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

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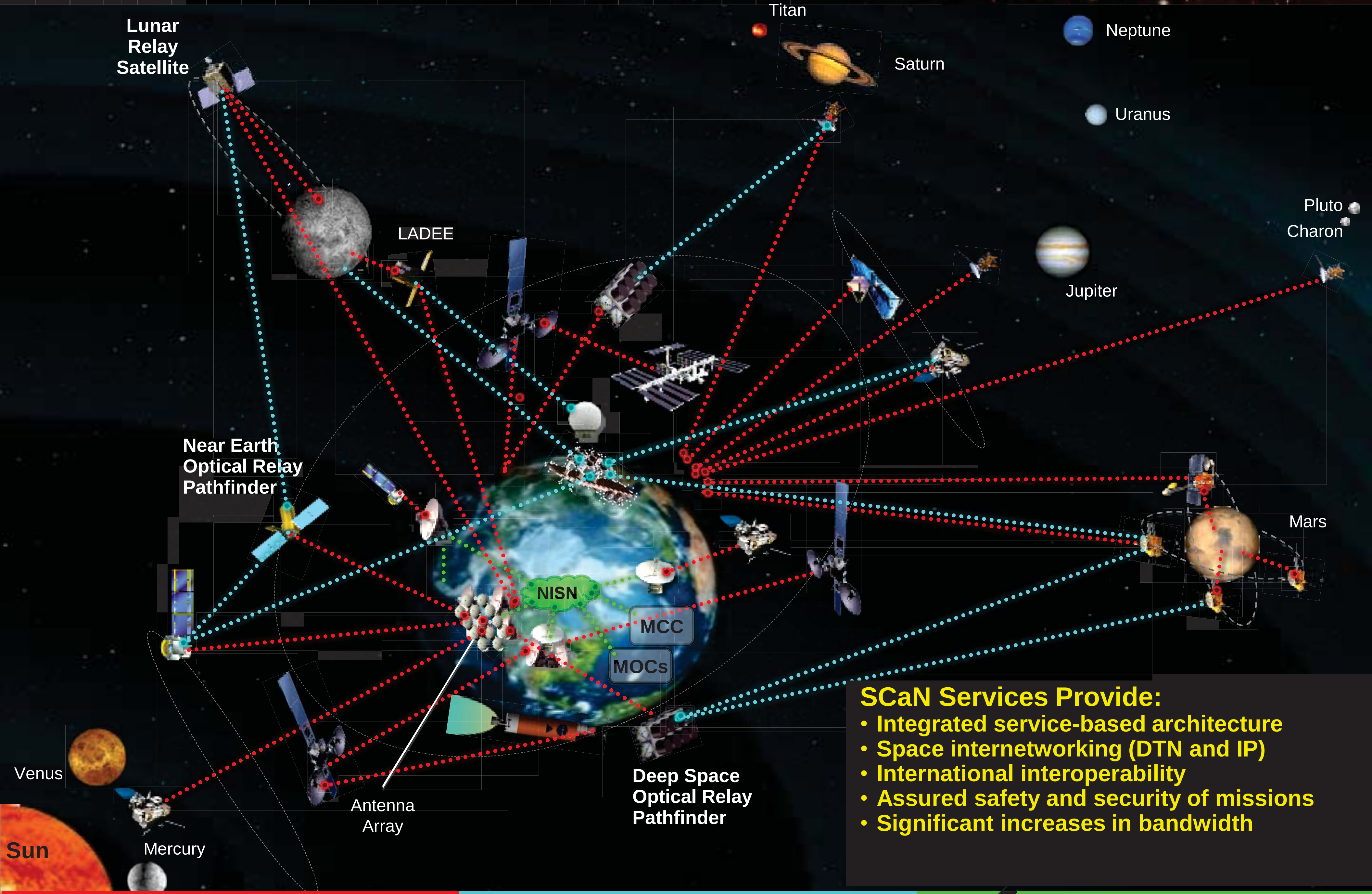
SCaN Notional Integrated Communication Architecture



