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Space Communications and Navigation (SCaN) Testbed Project

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field, Ohio 44135

SCaN TESTBED PROJECT

SCaN Testbed Flight and Ground System Description

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PREFACE

National Aeronautics and Space Administration (NASA) is developing an on-orbit, adaptable, Software Defined Radio (SDR)/Space Telecommunications Radio System (STRS)-based testbed facility to conduct a suite of experiments to advance technologies, reduce risk, and enable future mission capabilities on the International Space Station (ISS). The Space Communications and Navigation (SCaN) Testbed Project will provide NASA, industry, other Government agencies, and academic partners the opportunity to develop and field communications, navigation, and networking technologies in the laboratory and space environment based on reconfigurable, software defined radio platforms and the STRS Architecture. The project was previously known as the Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT), Also included are the required support efforts for Mission Integration and Operations, consisting of a ground system and the Glenn Telescience Support Center (GRC TSC). This document has been prepared in accordance with NASA Glenn's Configuration Management Procedural Requirements GLPR 8040.1 and applies to the SCaN Testbed configuration management activities performed at NASA's Glenn Research Center (GRC). This document is consistent with the requirements of SSP 41170, Configuration Management Requirements, International Space Station, and GLPR 7120.5.30 Space Assurance Requirements (SAR).

This document describes the functional operation of the SCaN Testbed and provides a top level overview of information a prospective Experimenter will require in order to conduct experiments using the SCaN Testbed. Also included is an overview of the Mission Operations Network to provide the experimenter a holistic understanding to utilize the SCaN Testbed.

DOCUMENT HISTORY LOG

Status (Preliminary/ Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline	–	06/23/2011	Initial Release
Revision	A	04/26/2012	Incorporated CONN-CR-0560. Updated document with more complete Ground Integration Unit and WSC SDR information.

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1.0 INTRODUCTION

The Space Communications and Navigation (SCaN) Testbed Project will provide an on-orbit, adaptable, Software Defined Radios (SDR) and STRS-based facility on the ISS to conduct a suite of experiments to reduce risk and enable future mission capability. The SCaN Testbed Experiments Program objective is to devise and conduct on-orbit experiments to validate and advance the open architecture standard for SDRs; advance communication, navigation, and network technologies to mitigate specific NASA mission risks and to enable future mission capabilities.

1.1 Purpose

The purpose of this document is to describe the functional operation and capabilities of the SCaN Testbed and identify top level information a prospective experimenter would require in order to conduct experiments. Identified below are several research and technology areas the SCaN Testbed was designed to support.

- Software defined radio TRL advancement
- SDR reconfiguration
- SDR-based S-band Communications
- SDR-based Ka-band Communications
- On-board data management function and payload networking
- SDR-based GPS Navigation

1.2 Scope

The scope of this document covers the SCaN Testbed and corresponding operational systems. It provides a description of the system required for PI-led experimenters to propose experiments using SCaN Testbed capabilities.

2.0 DOCUMENTS

This section lists the NASA/Government and non-NASA/Government specifications, standards, guidelines, handbooks, or other special publications applicable to the application of this document. Access to Sensitive But Unclassified (SBU) controlled documents by experimenters/SCaN Testbed users can be made available after experimenter utilization approval. Sensitive but Unclassified is a NASA classification marking for proprietary or export controlled documents and information.

2.1 Applicable Documents

Applicable documents are those documents that form a part of this document. These documents carry the same weight as if they were stated within the body of this document.

Table 2-1—Applicable Documents

Document Number	**Applicable Document**
GRC-CONN-OPS-0371	Ground Systems Description and GIU User's Manual Status: Baseline, Effective Date: 9/9/2011
GRC-CONN-ICD-0023 Volume 1	CoNNeCT/GD SDR Interface Control Document Status: Baseline, Effective Date: 12/18/2009
GRC-CONN-ICD-0030 Volume 3	JPL STRS Operating Environment Data I/O Interface Desc. ICD SBU, Status: Draft In Review, Revision: A, Issue Date: 10/18/2010
GRC-CONN-ICD-0030 Volume 5	JPL Baseline Proc Mod Boot Code Comm & Telemetry Dictionary SBU, Status: Draft In Review, Revision: A, Issue Date: 10/18/2010
GRC-CONN-ICD-0090 Volume 1	CoNNeCT/Harris SDR Interface Control Document Status: Baseline, Effective Date: 10/15/2009
NPR 7150.2A	NASA Software Engineering Requirements Revision A, Effective Date: 11/19/2009
NASA/TM—2010-216809	Space Telecommunications Radio System (STRS) Architecture Standard

2.2 Reference Documents

Reference documents are those documents that, though not a part of this document, serve to clarify the intent and contents of this document.

Table 2-2—Reference Documents

Document Number	Reference Document
GRC-CONN-ICD-0427	CCC-CEC ICD Revision: Baseline, Effective Date: 1/4/2011
GRC-CONN-PLAN-0133	Missions Operation Plan Revision: Baseline, Effective Date: 07/19/2010
GRC-CONN-PLAN-0141	GIU Integration and Test Plan Status: Baseline, Effective Date: 7/19/2010
RTL-USR-4K95	S-Band TSIM User Guide Revision: 1.3, Date: 11 December 2009
450-SNUG	Space Network Users' Guide (SNUG) Revision: 9, Publication: August 2009
453-NENUG	Near Earth Network (NEN) Users' Guide Revision: 1, Publication: January 2010
	Ka-Band TSIM User Guide Revision:

2.3 Order of Precedence for Documents

All documents used, applicable or reference, are to be the approved versions released per the Project's configuration management system. All document changes issued after baseline establishment shall be reviewed for impact on the system. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 FLIGHT SYSTEM OVERVIEW

The SCaN Testbed Operations Project is comprised of a Flight System and a Ground System, an overview is shown in Figure 3-1. The integrated flight system is commonly referred to as the SCaN Testbed. It is resident on an ExPRESS Logistics Carrier (ELC) on an exterior truss of the International Space Station (ISS). Figure 3-2 illustrates the location of the SCaN Testbed on the ISS. The SCaN Testbed will launch aboard the Japanese H-II Transfer Vehicle (HTV) Multi-Purpose Exposed Pallet (EPMP) to the ISS, and will be transferred to the Port side ExPRESS Logistics Carrier (ELC) 3 via Extravehicular Robotics (EVR).

