# DEVELOPMENT OF NASA'S SPACE COMMUNICATIONS AND NAVIGATION TEST BED ABOARD ISS TO INVESTIGATE SDR, ON-BOARD NETWORKING AND NAVIGATION TECHNOLOGIES

**Abstract**

NASA is developing an experimental flight payload (referred to as the Space Communication and Navigation (SCAN) Test Bed) to investigate software defined radio (SDR), networking, and navigation technologies, operationally in the space environment. The payload consists of three software defined radios each compliant to NASA's Space Telecommunications Radio System Architecture, a common software interface description standard for software defined radios. The software defined radios are new technology developments underway by NASA and industry partners. Planned for launch in early 2012, the payload will be externally mounted to the International Space Station truss and conduct experiments representative of future mission capability.

# Development of NASA's Space Communications and Navigation Test Bed aboard ISS to Investigate SDR, On-board Networking and Navigation Technologies

Richard C. Reinhart
CONNECT Principal Investigator
NASA Glenn Research Center

Thomas J. Kacpura, Sandra K. Johnson - NASA Glenn Research Center
and
James P. Lux, Jet Propulsion Laboratory

ReSpace ~ November 2010

# Briefing Overview

- NASA’s shift toward use of SDRs
- NASA’s SDR Standard Open Architecture: The Space Telecommunications Radio System (STRS) Standard
- SDR/STRS-based SCaN Testbed (Communication, Navigation, and Networking reConfigurable Testbed, (CONNECT), flight experiment installed on the truss of International Space Station (ISS)

Work sponsored by the
NASA Space Communications and Navigation (SCaN) Office

# Shift Towards SDR Technology

- NASA looking at how to use or infuse SDR technology into NASA missions and infrastructure

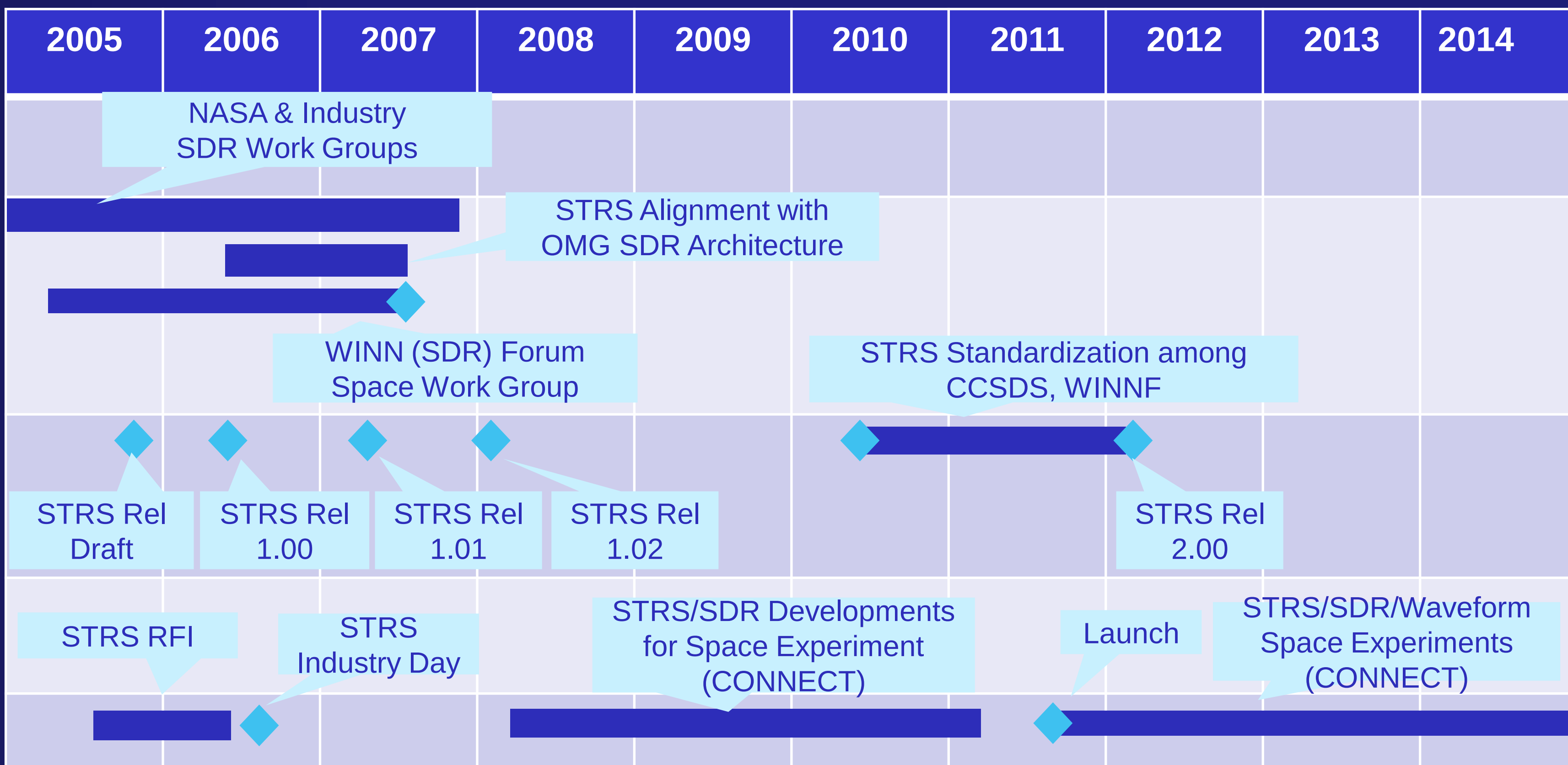
- Assess fixed (e.g. ASIC or OTP) DSP hardware vs SDR architecture
  - Industry pursuing processor & FPGA-based architecture
  - Enable NASA to leverage SDR developments across missions.
  - In-flight Reconfigurability