SCaN Services Provide:

- Integrated service-based architecture
- Space internetworking (DTN and IP)
- International interoperability
- Assured safety and security of missions
- Significant increases in bandwidth

Microwave Links	Optical Links	NISN

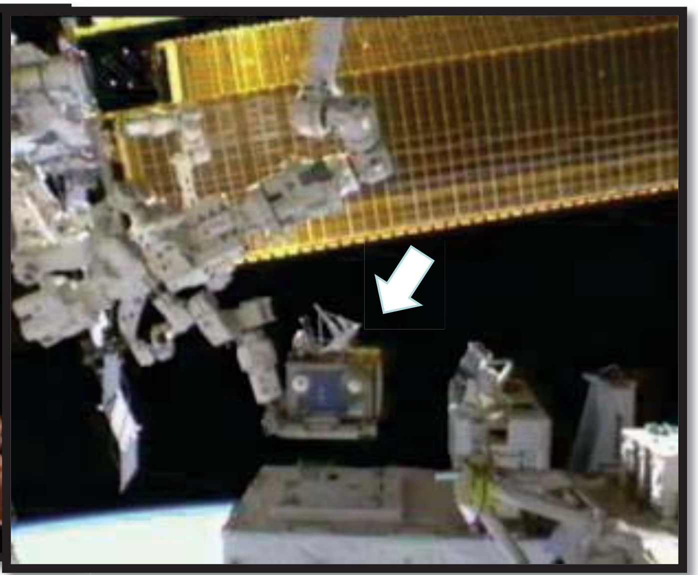
Next Generation Communication and Navigation Technology

- 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

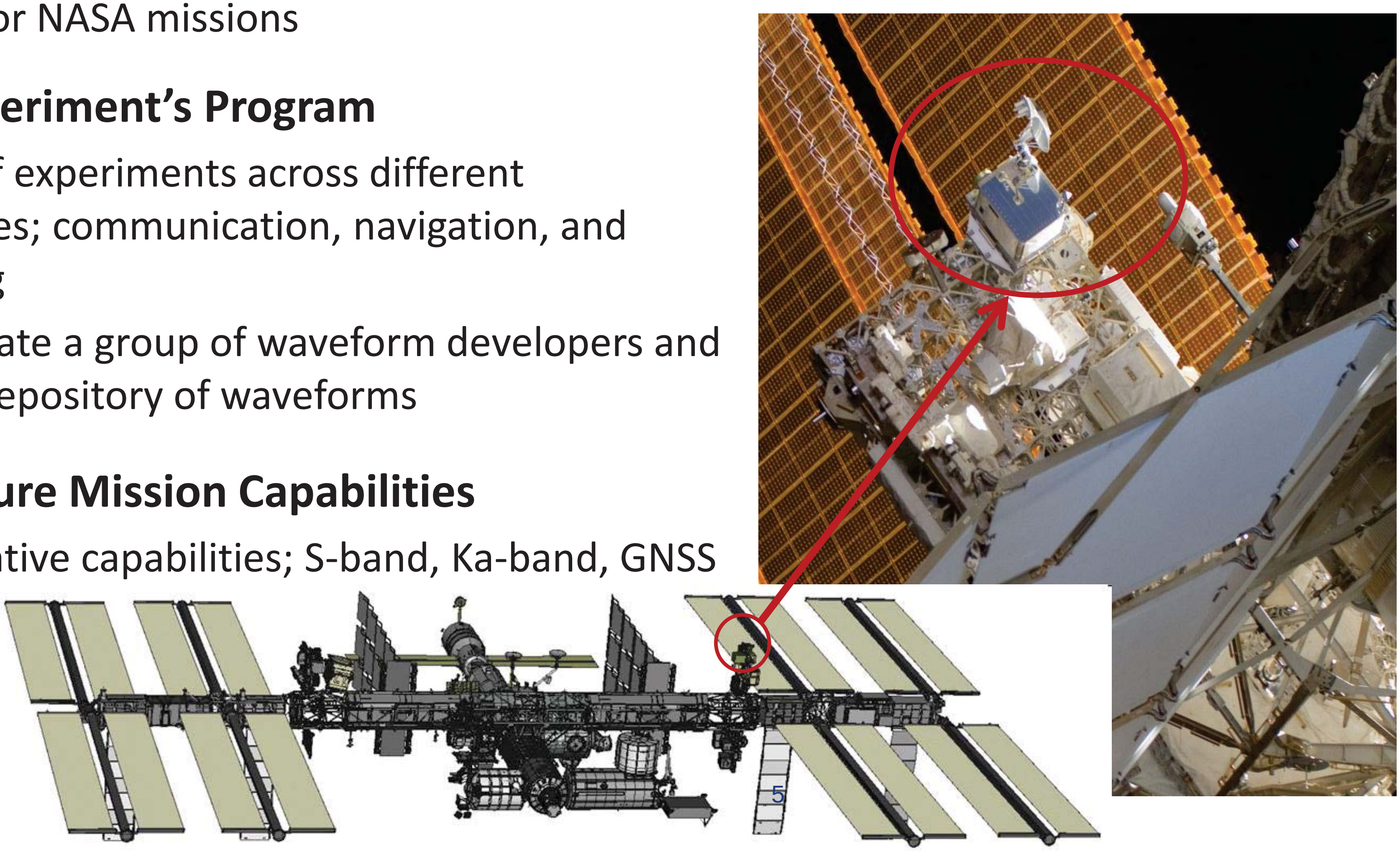
Pictures of Installation and First Operations