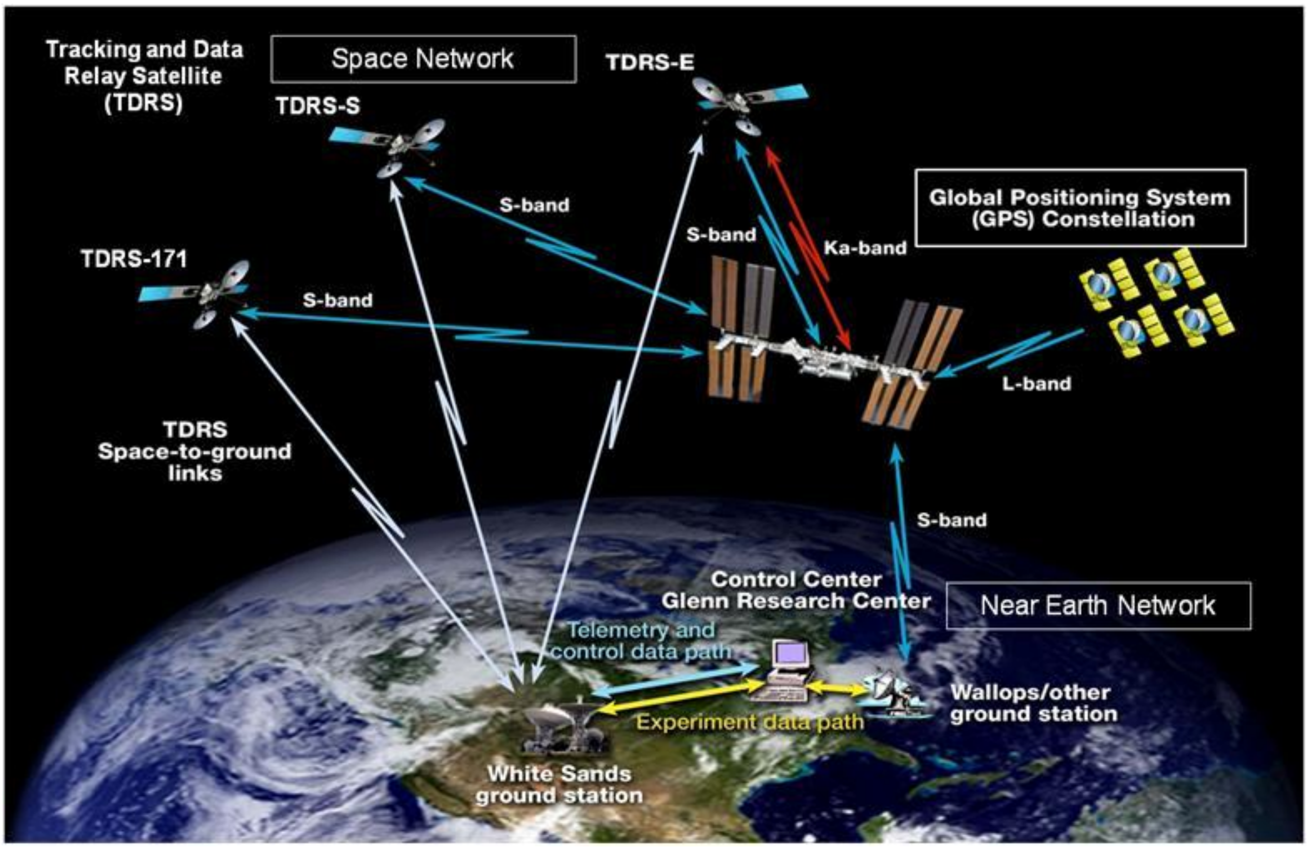

Figure 3-1—SCaN Testbed System Overview

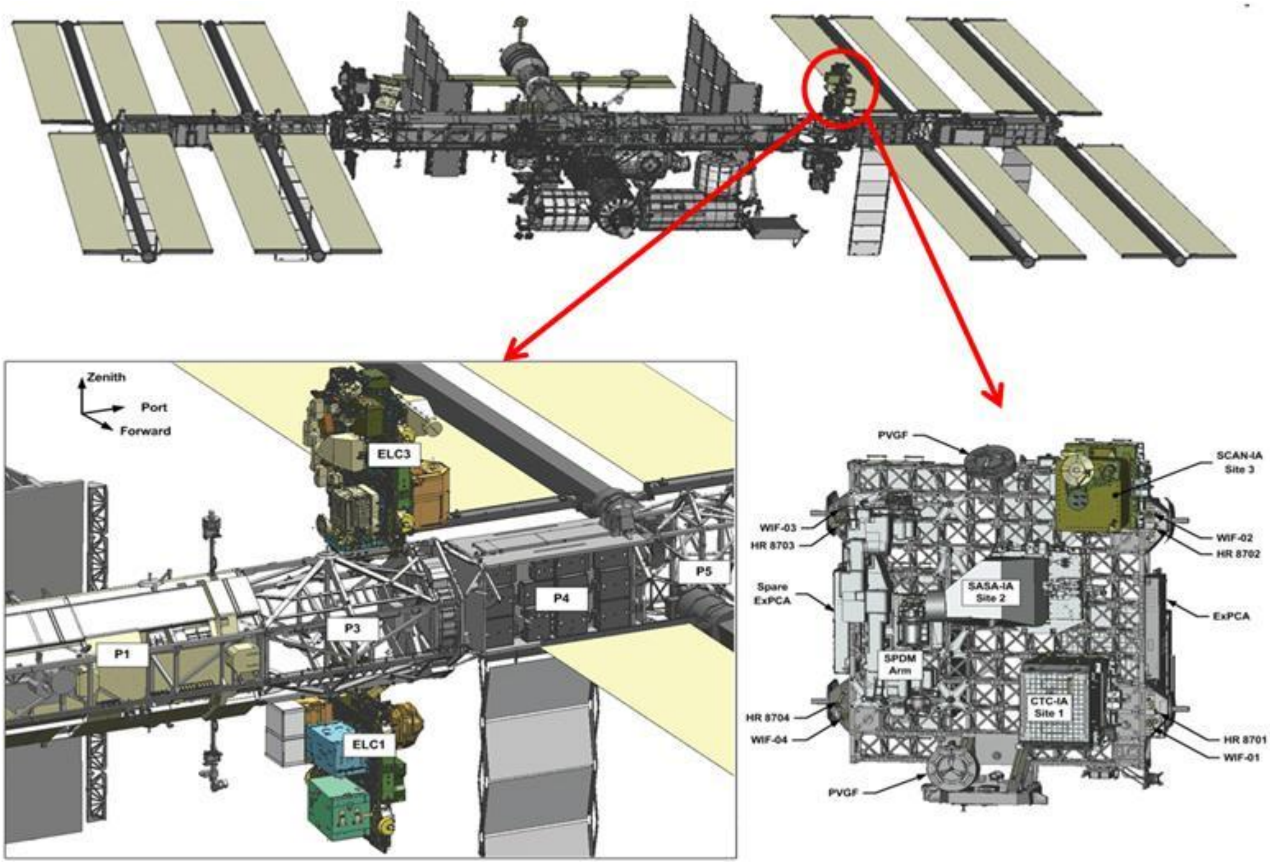

Figure 3-2—SCaN Testbed Location on ISS

The SCaN Testbed will consist of reconfigurable and reprogrammable Software Defined Radio (SDR) transceivers/transponders operating at S-band, Ka-band, and L-band, along with the required RF/antenna systems necessary for communications. Designed to operate for a minimum of two years, the three SDRs will provide S-band duplex Radio Frequency (RF) links directly with the ground, (also referred to as the Near Earth Network (NEN)), S-band duplex RF links with the Tracking and Data Relay Satellite System (TDRSS), (also referred to as the Space Network (SN)), Ka-Band duplex with TDRSS, and L-Band receive-only with the Global Positioning Satellite System (GPSS). The SCaN Testbed will be in low earth orbit and has multiple antennas providing connectivity to a series of NASA Space Network (SN) TDRSS satellites in geosynchronous orbits and NASA Near Earth Network (NEN) stations. The major components of the SCaN Testbed are shown in Figure 3-3.

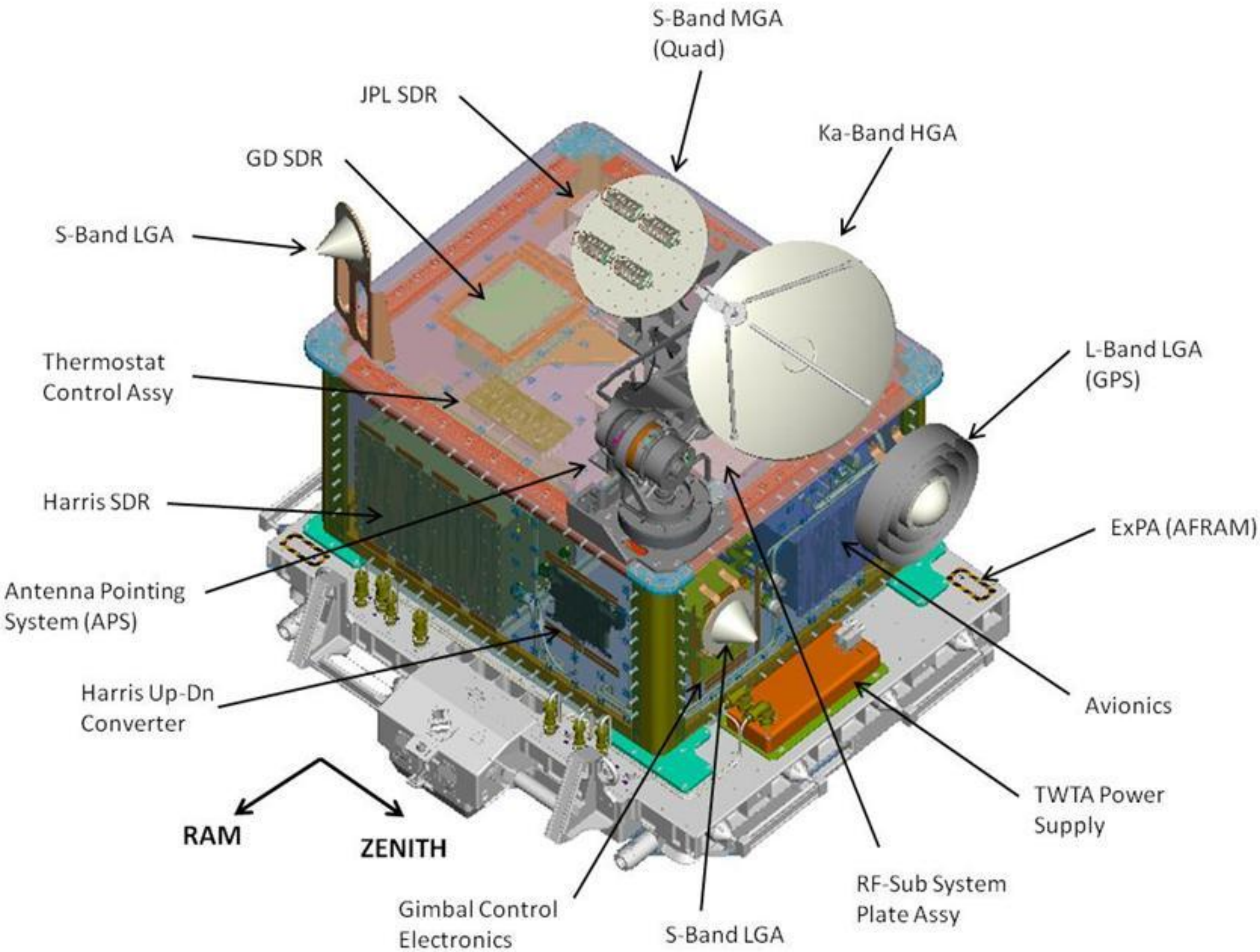

Figure 3-3—SCaN Testbed Major Components Viewed from Ram/Zenith Angle (Stowed Position Shown)

The SCaN Testbed system consists of a space-based flight system and a terrestrial-based ground system. The SCaN Testbed system interfaces with external systems to send and receive RF signals to and from space. These RF signals carry commands and data between the SCaN Testbed elements. Both the SCaN Testbed flight system and ground system send and receive commands, send and receive data, and manipulate (store, route, and process) data. The SCaN Testbed system consists of four primary subsystems. The four primary subsystems are the SCaN Testbed located on the Express Pallet on the ISS, the SCaN Testbed Support Equipment located at various ground stations, the SCaN Testbed Control Center (STCC) and the SCaN Testbed Ground Integration Unit with Support Systems both located at the Glenn Research Center.

The SCaN Testbed uses a frequency assignment between ISS and TDRS at S-band and Ka-band to send and receive data from the radios and antenna system. SCaN Testbed commands are sent from the SCaN Testbed Control Center located within the GRC Tele-Science Support (TSC) to the radios to configure and operate each radio. Communication with the SCaN Testbed through ISS is considered the primary path, this includes the wired path between the SCaN Testbed and ISS and the wireless path from ISS to the White Sands Complex (WSC). The WSC is wired to the remaining ground station facilities consisting of the Huntsville Operations Center (HOSC), the NASA Integrated Service Network (NISN) and the SCaN Testbed Control Center (STCC), the SCaN Testbed Experiment Center (STEC) is also part of the STCC.

A RF data connection will provide a direct bi-directional connection between the radios and ground stations. This second communication path (commanding and bidirectional data) is the experimental link with the SN and the NEN, this is the wireless path between the SCaN Testbed and Ground Stations such as the Wallops Ground Station. The TSC facility located at GRC allows payload developers and scientists on earth to monitor and control experiments onboard the International Space Station (ISS). Data from the radios are received at the White Sands Complex, Las Cruces, NM via TDRS and routed to GRC. For Global Positioning System (GPS) experiments, the JPL radio is configured to receive and process GPS signals. Data is collected on-board and sent to ground via TDRS or the primary path.

3.1 Avionics Subsystem

The Avionics Subsystem provides the electrical and command & data handling interface between ISS systems and the SCaN Testbed systems. These interfaces include power distribution and control, grounding and isolation, communication (commanding and data) interfaces with ISS, flight system health and status, and SCaN Testbed subsystem communications and control as shown in Figure 3-4. In addition, the Avionics Package contains software that can be reprogrammed on orbit to support experiment specific requirements. The Ground Support Equipment (GSE) interface is for pre flight test only.

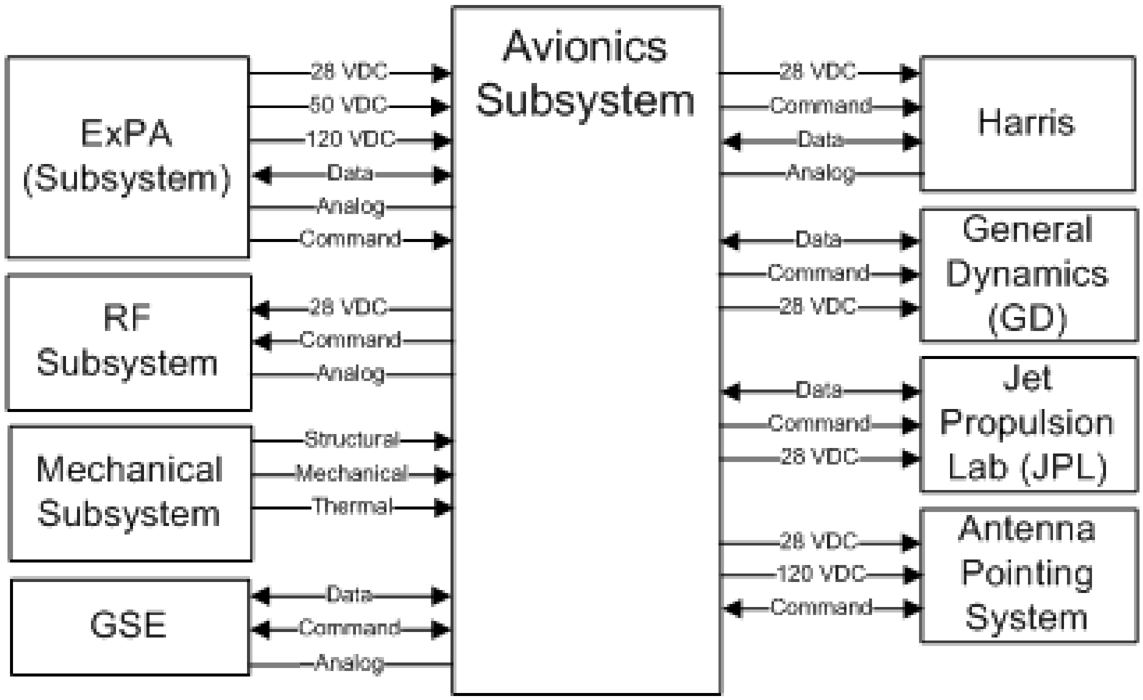

Figure 3-4—Avionics System Block Diagram

3.1.1 Commanding and Data

The Avionics Subsystem interfaces with the SCaN Testbed subsystems through MIL-STD-1553 and Spacewire protocols; and with the ELC through dual redundant (A/B), RT MIL-STD-1553, and 100 Base Ethernet in accordance with IEEE 8802-3 (Ethernet link for data flow from the SCaN Testbed to the ELC only) protocols as shown in Figure 3-5. Each SDR has a command and control interface and data communications interface. The GD and JPL SDRs use MIL-STD-1553 for command and control and Spacewire for the data interface. The Harris SDR has two separate Spacewire interfaces, one for command/control and one for data. The RF subsystem Traveling Wave Tube Amplifier (TWTA) and coax switches are controlled through discrete digital lines. The Antenna Pointing System Gimbal Control Electronics (GCE) also interfaces with the avionics package for command and control through a MIL-STD-1553 interface.