Leverage commercial and NASA Labs' (JPL, APL) SDR product lines, with capability for typical or envisioned NASA functions and capability

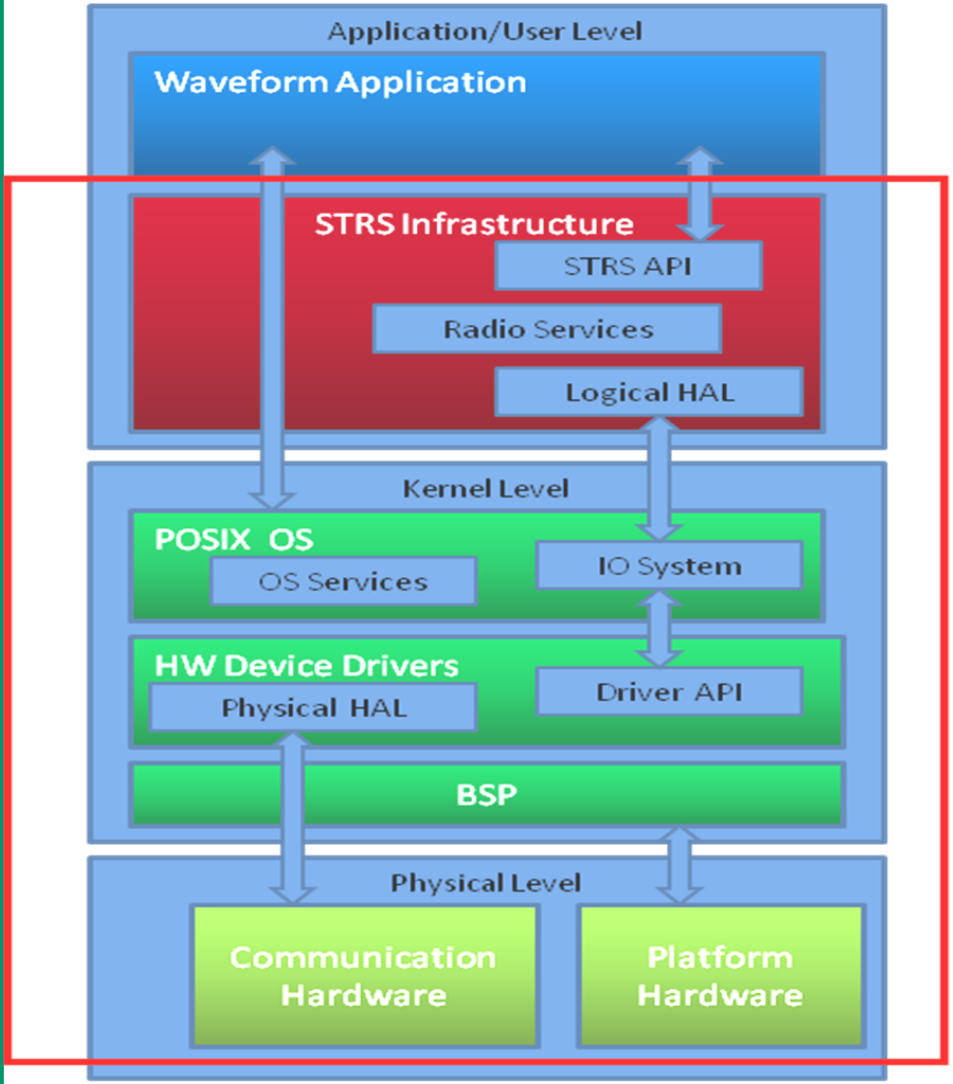
- Common SDR Architecture: Platforms and waveform STRS compliant
  - Separation of waveform application from SDR Platform
    - Abstract waveform from underlying hardware (need for standard architecture)
    - Platform and waveform requirements separation
  - Reduce long-term dependence on SDR developer for software upgrades

# Space Telecommunications Radio System (STRS) Development Process

- Agency initiative to infuse SDR Technology and Architectures
- Established ~2005 and supported by NASA, JPL, APL, AFRL
- Industry participation through Wireless Innovation (SDR) Forum, OMG
- Provide architecture commonality among mission use of SDRs