Launched: July 20, 2012

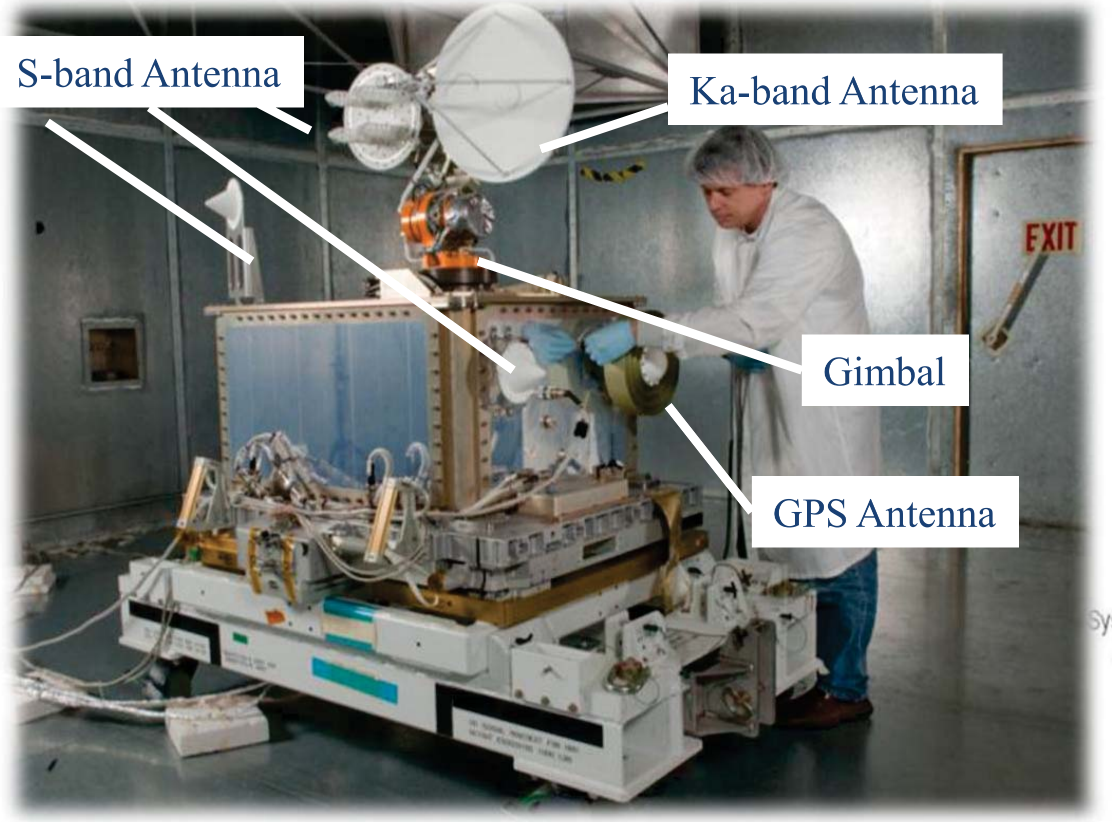


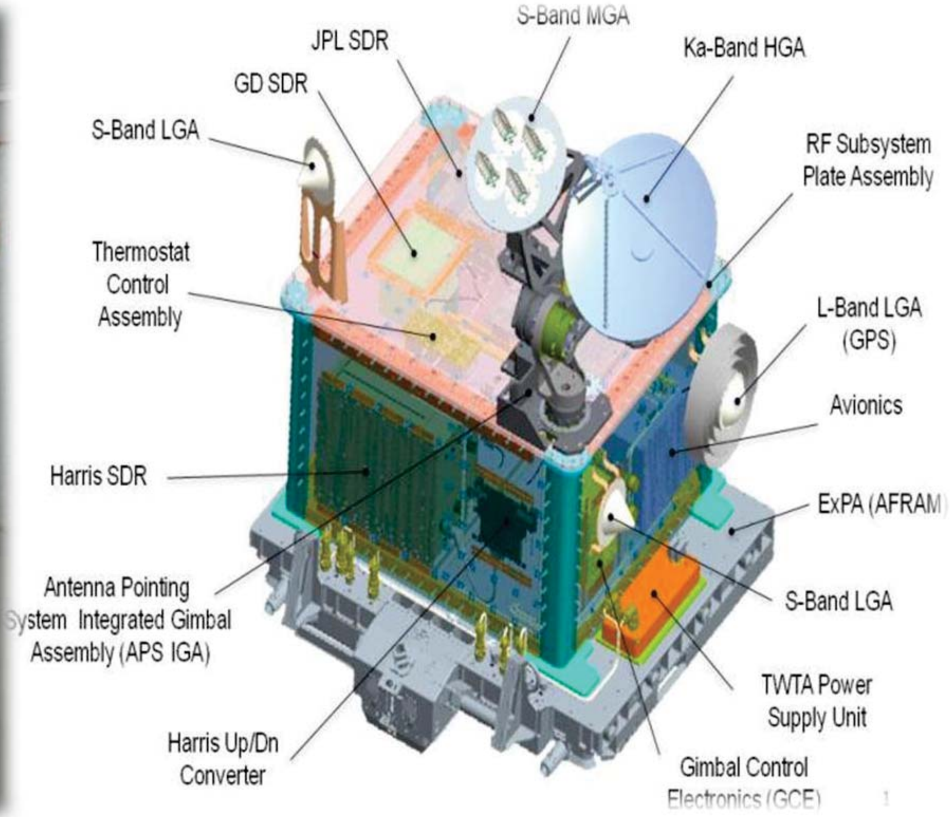
SCAN Testbed Mission Objectives

