launched: July 20, 2012

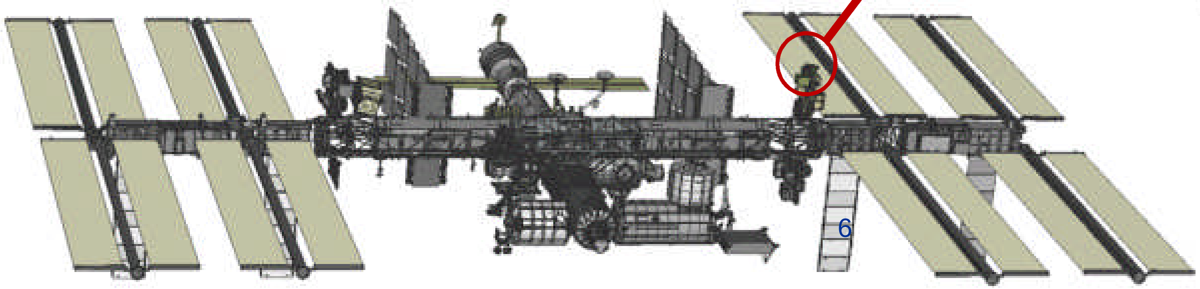




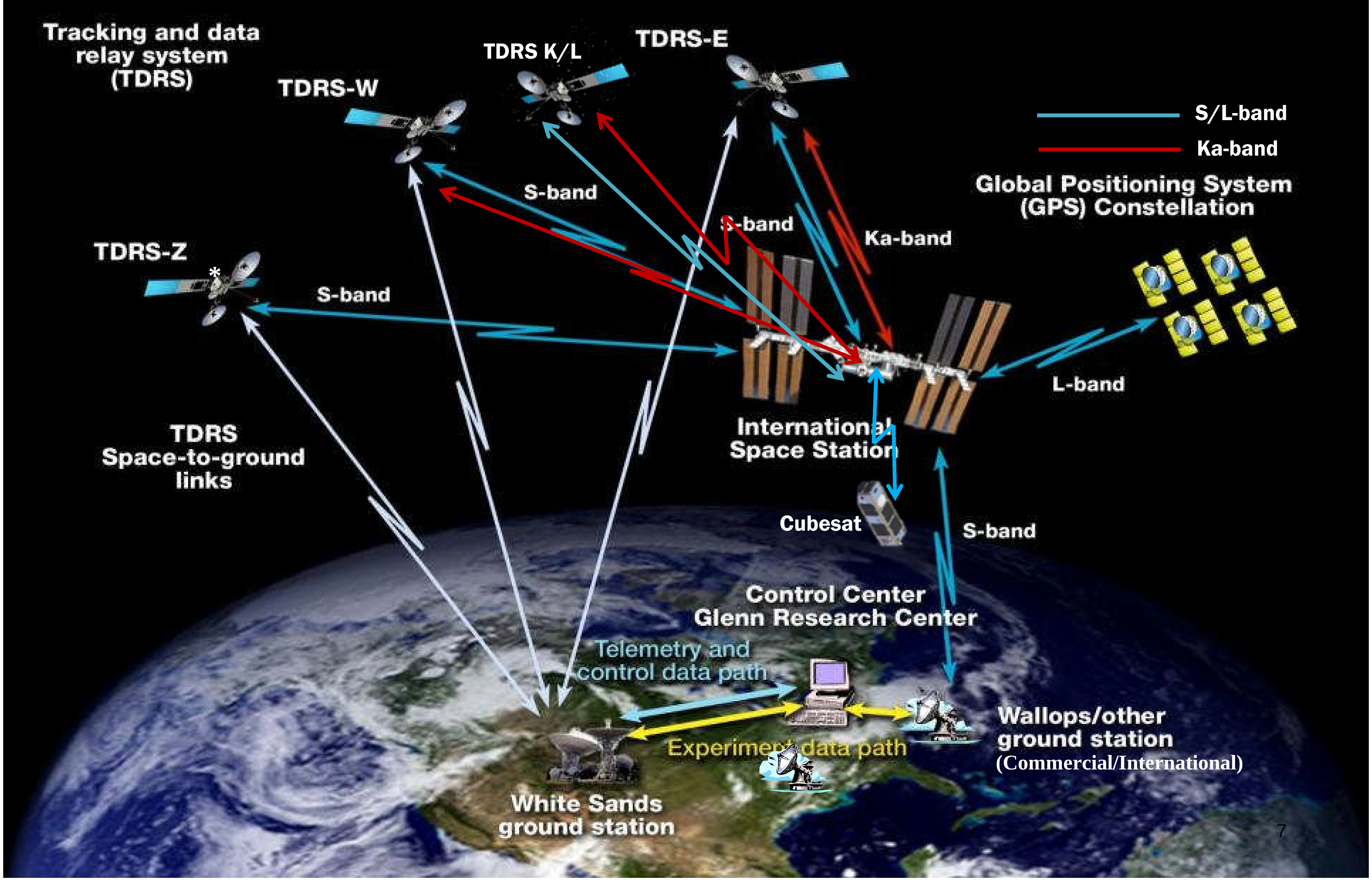
SCAN Testbed Mission Objectives

- **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, GPS





SCAN Testbed System Architecture



Why Use Software Defined Radios?