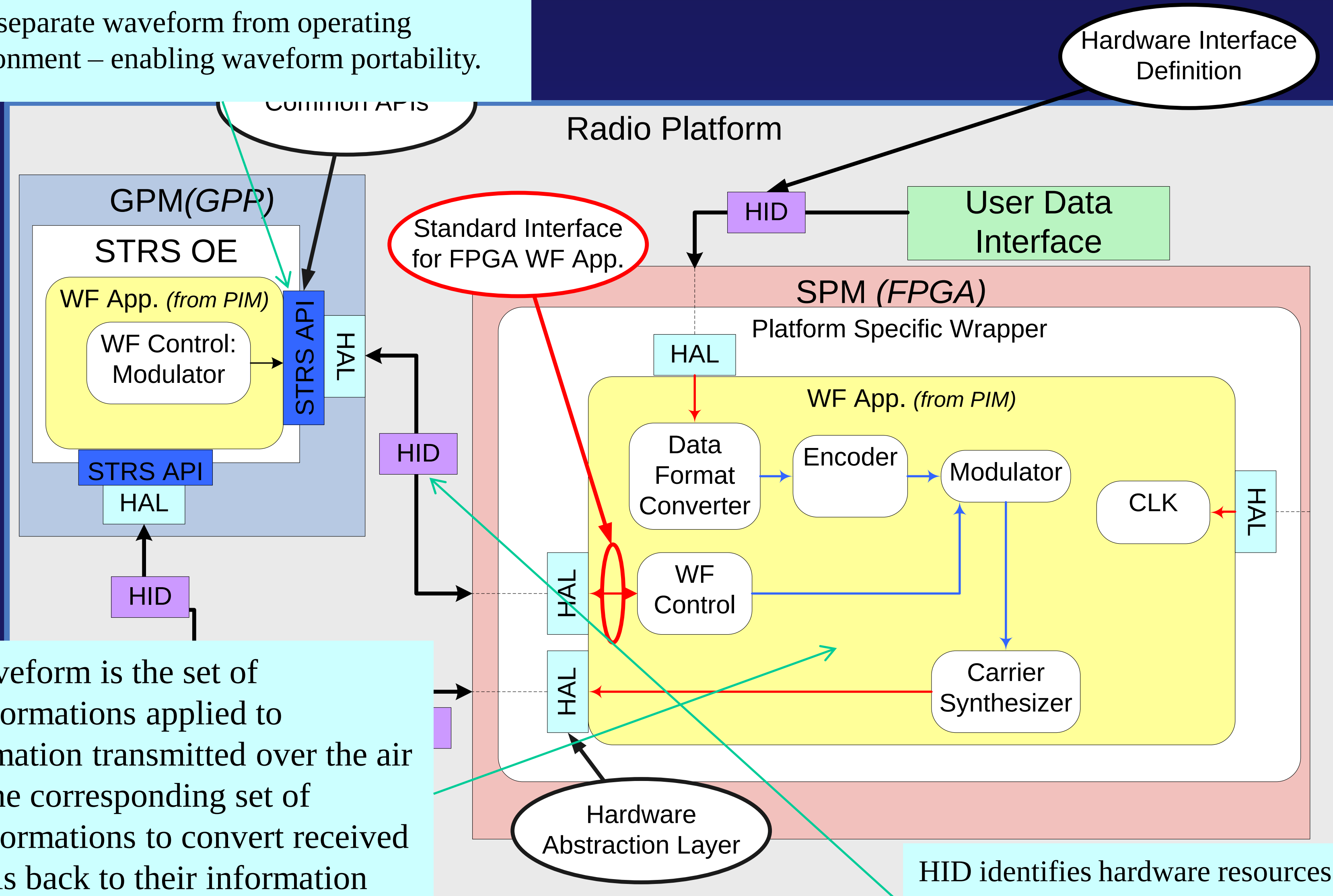
# STRS Simplified View




- Abstract app sw from underlying HW
  - Reduce mission dependence on radio provider for reconfigurations years after development/launch.
  - Minimum set of hardware and software interface
- Promote portability/reuse
  - Avoid proprietary application designs/ implementations.
- Mission flexibility, for different levels of available resources. – scalable
- Architecture simplified by mission planning and hw resource allocation.
  - No radio hardware discovery or dynamic WF allocation change across hardware – fewer resources (e.g. power, memory)
- Enable waveform component contributions to repository for reuse

# STRS Interface Highlights

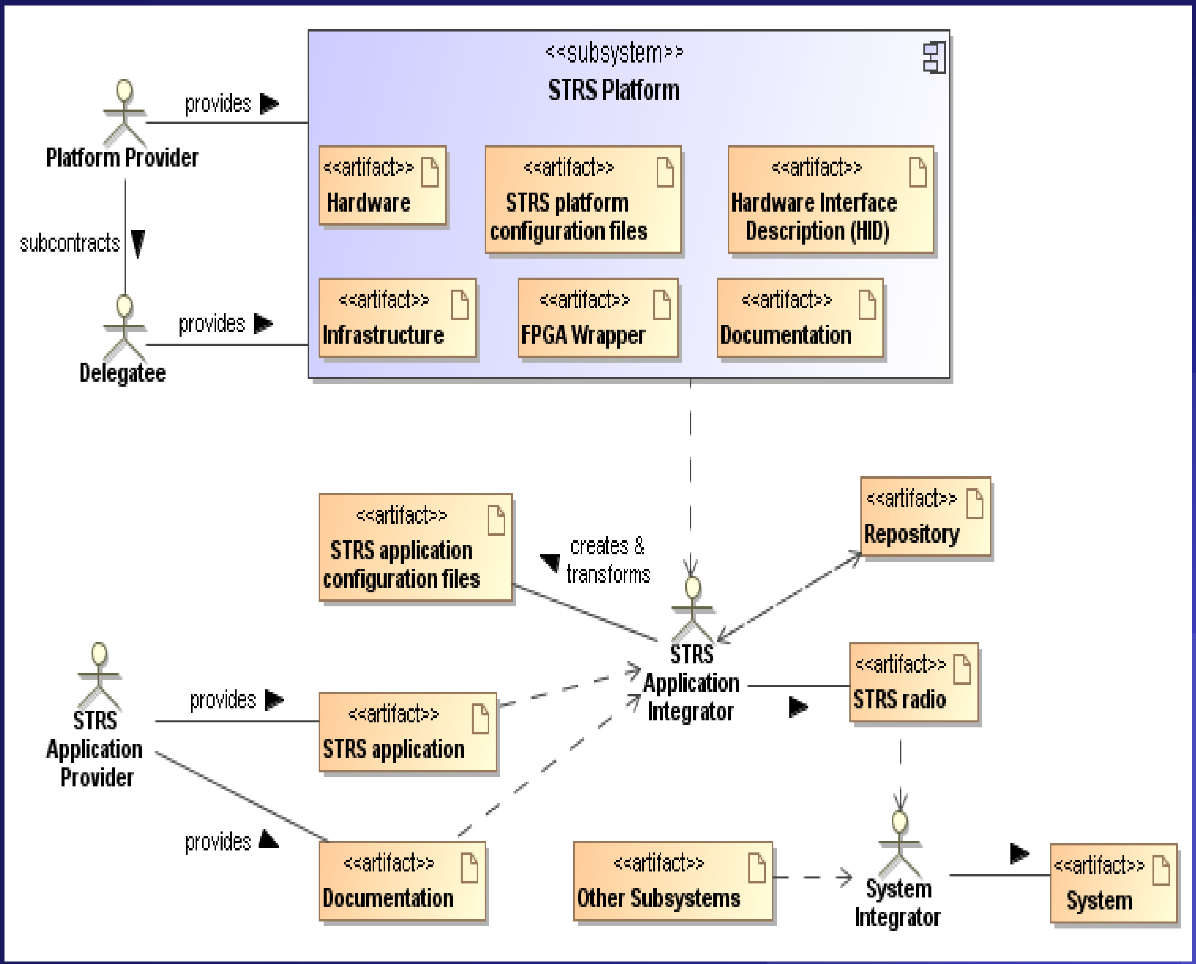
APIs separate waveform from operating environment – enabling waveform portability.