- **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, GNSS



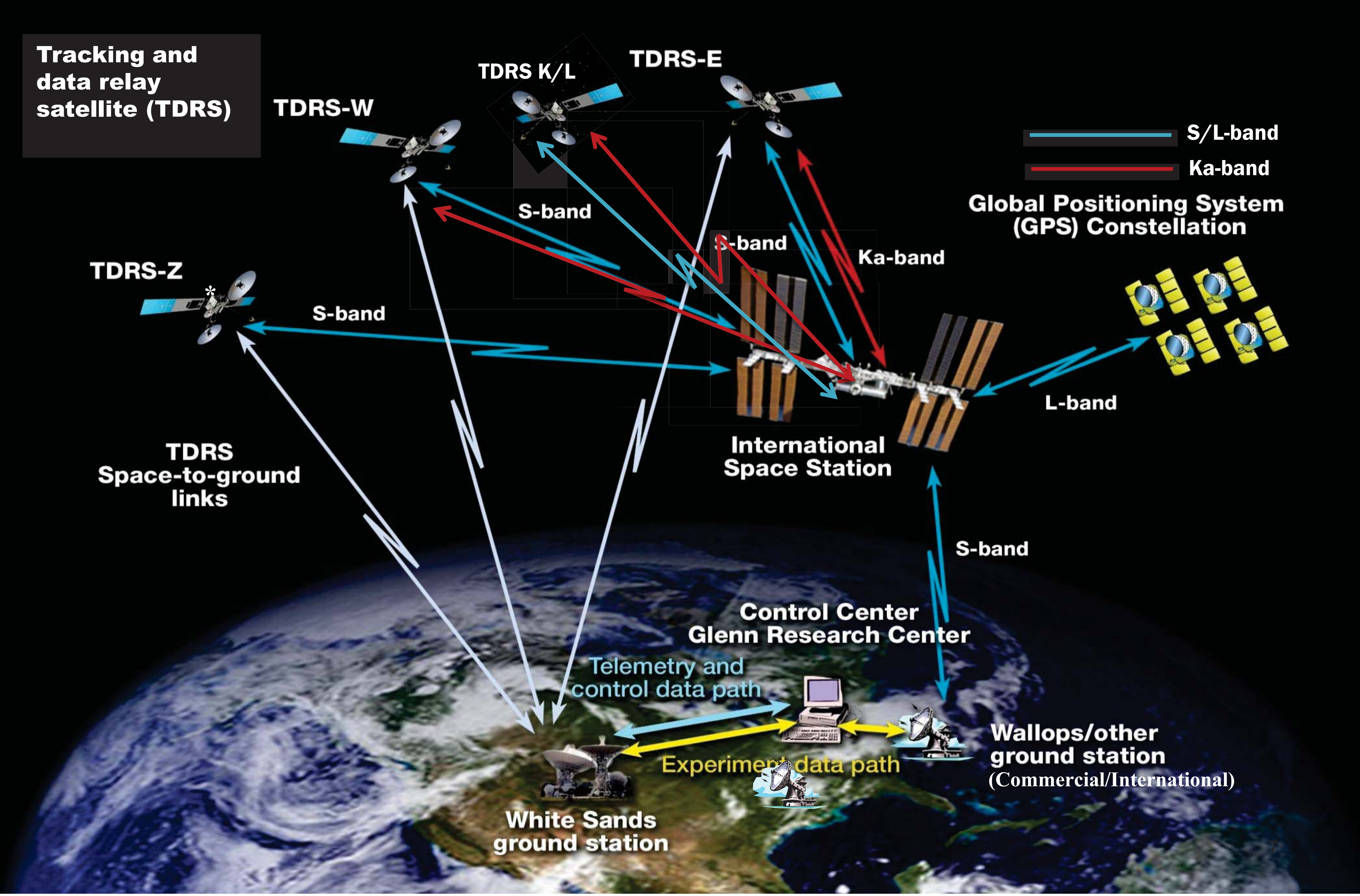
SCaN Testbed – Software Defined Radio-based Communication System





- **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)