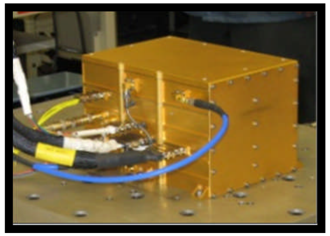
- **SDRs provide <u>unprecedented operational flexibility</u> that allows communications functions in software to be updated in development or flight**
  - Functions can be changed within the same SDR across mission phases
    - E.g., range safety functions in launch phase, mission ops functions in mission phase
  - Technology upgrades can be made in flight
    - E.g., modulation methods, new coding schemes
  - Failure corrections can be 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 <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
(Data)

Output
(Signal)

Impact of SCaN Testbed Technology

- **Reconfigurable devices are part of our missions. Understanding their function both individually and within the system is critical**

- **Open platform model to reduce developer dependence**
  - Platforms last for >10 years…software by NASA, others on space hardware

- **SDR 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 sw

- **Changing the culture associated with radio technology**
  - Routine verification of new sw on ground hardware, not the flight hardware
    - Pioneering techniques for rapid turnaround of software verification for flight applications. We are unique to change functions often and intentionally…
  - Consider the platform along with the application
    - Requirements, test waveforms for 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 new L5 signals in space. Conducting tests with the newest GPS satellites.
- Progress on waveform repository technical aspects and licensing issues – a key element of the SCaN Testbed

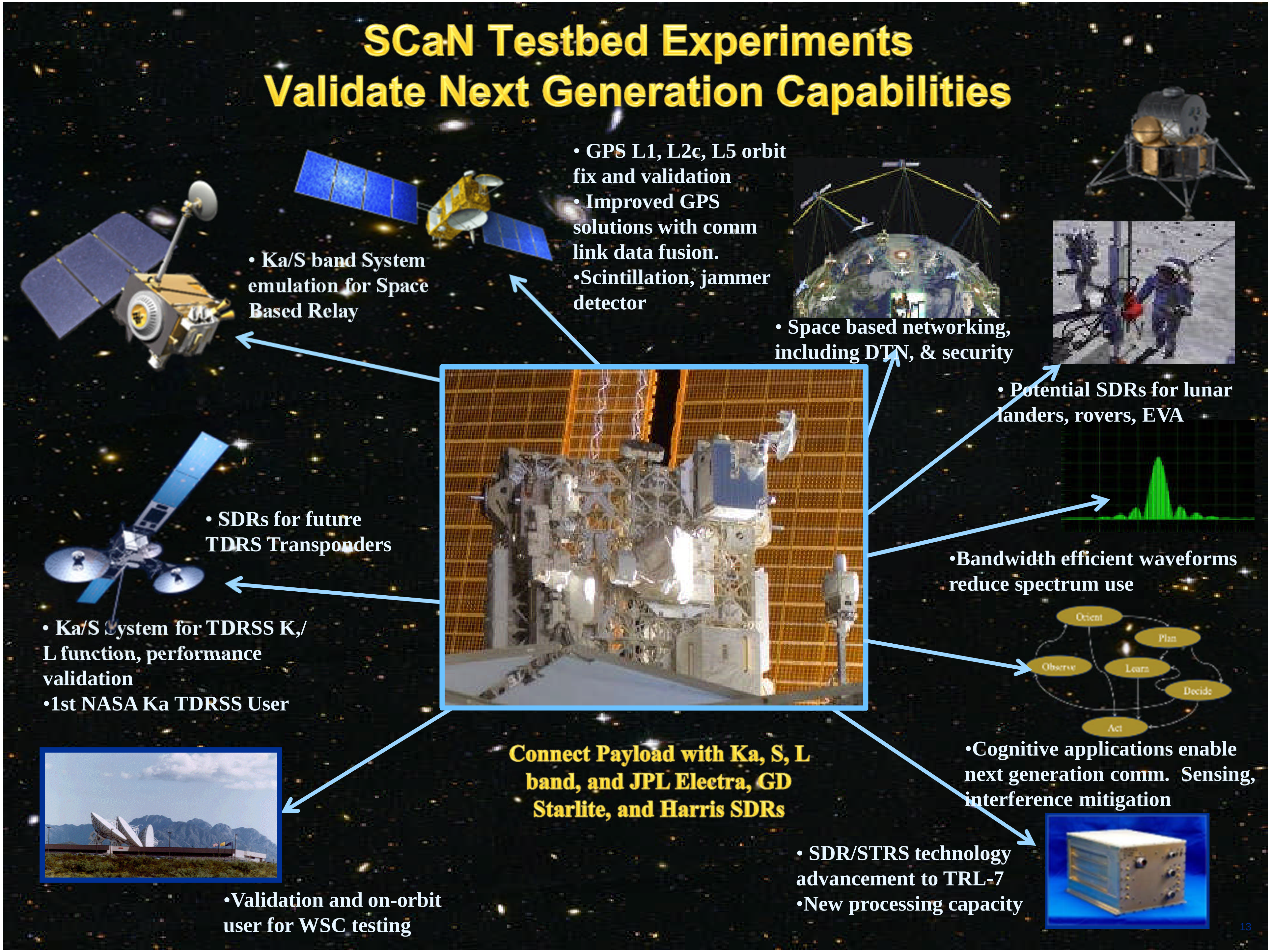
Demonstration in space is key to accomplishments