A waveform is the set of transformations applied to information transmitted over the air and the corresponding set of transformations to convert received signals back to their information contents

HID identifies hardware resources available to waveform developer, separating WF from HW dependency.

# SDR Developer Roles




- Platform Supplier
  - Hardware
  - Operating Environment
- Waveform Developer
  - Waveform App
- SDR Integrator
  - Combines waveform applications with the platform.
  - non-SDR model, the integration is done at the radio manufacturer
- System Integrator
  - integrates the complete radio (hw/wf) with the rest of the spacecraft.

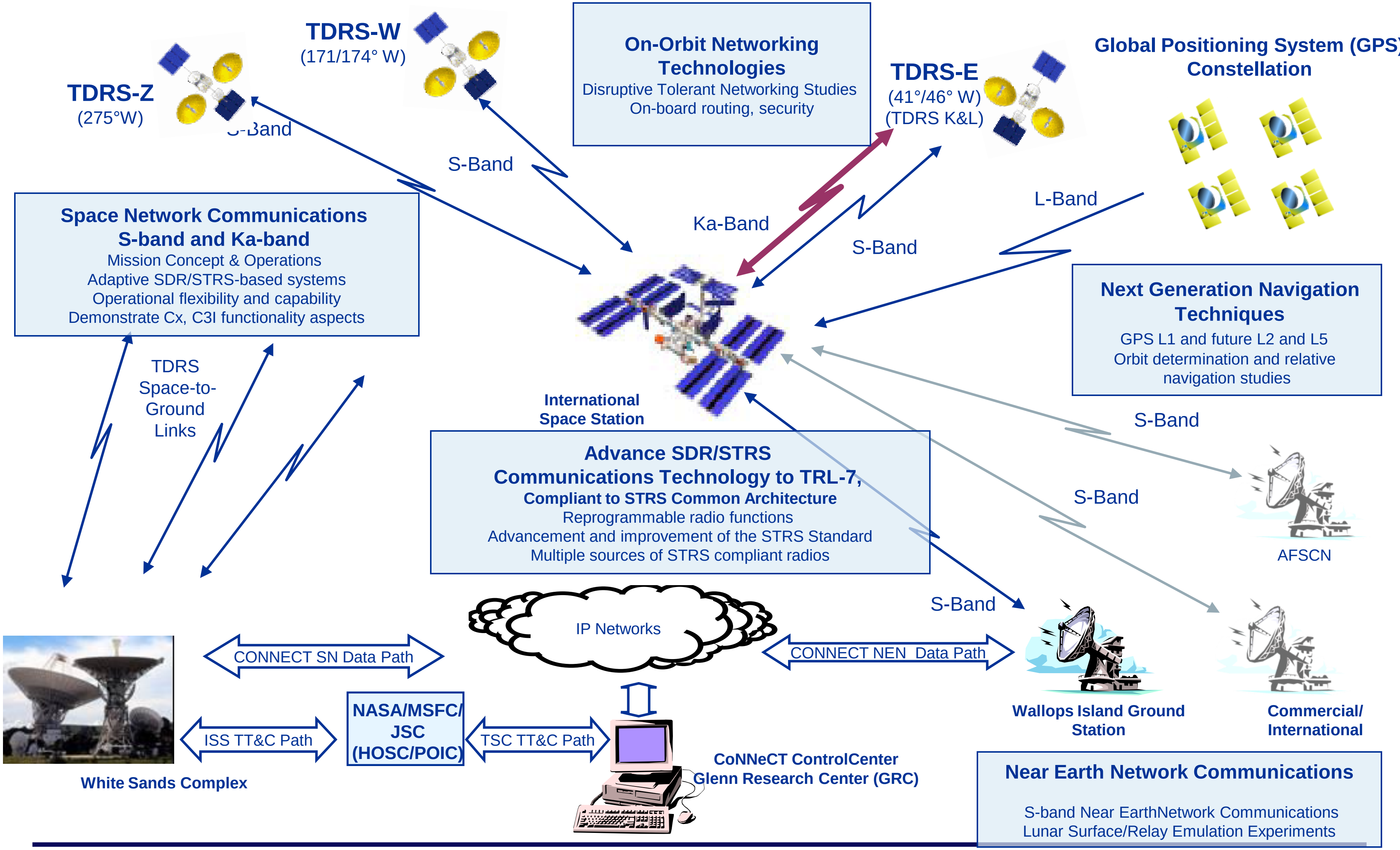
# SDR Flight Experiment
# SCaN Testbed Mission Objectives

- **SDR-based ISS NATIONAL LABORATORY Capability**
  - Reconfigure SDR (e.g. STRS OE, wf updates, modulation, coding, framing, filtering)
    - Bit streams to arbitrary link layer protocols
  - Load/run/reconfigure third party sw applications external to SDRs (flight computer)
    - On-board networking (e.g. DTN), routing, and security applications
  - Flexible interaction between applications and SDRs

- **SDR TECHNOLOGY DEVELOPMENT**
  - Platform & waveforms compliant to STRS
  - Separating SDR performance from link performance
  - Promote development and Agency-wide adoption of NASA’s SDR Standard, STRS