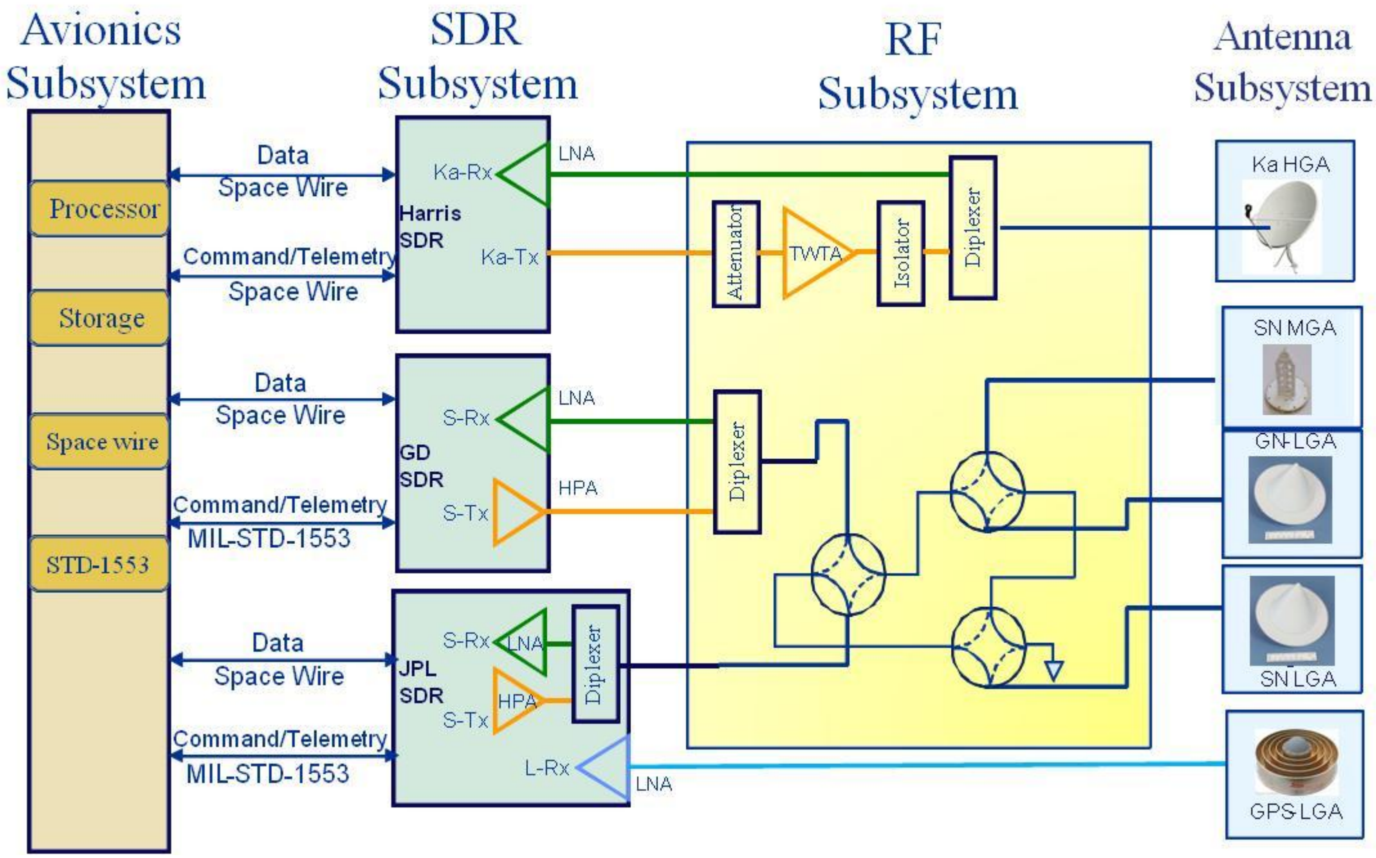

Figure 3-5—Flight System Block Diagram

3.2 Radio Frequency Subsystem

The Radio Frequency (RF) Subsystem is comprised of a Traveling Wave Tube Amplifier (TWTA), Coaxial Transfer Switches, Antennas, Diplexers, an RF Isolator, an RF Attenuator, and transmission lines to interconnect the RF Subsystem components with the radios. The RF Subsystem radiates RF signals intended for TDRS and the ground; and receives RF signals from TDRS, the ground, and the GPS system. The architecture of the SCaN Testbed has the ability to send RF signals from two separate SDRs to two antennas simultaneously. The ability to send RF signals from two separate SDRs to the same antenna or from a single radio to two different antennas is not supported by the architecture and cannot happen due to switch positions required.

The RF Subsystem contains four active devices: the TWTA and three switches. All components that comprise each of the three RF paths; Ka-band, S-band, and L-band are shown in Figure 3-5. The RF Subsystem interfaces with the Avionics Subsystem, the Flight Enclosure, the Antenna Pointing Subsystem, and the three Radios.

3.2.1 High Power Amplifier

The TWTA is a Ka-band high power amplifier that can generate up to 40 watts of microwave RF power. The Avionics Subsystem controls the TWTA through both a discrete logic command interface and the 28 Vdc power supplied from the TWTA Power Supply Unit (PSU). The TWTA was developed and provided by L-3 Communications. The TWTA PSU converts 120Vdc from ISS to 28Vdc for use by the TWTA. The TWTA must be actively commanded by the Avionics Subsystem to operate.

The inadvertent activation of Ka-Band RF has been identified as a catastrophic hazard. To implement the required two-fault tolerance and prevent inadvertent activation the following controls of this hazard have been identified:

- ELC 28 Vdc and 120 Vdc power to SCaN Testbed. The SCaN Testbed shall be powered down during EVA, EVR, and docking or undocking of visiting vehicles in the Boresight Radiation Zone (BRZ). This will be a Flight Rule for ISS Operations.

- Power to the SCaN Testbed TWTA. If the TWTA is not operating, the hazard cannot exist, as the TWTA is required to generate the Ka-band radiation. The SCaN Testbed software controls the power to the TWTA, and the command to the discrete signal to turn the power on will be considered a safety-critical command. The software will be designed and built to power up the SCaN Testbed in a “safe mode”, which in this case is defined as the power to the TWTA being off. The software to turn on the TWTA will be built in compliance with SSP 50038.

- Power to the SCaN Testbed Harris SDR. If the Harris radio is not operating, the hazard cannot exist, as the Harris radio is the only one of three radios that can produce Ka-band transmissions. The SCaN Testbed software controls the power to the Harris radio, and the command to the discrete signal to turn the power on will be considered a safety-critical command. The software will be designed and built to power up the SCaN Testbed in a “safe mode”, which in this case is defined as the power to the Harris radio being off. The software to turn on the Harris radio will be built in compliance with SSP 50038.

The second and third control will be implemented by GRC software developers. The software will comply with SSP50038’s General Requirements and the Must Not Work Requirements. SCaN Testbed developers will implement Control Path Separation to meet SSP50038’s requirements. Control Path Separation is accomplished using a separate task for each of the safety critical power control tasks (e.g., one for the Harris SDR and one for the TWTA power control).

The Harris and TWTA power commands have been identified as safety critical commands and like all safety commands must come from an operator at the Payload Operations Integration Center (POIC) at MSFC not at the Telescience Support Center (TSC) at GRC. These power commands utilize an ARM/FIRE type sequence. The ARM command must come first and the power must follow within 60 seconds.

3.2.2 Coaxial Transfer Switches

The S-band Coaxial Transfer Switches (CTS) are used to route the microwave RF signals from the various SDRs to the various antennas. The switches are controlled by the Avionics Subsystem via pulsed 28 Vdc power and switch positions are monitored by the avionics package. Different combinations of switch states will allow the SDRs to connect to different antennas. Each S-band SDR has access to each S-band antenna through the transfer switch network. The switches are dual input/dual output switches routing two inputs to two outputs simultaneously. Detailed information for the switch nomenclature is identified in Figure 3.2.2-1. Table 3.1 identifies the allowable combinations of switch positions to route the two S-band SDRs to the various antennas.

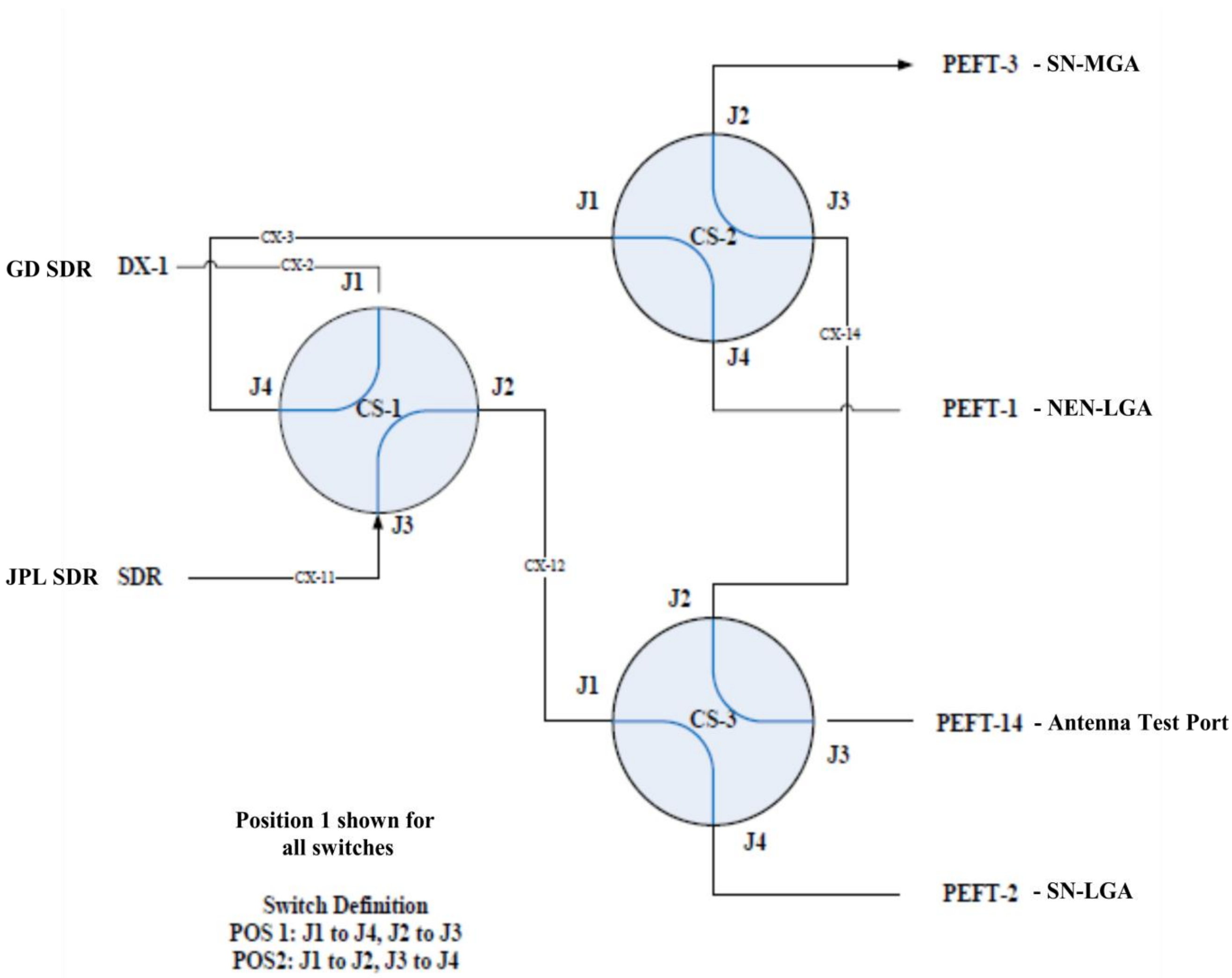

Figure 3-6—S-band RF Path Definition - CTS Matrix Switch Positions

Table 3-1—S-band RF Path Definition - SDR to Antenna

Path	SDR	CS-1 Pos/Path	CS-2 Pos/Path	CS-3 Pos/Path
1	GD	1	1	NC
2	GD	2	NC	1
3	GD	1	2	NC
4	JPL	2	1	NC
5	JPL	1	NC	1
6	JPL	2	2	NC
7	ANTENNA TEST PORT	NC	2	1
8	ANTENNA TEST PORT	NC	NC	2
9	ANTENNA TEST PORT	NC	1	1
10	GD	2	1	2
11	JPL	1	2	2
12	GD	2	2	2
13	JPL	1	1	2

3.3 Antenna Pointing System

The Antenna Pointing Subsystem (APS) moves the S-Band Medium Gain Antenna and the Ka-Band High Gain Antenna in two rotary axes to track TDRS satellites from the ELC3 location on ISS. The gimbaled antennas are locked for launch and deployed on-orbit. The SCaN Testbed Flight System antenna Field-of-View characteristics are shown in Figures 3.3-1 through 3.3-5.