Experiment Program Goals

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

- **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**
  - Tech advancement/flight validation (bandwidth efficient, cognitive, coding, networking, GPS)
  - Mission concept demo (e.g. next gen relay, lander communication),
  - Supporting other NASA activities (e.g. TDRS-K, Space Network updates)
  - Science experiments


SCaN Testbed Experiments
Validate Next Generation Capabilities
• GPS L1, L2c, L5 orbit fix and validation
• Improved GPS solutions with comm link data fusion.
•Scintillation, jammer detector
• Ka/S band System emulation for Space Based Relay
• Space based networking, including DTN, & security
• Potential SDRs for lunar landers, rovers, EVA
• SDRs for future TDRS Transponders
•Bandwidth efficient waveforms reduce spectrum use
• Ka/S System for TDRSS K,/ L function, performance validation
•1st NASA Ka TDRSS User
Orient
Plan
Observe
Learn
Decide
Act
•Cognitive applications enable next generation comm. Sensing, interference mitigation
Connect Payload with Ka, S, L band, and JPL Electra, GD Starlite, and Harris SDRs
• SDR/STRS technology advancement to TRL-7
•New processing capacity
•Validation and on-orbit user for WSC testing
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What Experiment Can I Do?

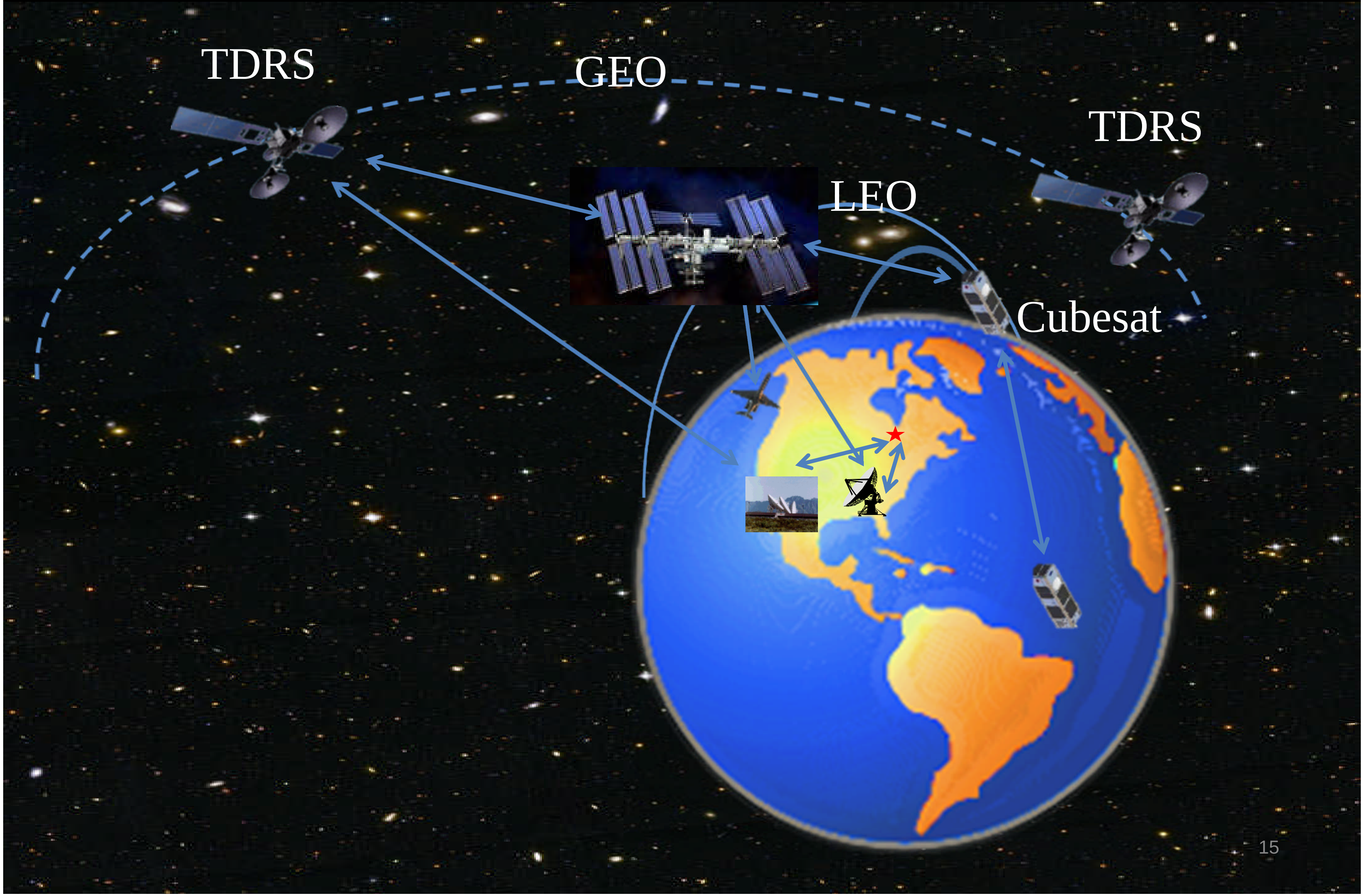
- **Research or New Product Developments & Technology:**
  - Spectrum/power Efficient Techniques (new modulations and coding)
  - Cognitive Radio Applications and Adaptive Waveforms
    - Signal sensing & interference mitigation
  - GPS demonstrations (L1/L2, L5, GPS corrections/augmentation), jammer detectors, scintillation (e.g. solar flares)
  - Networking including Disruptive Tolerant Networking (store/forward), adaptive routing, secure routing, sensor web app, formation flying