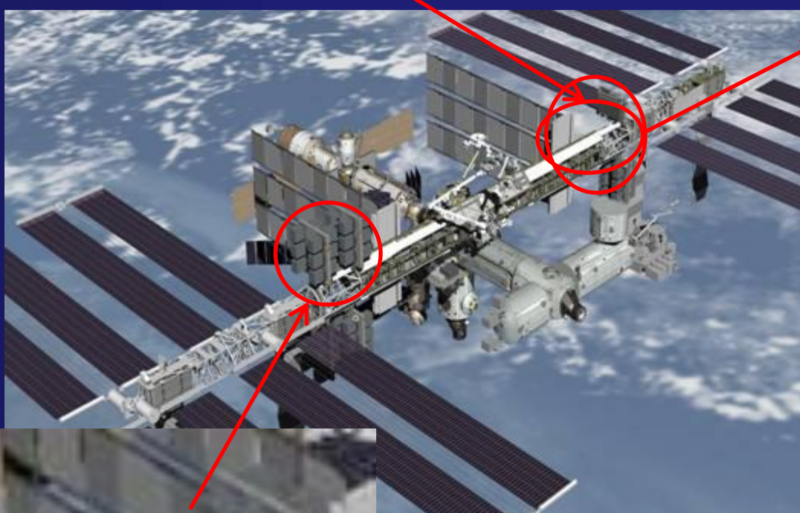
- **VALIDATION OF FUTURE MISSION OPERATIONAL CAPABILITIES**
  - Capability representative of future missions
    - Comm Data rate, performance, networking/routing, navigation/GPS
  - Understanding SDR performance (reliability, SEE, telemetry, instrumentation)
  - Multiple and simultaneous RF Links (Ka-band, S-band, L-band/GPS)

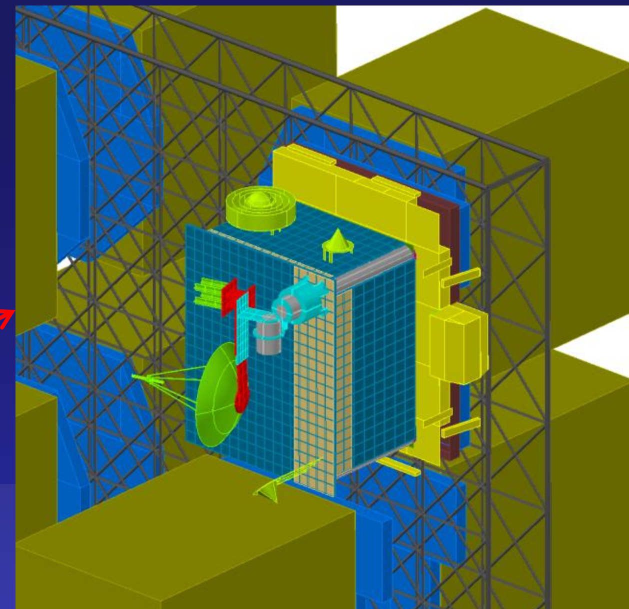
# Communications, Navigation, and Networking reConfigurable Test bed (CONNECT)



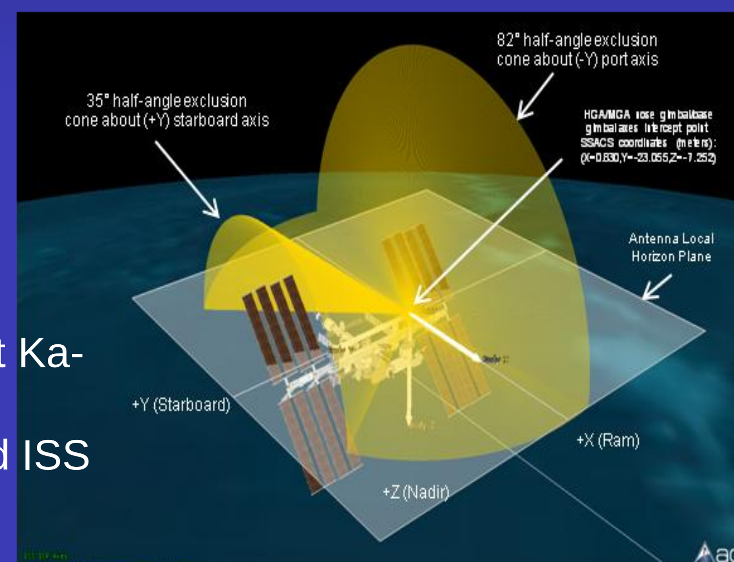
# SCAN Testbed as an External Payload on ISS

SCAN Testbed is located on the ISS port (P3) ELC, mounted on the starboard side of the P3 ELC on the zenith/ram corner