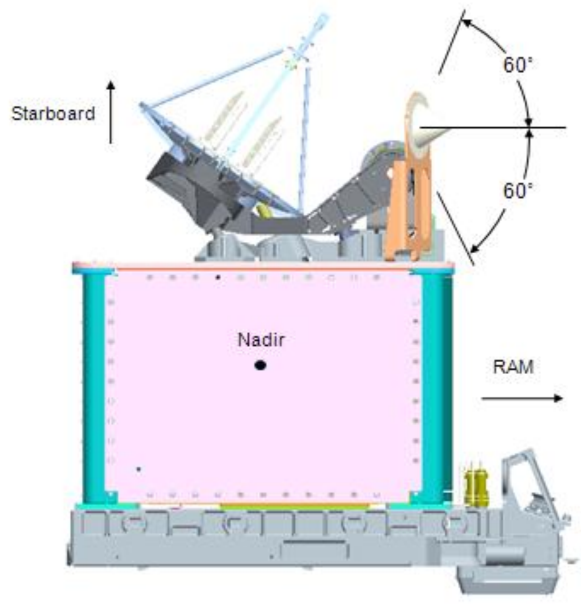

Figure 3-7—Antenna Nadir Field-of-View

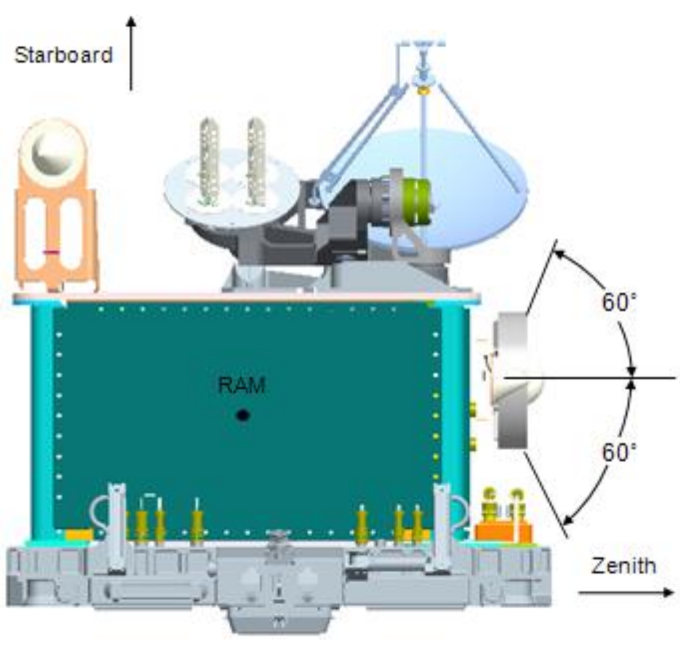

Figure 3-8—Antenna Ram Field-of-View

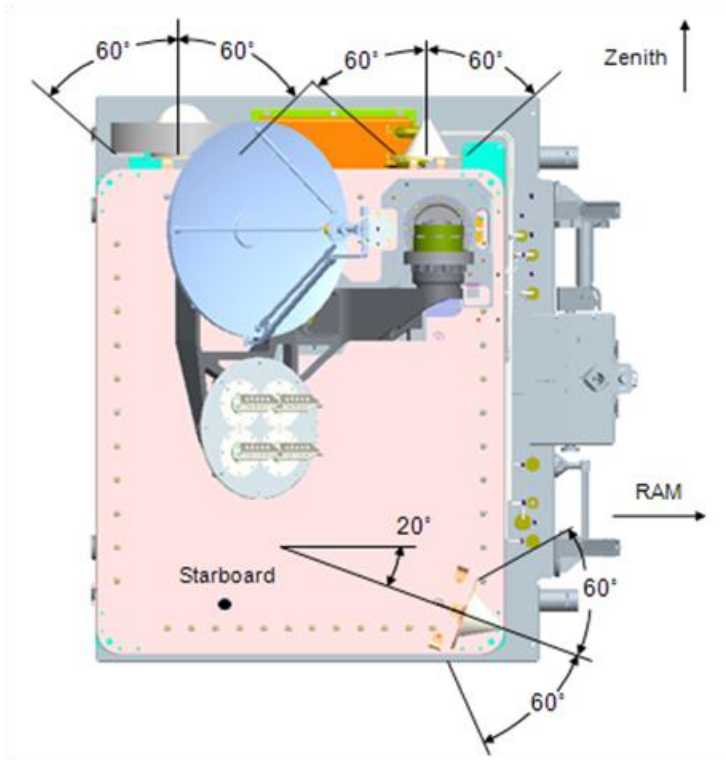

Figure 3-9—Antenna Starboard Field-of-View

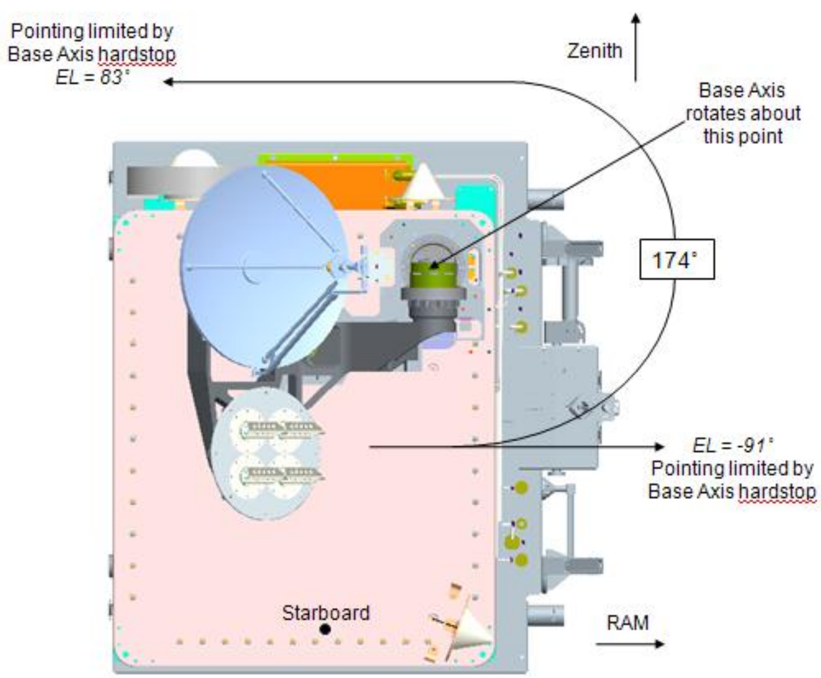

Figure 3-10—Antenna Starboard Ka Field-of-View

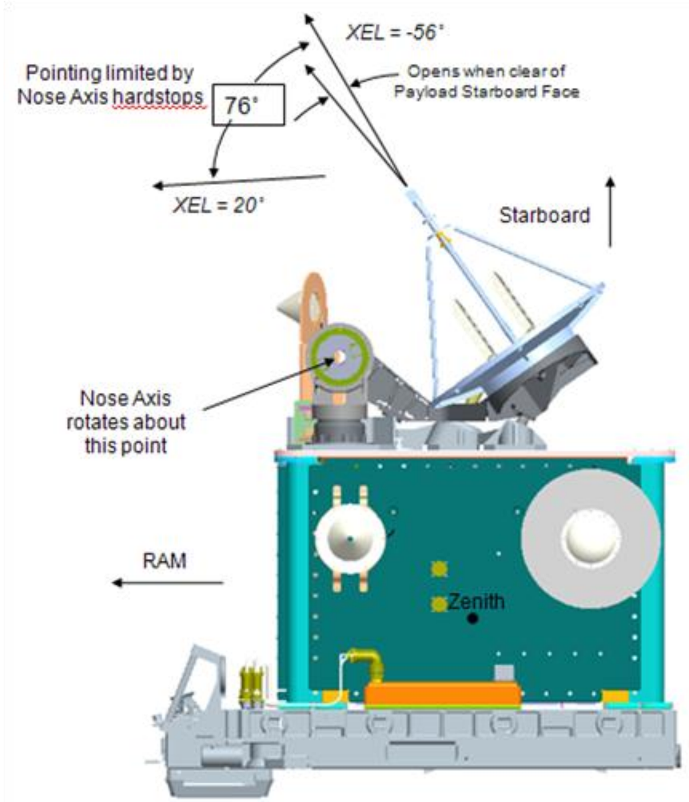

Figure 3-11—Antenna Zenith Field-of-View

3.4 Software

The SCaN Testbed avionics subsystem and the three SDRs are launched with a default version of software/firmware that has been purposely designed to be modified while operational on the ISS. Once this software/firmware is modified it will have to be reloaded if the original launch configuration is required. Each of the three SDR’s software and firmware can be reconfigured/updated from the ground, while only software can be reconfigured/updated from the ground for the avionics system. The default versions have been developed and implemented in accordance with NPR 7150.2, NASA Software Engineering Requirements, and the procedural requirements it specifies for Class C software. Any reconfigurations/updates to the avionics subsystem default version will be developed and implemented in accordance with Class C procedural requirements as stated in NPR 7150.2, NASA Software Engineering Requirements. Any reconfigurations/updates to any individual or combination of the SDRs default version will be developed and implemented in accordance with Class E procedural requirements as stated in NPR 7150.2, NASA Software Engineering Requirements, as a minimum, plus selected augmented Class D requirements as supplied by NASA and negotiated between NASA and the Experimenter.

3.4.1 Avionics Subsystem Software

The avionics infrastructure software runs on a single-board computer to process commands, provide thermal monitoring and control, communicate with the radios and ISS, command and configure the radios, control RF subsystem switching, command the APS, collect sensor data, send telemetry to the ground, and perform data and file management. Infrastructure software development and subsequent revisions for the Avionic subsystem is the responsibility of the Project. Experimenters may also run software on the avionics for experiments. Experimenter software might include such functions as network routing among radios using IP or DTN protocols, data simulation from a stored file, collection of data received by a radio or other application. Experimenter software running on the avionics will be integrated by the Project in conjunction with the experimenter's support.

3.4.2 Software Defined Radio Software

Each of the three Software Defined Radios has an Operating Environment (OE), which includes an operating system and provides infrastructure services to applications and waveforms in accordance with the Space Telecommunications Radio System Standard (STRS). In addition to the OE, each SDR runs waveform applications which implement the unique capabilities of the radio to receive and transmit radio frequency (RF) signals. The OE is the STRS architecture standard middleware that abstracts the SDR hardware from the waveform application software (i.e. general purpose processor code and Field Programmable Gate Array (FPGA) configuration data). Each SDR has an OE which acts as an operating system to process commands, interact with hardware, and configure the SDR. All three OEs comply with the STRS Standard. Each SDR must run waveforms which implement the capability of the radio and generate the RF signal that will be transmitted.

OE updates, if needed, will generally be developed by the Project in partnership with the SDR platform developer. Waveform applications will be developed and provided by experimenters for operation on the individual SDRs.