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

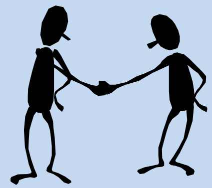
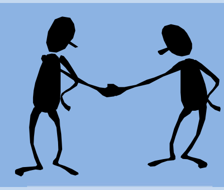
- **Conops**
  - Use on-orbit processing capacity in new and different ways

- **NASA**
  - In-orbit target of opportunity for e.g. TDRS-K/L tests, space network updates

System Architecture Concept Experiment Examples



Ways to Start the Experiment Process

Intended Org	Call	Proposal	Evaluation	Agreement	Available Funding
University	Cooperative Agreement Notice (CAN)	Submit via NSPIRES to Principal Investigator	Three review periods (proposal due dates): Sept, Jan, May	Cooperative Agreement	
Commercial	Experiment Opportunity (EO)	Submit to 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	Submit to NASA SBIR annual call	NASA review, per SBIR process	Contract	

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

- **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 SDR Standard has been referenced in SDR standards bodies for applicability to Earth-based, resource constrained radio systems**

- **Strong relevance to future Agency communication and navigation needs**

Summary

- **SCaN Testbed launched, on-orbit and SDRs performing great!**

- **SCaN Testbed available to commercial, university, and other partners for experiments!**
  - University - NSPIRES: http://nspires.nasaprs.com/external/index.do
  - Commercial/Non-profit FedBiz Ops: https://www.fbo.gov/
  - Small Commercial: SBIR: http://sbir.gsfc.nasa.gov/SBIR/SBIR.html

- **SCaN Testbed advancing SDR technology and applications aboard ISS!**

For more information

Visit SCaN Testbed on-line:

http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed

or

Contact: Richard Reinhart

Principal Investigator, SCaN Tesbed

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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, Joseph Downey, David Chelmins, Dan Bishop, Dale Mortensen, Mary Joe Shalkhauser, Steve Hall, Neil Adams, David Kifer, Jeff Glass, Janette Briones, David Brooks, Wesley 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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- **Programmatic Contact**
  - Project Manager
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    - 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/

NSPIRES Website for university proposals

NSPIRES - Solicitations Open - Windows Internet Explorer

http://nspires.nasaprs.com/external/solicitations/solicitations.do?method=open&stack=push

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NASA Solicitation and Proposal Integrated Review and Evaluation System

|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)	NNH12ZDA006O	02/07/2012	--	02/06/2017
Use of the Space Communications and Navigation (SCaN) Testbed: A Communications, Navigation and Networking Reconfigurable Testbed	NNC12ZBH002C	08/10/2012	--	[illegible]

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Federal Business Opportunity WebSite for commercial proposals