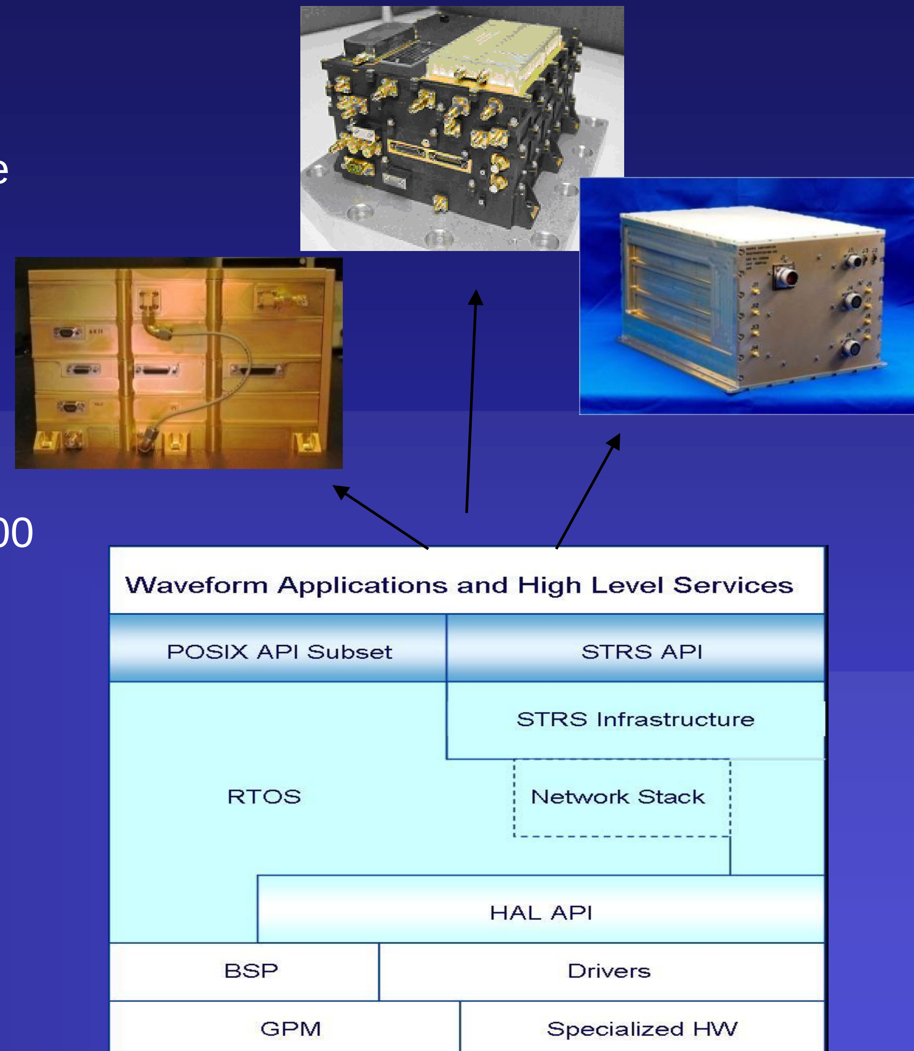
Typical coverage to TDRSS at Ka-band and S-band avoid solar reflectors, thermal panels, and ISS structure, pointing zenith



# SDRs are the core of the CONNECT Communication System

## Advance SDR Platforms to TRL-7

- General Dynamics (S-band)
  - Virtex II, ColdFire Processor (60 MIPS), VxWorks OS, EDAC, CRAM (Chalcogenide RAM) Memory
- JPL (S-band, L-band)
  - Virtex II, Sparc Processor (100 MIPS) , RTEMs OS,  EDAC
- Harris (Ka-band )
  - Virtex IV, AiTech-PowePC Processor (~1000 MIPS), DSP (1 GFLOP), VxWorks OS, Scrubbing ASIC
  - First Ka-band transceiver




## STRS

- Single Standard on each SDR, and  WF
- Compliance through automated tools, inspection, observation at runtime

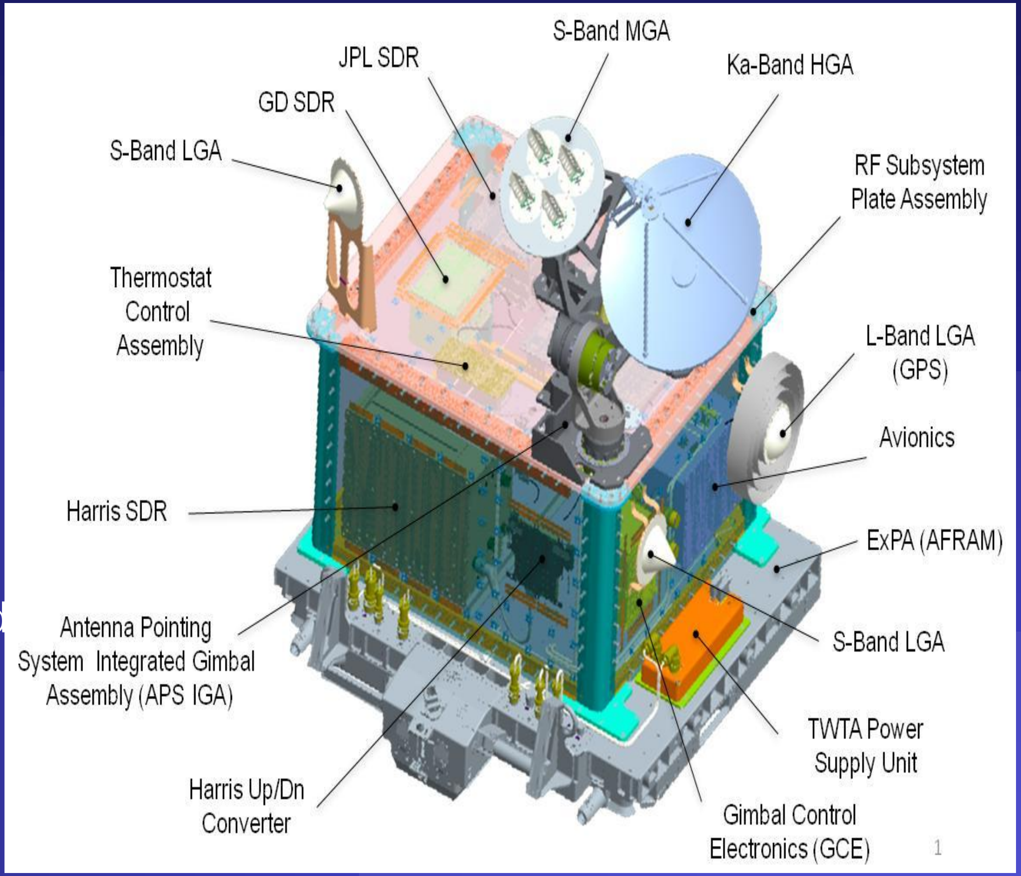
# Experiment Waveform Development Comm Technology (Launch Capability)