3.5 Software Defined Radios

At the core of the Flight System are three unique software defined radios (SDRs) provided by government and industry partners. In general, an SDR system is a radio in which some or all of the physical-layer and higher layer functions are implemented in software and/or firmware. In a generic SDR, the signal received at the antenna is amplified by a low-noise amplifier and then immediately digitized by an analog to digital converter, processed by the software functionality of the SDR's digital processing, and exits the SDR in a digital baseband form. Conversely, digital baseband data entering the SDR is processed by the software functionality of the SDR's digital processing, converted to an analog RF signal by a digital to analog converter, and amplified by a high-power amplifier before being transmitted through the antenna. The SCaN Testbed has three separate SDR systems. In addition to the capabilities identified below, all radios are capable of support networking, navigation, time transfer, file management, and data analysis.

- The JPL provided SDR leverages off the developments of the Electra radio. This SDR is capable of full-duplex, TDRSS-compatible, STRS-compliant S-band communications and receive-only GPS L-band navigation.
- The Harris Corporation provided SDR was developed under a cooperative agreement with GRC. This SDR is capable of full-duplex, TDRSS-compatible, STRS-compliant Ka-band communications.
- The General Dynamics (GD) provided SDR was developed under a cooperative agreement with GRC. This radio leverages developments of the TDRSS fourth-generation transponder and is capable of full-duplex, TDRSS-compatible, STRS compliant S-band communications.

The radios are mounted to the Flight Enclosure and functionally interface with the Avionics and RF systems as shown in Figure 3-5. Note certain capability configurations enable multiple SDR use for networking and/or routing experiments.

3.5.1 General Dynamics (GD) Software Defined Radio

The GD radio will utilize S-band for forward and return links to TDRSS or direct links to a ground station, this radio is a reprogrammable S-band transceiver designed for space use. The delivered SDR is compliant with the STRS architecture. The S-band SDR operates at two unique frequency pairs for operation with the multiple access service of TDRSS or the single access service of TDRSS. Either frequency can be used for the direct to ground link. Each operating frequency provides a 6 MHz wide RF link for use by the experimenter waveform application. The GD SDR contains Actel RTAX and Xilinx QPRO Virtex II Field Programmable Gate Arrays (FPGA), a ColdFire micro processor, and utilizes Verilog and Very high speed integrated circuits Hardware Description Language (VHDL) Hardware Description Languages.

3.5.2 Jet Propulsion Laboratory (JPL) Software Defined Radio

The JPL radio utilizes S-band for forward and return links to TDRSS or direct links to a ground station. The JPL SDR also receives GPS frequencies of L1, L2, and L5 as shown in Table 3.2. This radio is a reprogrammable S-band transceiver designed for space use. The delivered SDR is compliant with the STRS architecture. The JPL S-band SDR operates at any frequency in the 2.025-2.120 Rx band and 2.2-2.3 Tx band. The waveform loaded at launch uses two discrete frequencies and works with the multiple access service of TDRSS or the single access service of TDRSS. Either frequency of the launch waveform can also be used for the direct to ground link. The JPL radio has an 11 MHz receive bandwidth available for experimenter waveform applications while the launch waveform uses a 6 MHz receive channel. The JPL transmitter has a 16 MHz bandwidth available to experimenters, however the current regulatory approval is for two 6 MHz channels at S-Band. The use of other transmit frequencies within the capabilities of the radio would require National Telecommunications and Information Administration (NTIA) approval. The JPL SDR contains Actel RTAX 2000 and Xilinx FPGAs, an Actel 697 with SPARC processor, RF converter section, and a nominally 10W power amplifier (approximately 7.5 Watts after losses).

Table 3-2—L-band Waveform Parameters for JPL

GPS Signal Description	Frequency	Reference
L1 C/A Code	1575.42 MHz	IS-GPS revision D
L2 Civil Code	1227.60 MHz	
L5	1176.45 MHz	IS-GPS-705

3.5.3 Harris Corporation Software Defined Radio

The Harris radio will utilize the TDRSS Ka-band service. This radio is a reprogrammable Ka-band transceiver designed for space use and the delivered SDR is compliant with the STRS architecture. The Ka-band SDR operates at a unique Ka-band frequency pair for operation with the single access Ka-band service of TDRSS. The Ka-band SDR provides a 225 MHz wide RF link for use by the experimenter waveform application. The Harris SDR contains Xilinx Vertex-4 FPGAs, an AITech 950 single board computer utilizing the VxWorks Operating System, and an S-band to Ka-band RF converter.

3.5.4 White Sands Complex Software Defined Radio

The White Sands Complex Software Defined Radio (WSC-SDR) will be located at the Space Network's White Sands Complex to provide a reprogrammable ground radio for experiments. The WSC-SDR is designed to facilitate waveform implementation for SCaN Testbed experimenters beyond TDRSS legacy waveforms. Given the unknown nature of SCaN Testbed experiments, the WSC-SDR will focus on providing a generic signal processing capability. The WSC-SDR will be a platform for SCaN Testbed experimenters to create a matched modulator and demodulator for the waveforms loaded onto SCaN Testbed's space segment.

The WSC-SDR contains the FPGA, CPU, and GPU resources sufficient to demodulate and decode a waveform transmitted from the Harris radio that includes high-order modulation and LDPC encoding on the 225 MHz KaSAR service or the 6 MHz S/MA and SSA return service by interfacing with the Space Network's 225 MHz IF service. It is also capable of encoding and modulating data for the S- and Ka-band forward service, once the Space Network makes the service available. The WSC-SDR will provide a digital signal processing (DSP) capability through the combination of field-programmable gate arrays, multiple multi-core central processing units, and one or more graphical processing units. Experimenters will access these hardware capabilities by utilizing VHDL and higher-level software to implement their unique designs. A similar SDR will also be available as part of the GRC Supporting Systems for experiment development and test.

As summarized above the WSC-SDR is designed to provide a generic signal processing capability to SCaN Testbed experiments. The radio will reside in the same rack as the SCaN Testbed WSGT Front-End Processor (FEP). The radio will provide a bi-directional RF interface compatible with WSC's 370 MHz SSA and KaSA IF services. Experimental data will be returned to the SCaN Testbed ground system at GRC via a TCP network connection over the SCaN Testbed VPN. A second network interface will provide control of the WSC-SDR and system health and status telemetry during operation. The WSC-SDR will also accept 10 MHz, 1 pulse-per-second (PPS), and IRIG-B references from the WSC Common Time and Frequency System (CTFS).

3.6 Experiment Operations

After the initial checkout and commissioning, the communications experiments will examine the operational paradigm-shift of using the flexibility offered by SDR for space communications and navigation. Experiments will be conducted using the capabilities of the radio such as communications and navigation waveforms and applications. These investigations will use the frequency bands S-band, L-band for GPS, and Ka-band. GPS reception will focus initially on the L1 signals and future L2 and L5 signals during the operations stage as they become available. Parameters such as availability, integrity, and performance will be evaluated. Networking capability is envisioned as part of the payload design. Ka-band experiments will include high rate communications, tracking, and pointing and channel characterization. The SCaN Testbed is intended to be reconfigured from the ground with new software and firmware. Applications and waveform parameters such as forward error correction codes (e.g., low density parity check, block codes, Reed Solomon), adaptive power control, signal (pre)distortion (e.g., filtering), acquisition, and timing signals/parameters will be varied. SDR assessments will include Single Event Upset (SEU) fault mitigation and software reliability studies. The radios and waveforms will be compliant with the STRS architecture. The lessons learned from utilizing STRS will be the basis for updating the standard in the future, likewise, updated architecture implementations can be investigated.

Some experiments may involve modifying SDR waveforms or payload controller applications. These new applications and/or waveforms, once verified on the ground, will require reliable file transfer to the target elements of the SCaN Testbed on-board system. Once installed, a sequence of pre-defined events will demonstrate the new capabilities. SCaN Testbed experiments will fall into five general categories: advancing STRS/SDR technology, advanced communication concepts, on-orbit networking technology, and next generation navigation techniques.

SCaN Testbed performance data will be collected and assessed over the life of the project. Comparisons will be made with archived ground unit verification and previous on-orbit performance to assess overall system health, determine sustaining engineering priorities, assist with anomaly resolution, and support experiment operations.

3.6.1 Waveforms

Waveform software and firmware defines functionality for most of the SDRs. STRS defines standards for SDRs to maximize waveform firmware and software reuse and reduce porting effort between various radios. All three SCaN Testbed radios will be launched with baseline STRS-compliant waveforms. A sample of the baseline waveforms provided and used by the Mission PI Team and in-house experiment team are provided in Tables 3.3 and 3.4.

SDRs consider a waveform much more than just the over-the-air electromagnetic signal. A SDR waveform encompasses all of the processing that occurs to take user data to and from the over-the-air signal. The waveform is an application running on the SDR. SCaN Testbed waveforms will be run on the three radios using their specific hardware devices, however, all three SDRs will have processor based software and FPGA-based firmware that implements the waveform processing functions.

The SCaN Testbed is intended to have waveforms uploaded to the radios to replace or complement the initial waveforms.

3.6.2 Waveform Updates

New waveforms and operational environment software will be developed on a SCaN Testbed development system and verified in the SCaN Testbed Ground Integration Unit (GIU) prior to being uploaded to the SCaN Testbed from the SCaN Testbed Control Center (STCC). The GIU is used for proof-of-concept development, evaluation, testing, and verification of SDR waveform experiments and avionics software upgrades. The GIU also includes the essential elements needed to develop Flight Operating Procedures, train Ground Operations Personnel, and perform flight anomaly resolution. The GIU with support systems consists of the GIU, an ExPRESS Logistics Carrier (ELC) Simulator (ELC-Sim), a Telescience Resource Kit (TReK) Workstation, TDRSS Simulators (T-Sim), a Near Earth Network Simulator (NEN-Sim), a Global Positioning Satellite Simulator (GPS-Sim), a WSC-SDR, and Ground Support Equipment (GSE). GSE is comprised of spectrum analyzers, power meters, power supplies, personal computers, and other general test equipment. The GIU includes SDR Engineering Models and an Avionics Package flight spare unit. The GIU also includes a TWTA, Gimbal Control Electronics (GCE), an Interconnect Harness, Temperature Sensors, an Antenna Pointing System (APS), Gimbals, an RF System custom version, and additional support equipment.

Verification on the GIU will include development of procedures and ground performance characterization as insurance to safeguard the payload. This verification will culminate in an experiment operational readiness review prior to scheduling use with the SCaN Testbed. The STCC mission operations team will then either have the software and firmware uploaded prior to the experiment period or upload the new software and firmware with the experiment co-located in the SCaN Testbed Experiment Center (STEC), as the experiment plan prescribes.

The required links for the waveform verification depend on the waveform itself, and may include the TDRSS S/MA, SSA, and Ka-band systems; the Near Earth Network; or GPS.

The SDRs can perform physical layer functions, and have the payload controller/data manager perform the higher layer functions or the SDR can perform many of the high level functions within the SDR itself. Part of the science and technology objectives are to investigate having the radio take on more functionality of the communication system. As the experiment period progresses, higher layer functionality and some control functions are expected to be incorporated into the SDRs to demonstrate the potential advantages of expanding the capabilities of the radios. This will involve loading new waveforms onto the radios and removing functionality from the payload controller/data manager service.