S/L-band

Ka-band

TDRS-W

TDRS K/L

TDRS-E

TDRS-Z

S-band

S-band

S-band

Ka-band

Global Positioning System (GPS) Constellation

L-band

International Space Station

TDRS Space-to-ground links

S-band

Control Center Glenn Research Center

Telemetry and control data path

Experiment data path

Wallops/other ground station
(Commercial/International)

White Sands ground station

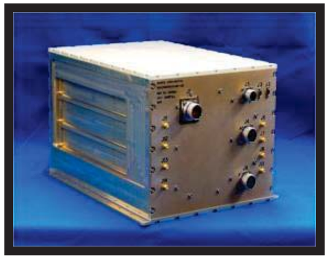
Why Use Software Defined Radios?

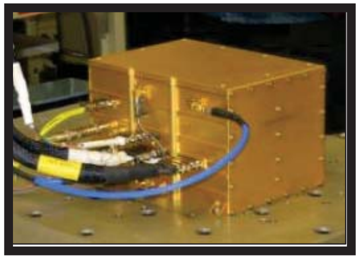
- **SDRs provide <u>unprecedented operational flexibility</u> that allows communications functions in software to be updated in development or flight**
  - Functions can be changed within the same SDR across mission phases
    - E.g., launch phase, mission ops functions in mission phase, technology upgrades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


Jet Propulsion Lab


Harris Corp.


General Dynamics Corp.

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

* STRS – Space Telecommunications Radio System, NASA Standard: NASA-STD-4009

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

Enabling Infrastructure and Mission Capability

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

	TDRSS Mode	Modulation	Data Rate (kbps)
Tx - S-band	DG1, Mode 1	SQPN	24, 192
	DG1, Mode 2	SQPN	24, 192
	DG1, Mode 2	SS-BPSK	24
	DG1, Mode 3	QPSK	Q: 1000 I: 1 kbps
	DG2	SQPSK	1000
	DG2	BPSK	192, 769
Tx	Ka-band	OQPSK	1000-100K
	Ka-band	OQPSK, 8PSK, 16APSK, GMSK	100-600 Mbps
Rx	S-band	QPSK. (PN spread)	18, 72
	S-band	BPSK (PN spread)	18
	S-band	BPSK (non-PN spread)	155, 769
	Ka-band	BPSK	1000-25K

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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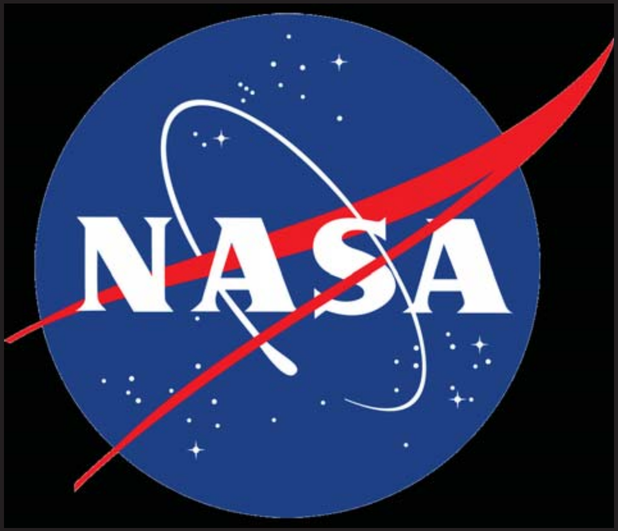
Or visit SCaN Testbed on-line:
http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed


NASA

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)

Processor

Memory

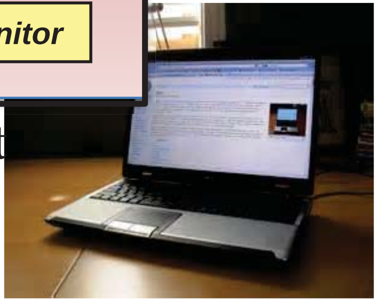
Hard Drive

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)