| | | | Transmit (Return) Link | | Receive (Forward) Link | | |
|---|---|---|---|---|---|---|---|
| | Platform Provider | Waveform Provider | Modulation | User Data Rate (kbps) | De-modulation | User Data Rate (kbps) | Coding/ Decoding |
| S-band DG1, Mode 1 | GD | GD | SQPN | 24, 192 | QPSK | 18, 72 | Rate 1/2 Viterbi |
| S-band DG1, Mode 2 | GD | GD | SQPN | 24, 192 | QPSK | 18, 72 | Rate 1/2 Viterbi |
| S-band DG1, Mode 3 | GD | GD | QPSK | <1000 | QPSK | 1000 | Rate 1/2 Viterbi |
| S-band DG2 | GD | GD | SQPSK | <1000 | QPSK | 1000 | Rate 1/2 Viterbi |
| S-band DG1 Mode 2 | JPL | GRC/GSFC | BPSK | 24, 96 | BPSK | 18, 26 | Rate 1/2 Viterbi |
| S-band DG2 | JPL | GRC/GSFC | BPSK | 192 | BSPK | 72 | Rate 1/2 Viterbi |
| Ka-band DG2 | Harris | Harris | SQPSK | 100 Mbps 12.5 Mbps | BPSK | 12.5 Mbps 3 Mbps | Rate 1/2 Viterbi |

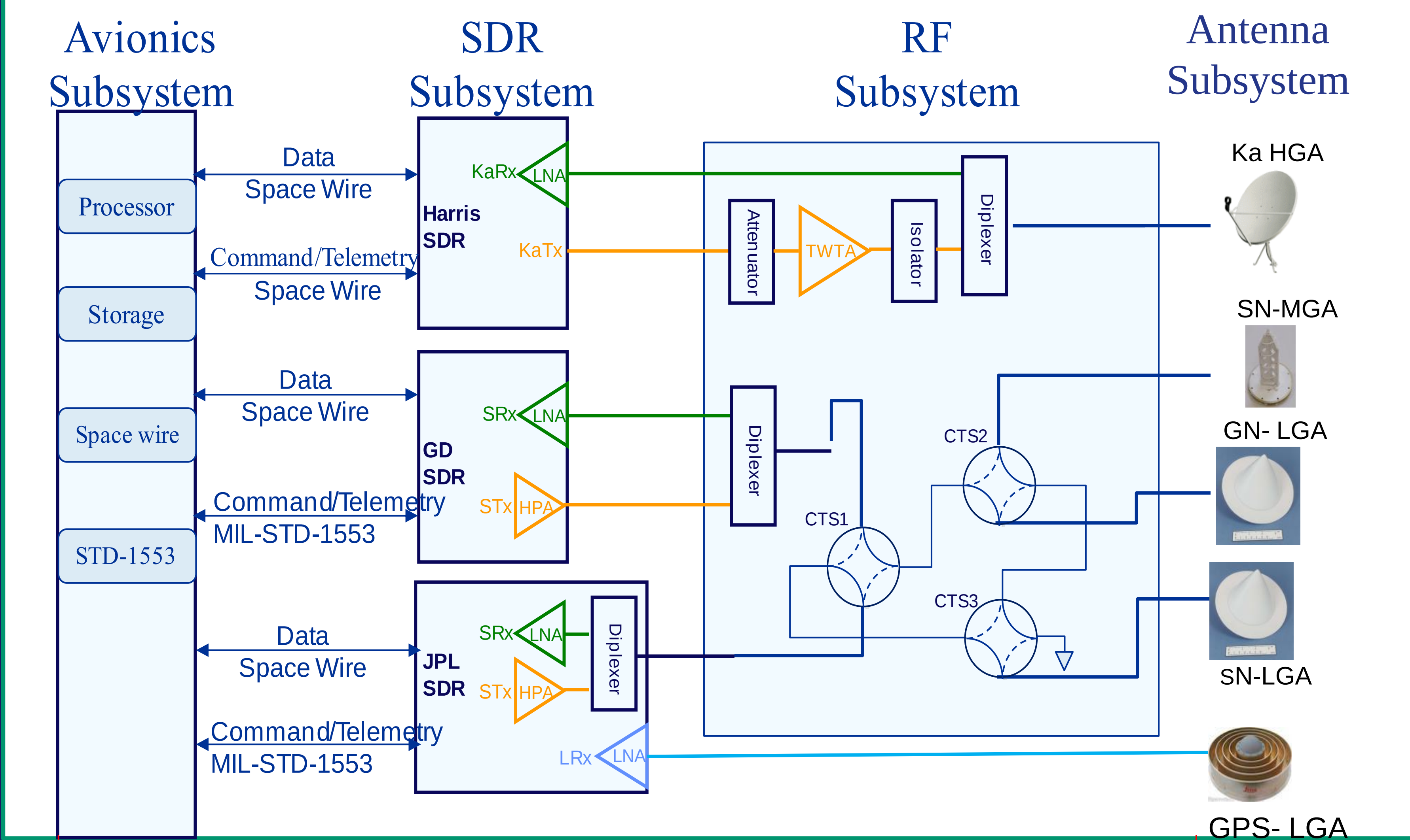
Specific waveform variations lead to numerous configurations