Table 3-3—Transmit Launch Waveforms

SDR	TDRSS Mode	Modulation	User Data Rate (kbps)	SNUG Data Source Reference	Applicable Service
GD	S-band DG1, Mode 1	SQPN I/Q Power Ratio – 1:1	24	B3.2.1a Balanced Power Single Data Source – Identical Data on the I and Q channels. I DR = Q DR = source DR	MA, SMA, SSA
GD	S-band DG1, Mode 1	SQPN I/Q Power Ratio – 1:1	192	B3.2.1b Balanced Power Single Source Data – Alternate I/Q Bits I DR = Q DR = ½ source DR	SMA, SSA
GD	S-band DG1, Mode 2	SQPN	24	B3.2.1a Balanced Power Single Data Source – Identical Data on the I and Q channels.	MA, SMA, SSA
GD	S-band DG1, Mode 2	SQPN	192	B3.2.1b Balanced Power Single Source Data – Alternate I/Q Bits	SMA, SSA
GD	S-band DG1, Mode 3	QPSK I/Q power ratio – 1:4.	Q: 1000 I: 1 kbps	B3.2.1f Unbalanced Power Dual Data Sources	SMA, SSA
GD	S-band DG2	SQPSK I/Q power ratio 1:1	1000	B3.3.1a Balanced Power Single Data Source – Alternate I/Q bits	SMA, SSA, NEN
JPL	S-band DG1, Mode 2	SS-BPSK	24	B3.2.1d DG1 Configurations. Single Data Source with Single Data Channel	MA, SMA
JPL	S-band DG1, Mode 2	SS-BPSK	24	B3.2.1d DG1 Configurations. Single Data Source with Single Data Channel	SSA
JPL	S-band DG2	BPSK	192.362	B3.3.1c DG2 Configurations. Single Data Source with Single Data Channel	SSA
JPL	S-band DG2	BPSK	769.45	B3.3.1c DG2 Configurations. Single Data Source with Single Data Channel	SSA, NEN
Harris	Ka-band DG2	SQPSK I/Q power ratio 1:1	12.5 Mbps	B3.3.1a Balanced Power Single Data Source – Alternate I/Q bits I DR = Q DR = ½ source DR	KaSA
Harris	Ka-band DG2	SQPSK I/Q power ratio 1:1	100 Mbps	B3.3.1a Balanced Power Single Data Source – Alternate I/Q bits	KaSA

Table 3-4—Receive Launch Waveforms

SDR	Spreading	Demodulation	User Data Rate (kbps)	SNUG Data Source Reference	Applicable Service
GD	Spread	QPSK. I/Q power ratio : +10 dB	18 (I channel)	Section 5.2.2.1a & 6.2.2.1a Unbalanced QPSK modulation”	MA, SMA, SSA
GD	Spread	QPSK. I/Q power ratio : +10 dB	72 (I channel)	Section 5.2.2.1a & 6.2.2.1a Unbalanced QPSK modulation	MA, SMA, SSA
JPL	Spread	BPSK	18	Section 5.2.2.2a & 6.2.2.2a BPSK Modulation (PN Modulation Enabled)	MA, SMA
JPL	Spread	BPSK	18	Section 5.2.2.2a & 6.2.2.2a BPSK Modulation (PN Modulation Enabled)	SSA
JPL	Nonspread	BPSK	155.346	Section 6.2.2.2b BPSK Modulation (PN Modulation Disabled)	SSA, NEN
JPL	Nonspread	BPSK	769.45	Section 6.2.2.2b BPSK Modulation (PN Modulation Disabled)	SSA
Harris	Nonspread	BPSK	3 Mbps	Section 8.2.2.2b BPSK Modulation (PN Modulation Disabled).	KaSA
Harris	Nonspread	BPSK	12.5 Mbps	Section 8.2.2.2b BPSK Modulation (PN Modulation Disabled).	KaSA

3.7 Experimenter Data

Telemetry information generated by the SDRs, flight avionics, and the antenna/gimbal are gathered by the PAS and sent to the STCC through the primary link. This data is displayed on TReK workstations both in the STEC and STCC. A partial set of the telemetry items can be displayed on the TReK workstation, in predesigned displays for each subsystem. Another option for viewing telemetry is the Ad Hoc displays with which the experimenters can customize the telemetry they view, for each subsystem. Log files can be created from the Ad Hoc screens and are saved to the TReK workstation. Mission Operations personnel will not be normally logging telemetry using the Ad Hoc displays in the STCC. Experimenters can log telemetry of interest using Ad Hoc displays on the STEC TReK workstation.

Raw experiment data is the unprocessed return-link experiment data received by the STCC over the experiment link after the NISN network overhead has been removed. Essentially this data is the same as the demodulated and decoded return-link experiment data at White Sands.
For data returned over the SN, the raw experiment data is stored temporarily in the WSC SFEP while being transmitted real-time to the experiment hardware for processing. After the pass, the copy of the raw data is transferred from the WSC SFEP directly to the STCC SFEP storage server. The data is then deleted from the WSC SFEP due to its limited storage capacity. Data processed using launch waveforms and downlinked over the NEN, is not received real-time but captured by WGS and then retrieved by Mission Operations from the WGS server, within that shift. The stored raw experiment data, transmitted over either network, can be used to rerun experiments in a playback configuration. The data is stored on the SFEP storage server for 6 months.

PI’s will be responsible for timely dissemination of experiment results and data publication. PIs will be expected to support NASA organized workshops and conferences such as SCaN Testbed Experimenters Conferences and ISS Utilization Conferences and present their findings.

4.0 MISSION OPERATIONS NETWORK OVERVIEW

The Ground System consists of the SCaN Testbed Control Center (STCC), the SCaN Testbed Experiment Center (STEC), the Ground Integration Unit (GIU), and the external ground systems and their interfaces located at the Huntsville Operations Support Center (HOSC), White Sands Complex (WSC), and Wallops Ground Station (WGS). The NASA Integrated Services Network (NISN) is the network that connects these entities. Other ground stations beyond WGS may also be used during operations, including White Sands 1, or user supplied ground stations. However, WGS is currently the baseline station and was used for operations planning and link analysis.

The SCaN Testbed and Ground System send and receive commands and data, and manipulate (stores, routes, and processes) data. The Flight System and Ground System interface with external systems to send and receive RF signals to and from space. The RF signals carry commands and data between the two SCaN Testbed elements. The Ground System provides terrestrial control of the Flight System through the SCaN Testbed Control Center, a top-level schematic of the Ground System is shown in Figure 4-1.

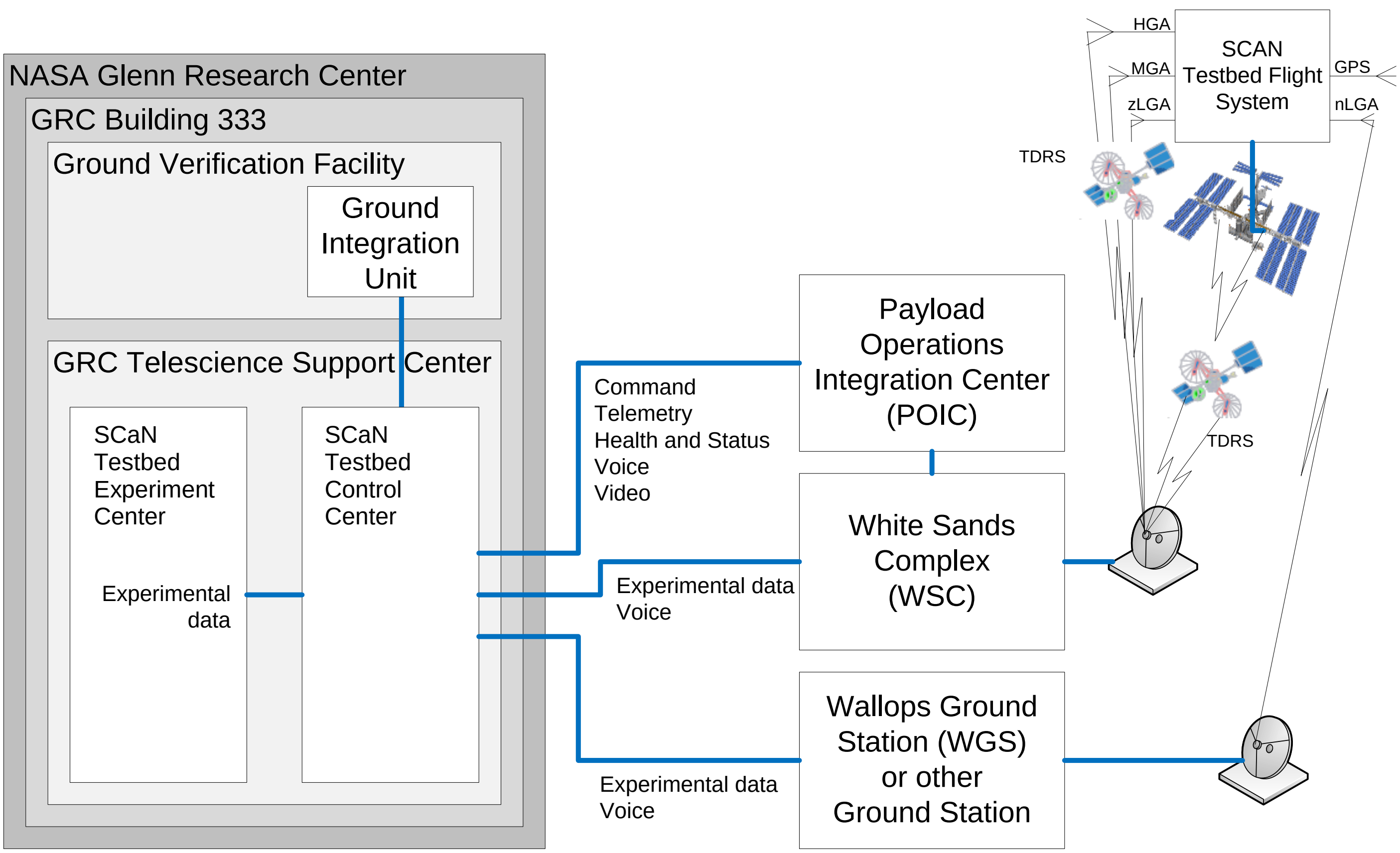

Figure 4-1—SCaN Testbed Ground System

4.1 Primary Communication Path Elements

There are two communication paths for the SCaN Testbed mission. The primary communications path (commanding and telemetry) will exist through the ISS S-band and Ku-band links. This link will be coordinated through the Marshall Space Flight Center (MSFC) Huntsville Operations Science Center (HOSC). The HOSC will receive the data from the SN and forward it to the Glenn Research Center (GRC) SCaN Testbed Control Center (STCC) through existing architecture.

The SCaN Testbed uses both the primary and experimental paths for commanding. Nominal commanding will use the primary path. Commands will originate from the GRC TSC except for 13 critical commands. The critical commands will be sent by the Payload Rack Officer (PRO) from the HOSC. The critical commands will reside only in the Payload Operations Integration Center (POIC) database. In the future the SCaN Testbed will have the capability to use its RF links to send non-critical commands through the SDRs to the Avionics. The TSC also contains the Telescience Resource Kit (TReK) - a suite of PC-based software applications to monitor and control payloads on-board the ISS. The TReK hosts a SCaN Testbed-specific Telemetry and Acquisition Display System (CTADS) to display telemetry data from the SCaN Testbed and configure commands for transmission. The primary path will be the baseline path for sending new software to the SCaN Testbed and receiving telemetry and flight system stored data.

4.1.1 Huntsville Operations Support Center (HOSC)/Payload Operations Integration Center (POIC)

The Payload Operations Integration Center (POIC), located within MSFC's Huntsville Operations Support Center (HOSC), houses the ground systems for managing the execution of on-orbit International Space Station (ISS) payload operations including telemetry, command, voice, video, information management, data reduction, and payload planning systems. All POIC ground systems are distributed to the STCC.

The POIC contains several data and network systems that provide various capabilities:
The Payload Data Services System (PDSS) is used to receive, process, store (for 2 years), and distribute International Space Station (ISS) 150 Mbps Payload telemetry data to the POIC, International Partners, Telescience Support Centers and other remote user facilities.

The Enhanced Huntsville Operations Support Center (EHOSC) performs command processing and real-time and near real-time telemetry processing for simulation, training, and flight operations.

The Payload Planning System (PPS) provides a set of software tools to automate the planning, scheduling, and integration on ISS payload operations during pre-increment planning, weekly planning, and real-time operations execution.

4.2 Experiment Communication Path Elements

The second communication path (commanding and bidirectional data) is the experimental link with the SN and the NEN. This link will be scheduled directly by the STCC with the supporting elements. This link includes S-band and Ka-band services to the Space Network and S-band to the NEN. Users will coordinate their ground station use with the STCC.

- Forward Link: GRC STCC through NISN to White Sands to TDRSS to SCaN Testbed.
- Return Link: SCaN Testbed to TDRSS to White Sands through NASA Integrated Services Network NISN to GRC STCC.
- Uplink: GRC STCC through NISN to Ground Station (e.g. WFF) to SCaN Testbed.
- Downlink: SCaN Testbed to Ground Station (e.g. WFF) through NISN to GRC STCC.

4.2.1 Tracking and Data Relay Satellite (TDRS)

The SCaN Testbed located on the ISS will communicate with WSC ground stations via TDRS satellites using Ka-band and S-band. The Tracking and Data Relay Satellite System (TDRSS) is used by NASA and other United States government agencies for communications to and from independent "User Platforms" such as the SCaN Testbed on the ISS. Full details of the TDRSS are contained in the Space Network Users Guide (SNUG).

4.2.2 White Sands Complex (WSC)

The White Sands Complex (WSC) consists of two highly automated functionally identical ground terminals. The White Sands Ground Terminal Upgrade also known as Cacique, and the Second TDRSS Ground Terminal also known as Danzante, provide a relay interface between the space segment, the ground segment and the other ground elements such as the HOSC.

The WSC, or TDRSS ground segment, includes the transmit and receive equipment to support the four types of available customer satellite communications services: Multiple Access (S/MA), Ku-Band Single Access (KuSA), Ka-Band Single Access (KaSA), and S-Band Single Access (SSA). The SN can provide customer platform tracking and clock calibration services for S/MA, SSA (including cross-support), and KuSA telecommunications services. The SN does not provide tracking or clock calibration services for KaSA customers. TDRSS provides either two-way range, two way doppler, or one-way doppler measurements. Sampled range and doppler data are routed from the WSC to the GSFC Flight Dynamics Facility for orbit determination.

During initial launch and commissioning the three SDRs will be loaded with Space Network User's Guide (SNUG) compatible waveforms. Hardware checkout and validation will be carried out with existing ground based receivers located at the White Sands Complex (WSC) TDRSS terminal and WGS NEN ground stations. SCaN Testbed experiments that require unique software and mission operations will have access to a SDR at the WSC separate from the legacy services. A SDR capable of modulating and demodulating the experimental waveforms loaded into the SCaN Testbed will be integrated into the White Sands Complex prior to the experiment operations phase.

4.2.2.1 Legacy Services

Several types of telecommunications services are simultaneously available to customers. The type of telecommunications service selected is determined by the data rate required, duration of service period, and customer platform telecommunications system design. The two primary telecommunications services are termed Multiple Access (MA) and Single Access (SA). The SA services are available at S-band, Ku-band, and Ka-band (F8-F10 only) frequencies. Legacy services consist of the following and are further described in the SNUG. Note that the legacy Ku band services are listed as a reference only. The SDRs do not have Ku band capabilities.

The SN can provide any of the following services:

- A forward service, defined as the communication path that generally originates at the customer control center and is routed through WSC to the TDRS to the customer platform.

- A return service, defined as the communication path that generally originates at the customer platform and is routed through the TDRS to WSC back to the customer control center and/or data acquisition location.

- Both forward and return services simultaneously.

MA (also referred to as S-band Multiple Access (SMA) for TDRS F8-F10) forward and return services operate at fixed S-band frequencies (nominally 2106.4 MHz forward and 2287.5 MHz return) and polarization (Left Hand Circular). Forward service operations are time-shared among TDRS customers where one customer is supported per TDRS at a time.

SA services available through each TDRS SA antenna are: S-band Single Access Forward, S-band Single Access Return, Ku-band Single Access Forward, Ku-band Single Access Reverse, Ka-band Single Access Forward (F8-F10 only), and Ka-band Single Access Reverse (F8-F10 only). Each TDRS SA antenna has one polarizer (either Left Hand Circular or Right Hand Circular) for each frequency band (S, Ku, or Ka). The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same SA antenna.

The SN can simultaneously support S-band and K-band (either Ku-band or Ka-band (F8-F10 only)) forward and/or return services through one SA antenna to the same ephemeris. TDRS F8-F10 cannot simultaneously support Ku-band and Ka-band services through one SA antenna.

TDRSS S-band Single Access (SSA) services include forward and return telecommunications services, and tracking services. SSA return service includes service through the SN receive equipment and an automated IF service, where SN IF services are available to customers on a case-by-case basis, IF service requires the customer to provide the receiver equipment and the SN only provides the signal at the IF.

TDRSS Ka-band Single Access (KaSA) services include forward and return telecommunications services. KaSA Return service includes 225 MHz service through the SN receive equipment and IF service for the KaSA 225 MHz and KaSA 650 MHz channels, where the 225 MHz IF is not automated, but is being considered for automation and the 650 MHz service has been automated. Additionally, SN IF services are available to customers on a case-by-case basis, IF service requires the customer to provide the receiver equipment and the SN only provides the signal at the IF. Tracking services are not provided via KaSA.

4.2.2.2 Non-Legacy Services

Non TDRSS SNUG compliant waveforms will require additional equipment at WSC to process waveforms not currently supported by the SN. A ground based SDR will be designed and built to facilitate waveform implementation for SCaN Testbed experimenters beyond TDRSS legacy waveforms. The SDR will have two primary interfaces, an RF interface and an IP interface. The RF interface will be connected to the WSC IF service. The IP interface will be connected to the SCaN Testbed Virtual Private Network (VPN). The SCaN Testbed VPN connects equipment at WSC to the STCC at GRC via IP. Currently a Front-End Processor (FEP) will be located at both WSC and the STCC. The FEP converts IP encapsulated data to ECL/422 clock and data bidirectionally and then sends it to/receives it from the experimenter equipment. The FEP exists to allow legacy WSC equipment (with clock and data interfaces) to receive and transmit data to the STCC over IP on the SCaN Testbed VPN. The SDR will exchange packetized link data with the GRC FEP, allowing data to flow over the GRC FEP's ECL interface to the STCC.

A control computer for the SDR at WSC will reside at the STCC. This PC will also reside on the SCaN Testbed VPN, and will be exclusively used for the control and monitoring of the SDR at WSC as shown in Figure 4-2.

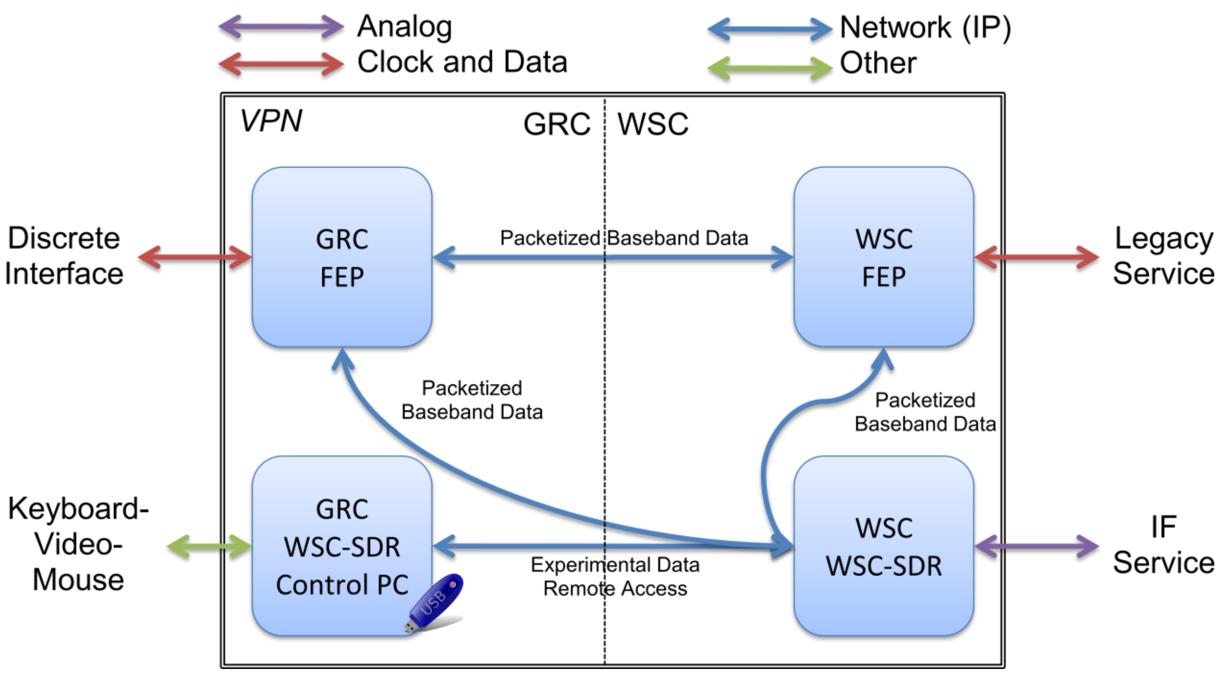

Figure 4-2—SCaN WSC-SDR and Control PC at GRC

4.2.3 Wallops Ground Station (WGS)/Other Near Earth Networks (NEN)

The SCaN Testbed can communicate directly with ground stations such as WGS or other ground stations over S-band. Experimenter equipment connected to the ground stations will be used for the ground experiment node. For experimenters using WGS, a NISN connection between the STCC and WGS is available to route data to the STEC.

4.3 SCaN Testbed Control Center (STCC)

The STCC is the Mission Operations SCaN Testbed Control Center. It will reside within the Telescience Support Center (TSC). The TSC facility located at GRC allows payload developers and scientists on earth to monitor and control experiments onboard the International Space Station (ISS). Data from the radios are received at WSC via TDRS and routed to GRC. The STCC will make use of the existing TSC interfaces to the HOSC. The STCC will use the TSC data network, which is an isolated network from the GRC campus network. Internet access to external sites will also be available via a separate network, both for scheduling and other interfaces such as the remote data access server.

The STCC will provide command and telemetry processing, experiment demonstration/execution, experiment data archiving, and health and status data archiving. The suite of data will be provided to approved users. The STCC will also interface with the Ground Integration unit (GIU) for on-orbit anomaly resolution and waveform and Flight System software verification prior to on-orbit upload. The GIU is a high fidelity duplicate of the flight SCaN Testbed. The STCC diagram is shown in Figure 4-2.