# Flight System Overview

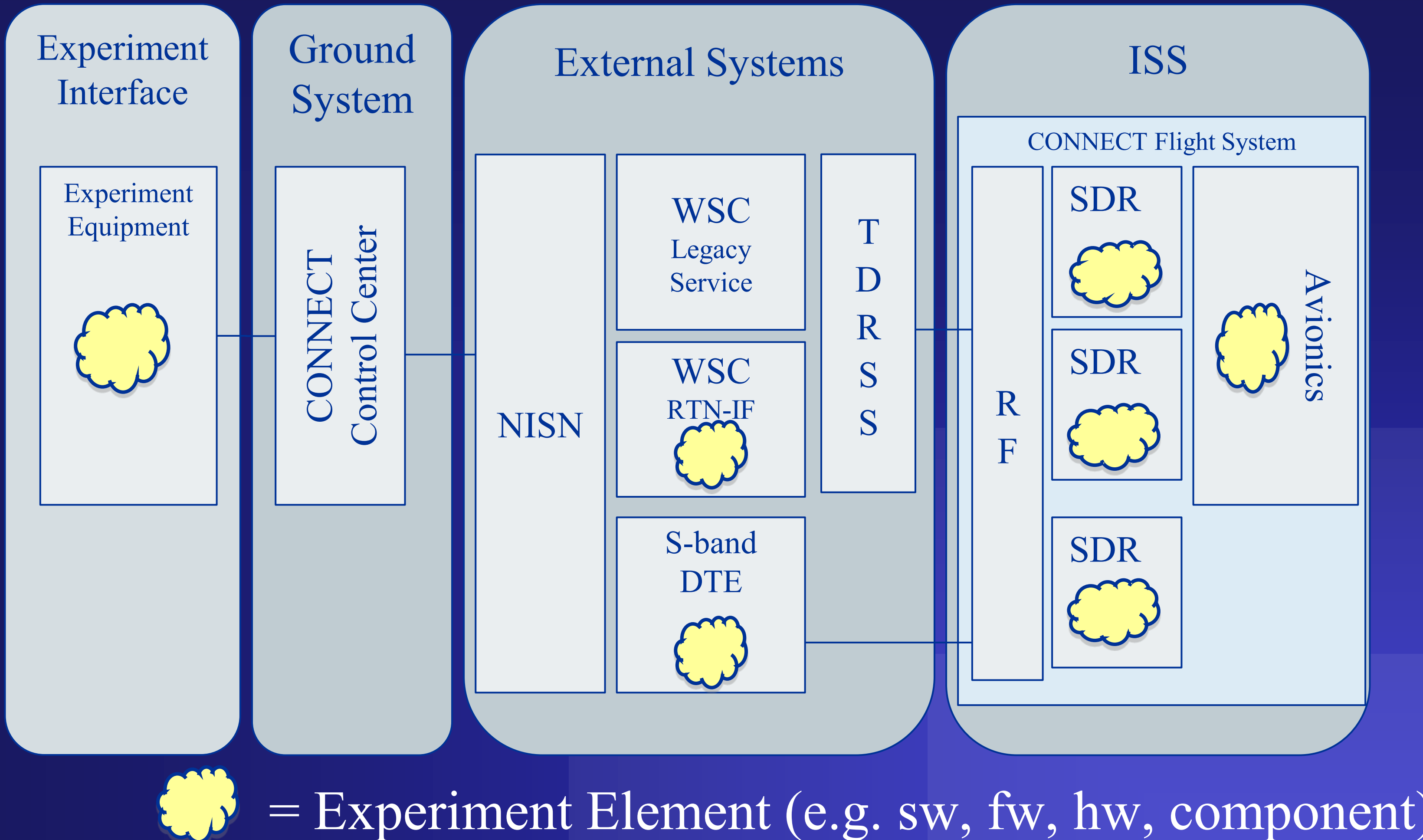
- Flight Computer/Avionics
- Communication System
  - SDRs
    - 2 S-band SDRs (1 with GPS)
    - 1 Ka-band SDR
  - RF
    - Ka-band TWTA
    - S-band switch network
  - Antennas
    - 2 - low gain S-band antennas
    - 1 - L-band GPS antenna
    - Medium gain S-band and Ka-band antenna on antenna pointing subsystem.
  - Antenna pointing system.
    - Two gimbals
    - Control electronics
- Flight enclosure provides for thermal control/radiator surface.



# SCaN Testbed Flight System Configuration



# Experimenter Access Points within CONNECT System




Experimenters have access to SDRs, avionics, various ground points

# Initial CONNECT Experiments

- Characterize GD and JPL SDR S-band performance over TDRSS
  - SDR-based TDRSS transponder (5th Gen)
  - On-orbit waveform performance
- Characterize Harris SDR Ka-band Performance over TDRSS
  - First Ka-band TDRSS transponder
  - On-orbit waveform performance
- SDR Platform Technology Assessments
  - On-orbit platform performance
- S-band and Ka-band IPv4 On-board Routing/Relay
  - Avionics IP routing, waveform independent
- GPS L1, L2, L5 Navigation
  - On-board GPS position determination using combination of signals
- DTN Node within SDR
  - DTN bundling functions within SDR
- TDRSS Waveform Development
  - Coherent mode waveforms added to launch capability

# CONNECT Phases

Phase I

Facility

FY08-FY12

- Core capabilities
- Flight System development/launch
- Flight Commissioning

Phase II

Experiments

FY12-FY15+

- NASA, industry, academia experiments
- Unique software and mission operations
- Minimum 2 year operations planned

**Announcement of Opportunity anticipated in 2011 for CONNECT Experiments for Phase II**

# SDR & STRS Architecture Conclusions

- STRS Architecture
  - Provides commonality among reconfigurable SDRs developed by NASA
    - Provides a coordinated method across the agency to apply SDR technology
  - Reduces SDR vendor dependence for waveform development
  - Tailored for resource constrained domains
  - Accommodates technology infusion, obsolescence
  - Standardization effort among WINNF, CCSDS, OMG in 2010-2011 timeframe

- SCaN Testbed, SDR Flight Experiment aboard International Space Station
  - Will provide an experiment opportunity for NASA, industry, and academia
    - Comm waveform development and operation in space
    - SDR-based mission concepts of operations
    - Networking experiments using avionics as router between SDRs, SDR nodes
    - GPS-based Navigation waveforms
  - Prove out STRS among multiple SDRs in space environment
  - Scheduled for launch in early 2012