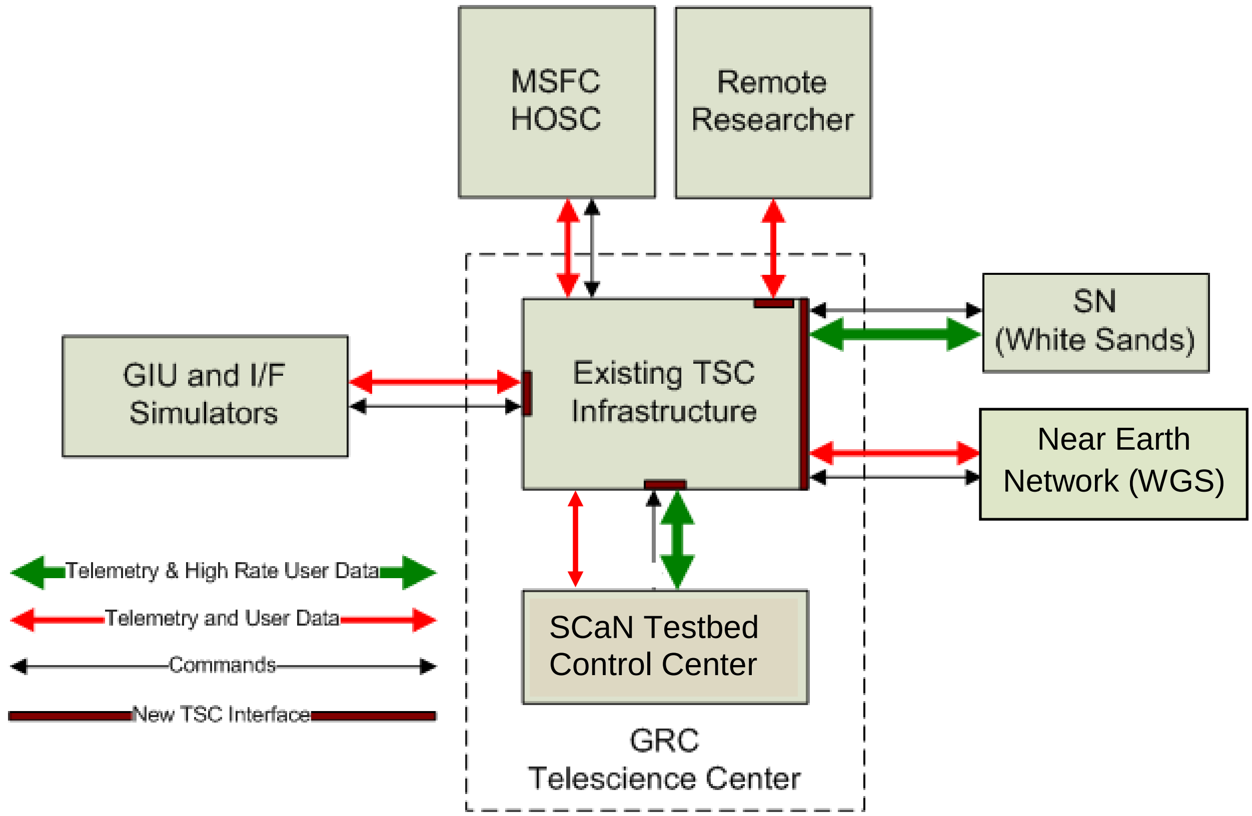

Figure 4-3—SCaN Testbed Control Center Functional Diagram

The existing TSC infrastructure includes command, data, voice loop, and video connections to the MSFC Huntsville Operations Support Center (HOSC). Interfaces through the NASA Integrated Services Network (NISN) to the Space Network (SN) and Near Earth Network (NEN) will support the evaluation of the on-orbit radio performance. A web server will host data for approved remote researchers.

4.4 SCaN Testbed Experiment Center (STEC)

The SCaN Testbed Experiment Center is the real time mission data analysis and interface for the experimenter team. It is physically adjacent to the STCC and located within the TSC. It is separate from the STCC because it is an experimental data center while the STCC is the overall operations center. The physical location is necessary because of the proximity of experiment supplied equipment to the STCC and the desire to analyze and make adjustments real-time during experimental data link connections with TDRS or a ground station. Future experimenters may be required to provide additional support equipment depending on what is needed and what is available. The interface is governed by the CCC-CEC ICD, GRC-CONN-ICD-0427.

4.5 Ground Integration Unit (GIU) With Support Systems

The GIU with Support Systems (GIUSS) consists of the GIU, Antenna Pointing System (APS) Rack, Test Equipment Interface (TEI) Racks #1 and #2, Power Acquisition System (PAS), two S-Band TDRSS Simulators (TSIM), Ka-Band TSIM and Data Acquisition System and Experiment Front End Processor (EFEP), ELC Suitcase Simulator (SCS), Telescience Resource Kit (TReK) Workstation, WSC-SDR and GPS antenna. GSE is comprised of spectrum analyzers, power meters, power supplies, personal computers, and other general test equipment.

The GIU includes SDR Engineering Models (EM) and an Avionics System (AS) spare Flight Model (FM). The GIU also includes two Travelling Wave Tube Amplifiers (TWTA) EM, Gimbal Control Electronics (GCE) EM, an Interconnect Harness EM, Temperature Sensors EM, an Antenna Pointing System (APS) EM, Gimbals EM, an RF System EM/FM/SE custom version, and additional Support Equipment (SE).

Experimenters can develop experiments by adding software/firmware and/or hardware in various places within the SCaN Testbed System illustrated in Figure 4-3. Each cloud represents locations where functions may be provided by experimenters within the system. Software/firmware can be installed and operated on the orbiting system on the software defined radios and/or avionics. On the ground, software/firmware can be installed and operated on the SDR at the White Sands Complex which is connected to the WSC IF service. Experimenters may also provide unique experiment hardware at either a Direct To Earth (DTE) station, or at the SCaN Testbed Experiment Center. Hardware at the STEC may send and receive directly with the data stream to the flight SDRs (via WSC) through the SCaN Testbed Control Center interface.

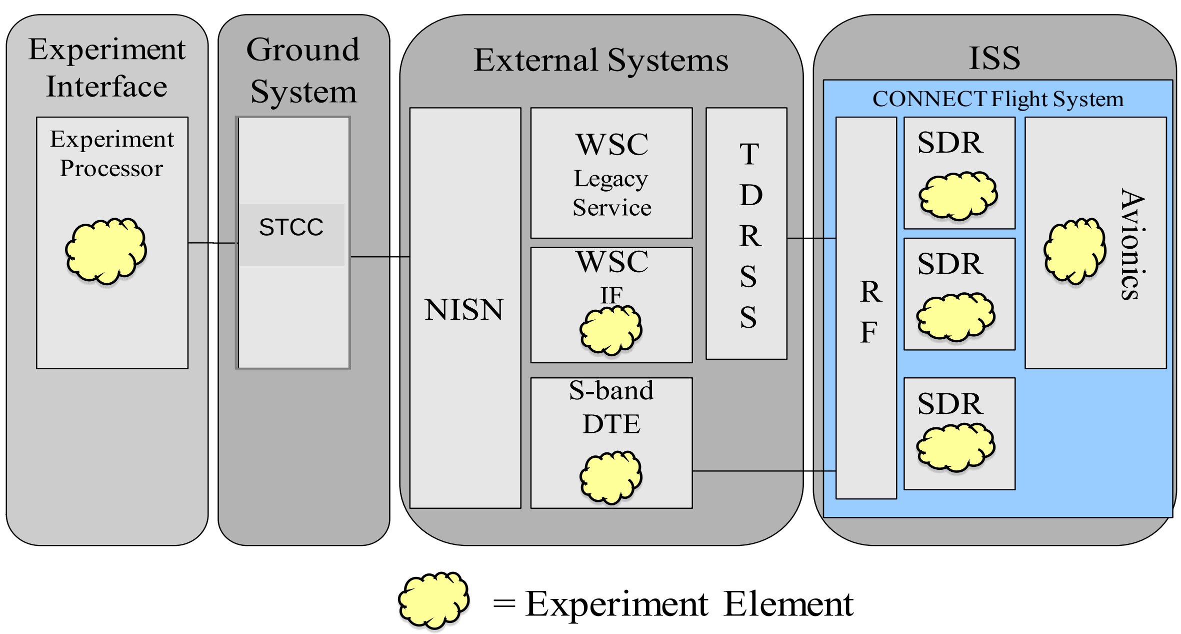

Figure 4-4—Experimenter Access Points

The Ground Integration Unit (GIU) will be utilized by experimenters for the following initial experiment development activities.

- Develop Avionics Software
- Develop Ground Software
- Develop an Operating Environment (OE) for a given radio
- Develop Waveforms for the radios
- Develop the On-Orbit Operating Procedures for Experiments

The GIU will support final experiment formal verification and validation consisting of the following.

- Avionics Software
- Ground Software
- Operating Environment (OE) for the radios
- Waveforms for the radios
- On-Orbit Operating Procedures for Experiments

The GIU will function as a tool to debug On-Orbit issues encountered on the Flight System.

APPENDIX A ACRONYMS AND ABBREVIATIONS

A.1 Scope

This appendix lists the acronyms and abbreviations used in this document.

A.2 List of Acronyms and Abbreviations

Table A-1—Acronyms

Acronym	Definition
AFRAM	Active - Flight Releasable Attachment Mechanism
APS	Antenna Pointing System
AS	Avionics System
BPSK	Binary Phase-Shift Keying
STCC	SCaN Testbed Control Center
STEC	SCaN Testbed Experiment Center
CM	Configuration Management
Comm	Communication
CONN	CoNNeCT
CoNNeCT	Communications, Navigation, and Networking reConfigurable Testbed
CPU	Central Processing Unit
CTADS	CoNNeCT Telemetry and Acquisition Display System
CTFS	Common Time and Frequency System
CTS	Coaxial Transfer Switch
D/A	Digital to Analog
D/C	Downconvert
DSP	Digital Signal Processing
DTE	Direct To Earth
DTN	Delay Tolerant Networking
EDS	Experiment Development System
EFEP	Experiment Front End Processor
EHOSC	Enhanced Huntsville Operations Support Center
ELC	Express Logistics Carrier
EM	Engineering Model
EPMP	Multi-Purpose Exposed Pallet
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
ExPA	ExPRESS Pallet Adapter
ExPRESS	Expedite the Processing of Experiments to the Space Station
Expt	Experiment
FEP	Front End Processor
FM	Frequency Modulation
FPGA	Field-Programmable Gate Array
FRAM	Flight Releasable Attachment Mechanism
GB	Gigabyte
GCE	Gimbal Control Electronics
GD	General Dynamics
GHz	Gigahertz
GIU	Ground Integration Unit
GIUSS	Ground Integration Unit with Support Systems
GLPR	NASA Glenn’s Configuration Management Procedural Requirement

Gov	Government
GPS	Global Positioning System
GPU	Ground Processor Unit
GRC	Glenn Research Center
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HC	Harris Corporation
HOSC	Huntsville Operations Support Center
HTV	H-II Transfer Vehicle
I/O	Input and Output
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronic Engineers
IF	Intermediate Frequency
IP	Internet Protocol
IRIG-B	Inter-Range Instrumentation Group - Time Code Format B
ISS	International Space Station
ITS	Integrated Truss Segment
JPL	Jet Propulsion Laboratory
Ka-band	26.5 to 40 GHz
KaSA	Ka-band Single Access
KaSAR	Ka-band Single Access Return
L-band	1 to 2 GHz
LDPC	Low Density Parity Check
LEO	Low Earth Orbit
LNA	Low Noise Amplifier
MA	Multiple Access
MHz	Megahertz
NASA	National Aeronautics and Space Administration
NEN	Near Earth Network
NISN	NASA Integrated Services Network
NTIA	National Telecommunications and Information Administration
OE	Operating Environment
Ops	Operations
PAS	Power Acquisition System
PC	Personal Computer
PDSS	Payload Data Services System
PI	Principal Investigator
POIC	Payload Operations Integration Center
PPS	Pulses Per Second or Payload Planning System
PS	Project Scientist
PSU	Power Supply Unit
QPSK	Quadrature Phase-Shift Keying
RF	Radio Frequency
RT	Remote Terminal
SA	Single Access
SAR	Space Assurance and Requirements
S-band	2 to 4 GHz
SBIR	Small Business Innovation Research
SBU	Sensitive But Unclassified
SCaN	Space Communications and Navigation
SCS	Suitcase Simulator
SDR	Software Defined Radio
SDS	Software Development System
SE	Support Equipment
SEU	Single Event Upset

SMA	S-band Multiple Access
SN	Space Network
SNUG	Space Network Users Guide
SQPN	Staggered Quadrature Phase
SQPSK	Staggered Quadrature Phase-Shift Keying
SRD	System Requirements Document
SSA	S-band Single Access
SSP	Space Station Program
STRS	Space Telecommunications Radio System
SW	Software
TCP	Transmission Control Protocol
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TEI	Test Equipment Interface
TReK	Telescience Resource Kit
TSC	Telescience Support Center
TRL	Technology Readiness Level
TSIM	TDRSS Simulator
TWTA	Traveling Wave Tube Amplifier
U/C	Upconvert
VDC	Volts Direct Current
VHDL	Very high speed integrated circuits Hardware Description Language
VPN	Virtual Private Network
WF	Waveform
WFF	Wallops Flight Facility
WGS	Wallops Ground Station
WSC	White Sands Complex
WSGT	White Sands Ground Terminal