458-REQ-0002

458 / SPACE NETWORK GROUND SEGMENT SUSTAINMENT PROJECT

Space Network (SN) Ground Segment Sustainment (SGSS) System Requirements Document (SRD)

Baseline

Effective Date: September 22, 2009

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Space Network (SN) Ground Segment Sustainment (SGSS) System Requirements Document (SRD)

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Preface

This document is under the configuration management of the Space Network Ground Segment Sustainment (SGSS) Project (Code 458) Configuration Control Board (CCB). Configuration Change Requests (CCRs) to this document shall be submitted to the SGSS Project CCB, along with supportive material justifying the proposed change. Changes to this document shall be made by Documentation Change Notice (DCN) or by complete revision.

Direct all comments, questions, or suggestions regarding this document to:

Space Network Ground Segment Sustainment (SGSS) Project
Code 458
Goddard Space Flight Center
Greenbelt, MD 20771

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Section 1. Introduction

This is the Space Network (SN) Ground Segment Sustainment (SGSS) System Requirements Document (SRD).

1.1 Purpose and Scope

This document defines the element level requirements applicable to the SGSS implementation contractor. SGSS Project requirements for which the implementation contractor is not responsible are out of scope for this document and are captured elsewhere. The SGSS SRD, in conjunction with the 458-IRD-xxxx series of Interface Requirements Documents (IRDs) and 458-IDD-xxx series of Interface Definition Documents (IDDs) form the complete specification for which the contractor shall be responsible.

This document is a decomposition of relevant requirements from the SGSS Mission Systems Requirements Document (MSRD), 458-REQ-0001. The intention of this document is to provide the foundation from which a modern SN Ground Segment (SNGS) can be constructed meeting or exceeding current SN Service and Tracking and Data Relay Satellite (TDRS) health and safety performance requirements and commitments, while meeting sustainment goals of operability, scalability, flexibility, extensibility, maintainability, reliability, and availability. This document captures the current set of SNGS requirements (derived in large part from the Requirements Specification for the White Sands Complex, the SN Users' Guide, and on-going SN upgrade project requirements), as well as requirements for new capabilities defined to meet the needs, goals, and objectives of the SGSS Project.

1.2 Document Status and Schedule

This document is the definition of the SNGS requirements for inclusion in the SGSS Implementation Contract Request for Proposal (RFP). This document is owned and controlled by the SGSS Project (Code 458). Future revisions to this document must be approved by the SGSS Project Configuration Control Board (CCB).

1.3 Document Organization

Section 1 defines the purpose, scope, document status, and organization of this document.

Section 2 identifies the parent document, applicable documents, and information documents used in the development of this document.

Section 3 lists the high-level objective of the Space Network, provides an overview of the SN and the SN Ground Segment, and defines the scope of the SGSS Project.

Section 4 defines general requirements pertaining to the entire SNGS including National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC), and industry standards, as well as software and hardware requirements.

Sections 5 - 16 define functional, performance, and operational requirements for the SNGS. These sections are used as logical repositories for requirements related in function and are NOT subsystem identifiers.

Section 17 defines external interface requirements. Appendix A provides definitions for terms used throughout the SGSS SRD.

Appendix B provides definitions for acronyms found in this document.

Appendix C provides traceability from each SRD requirement to the SGSS MSRD.

Appendices D-F provide details of specific User Service requirements.

Section 2. Related Documentation

2.1 Applicable Documents

NOTE: *The applicable portions of 450-SNUG: Space Network Users' Guide (SNUG) include user service functions and performance specifications only.*

Document No.	Document Title	Volume	Revision	Release Date
405-F7-ICD-001	ICD for the TDRS Spacecraft/Ground Segment			10/28/1993
450-SNUG	Space Networks User's Guide		9	08/02/2007
452-ICD-SN/CSM	Interface Control Document between the Space Network and Customers for Service Management		Original	05/04
452-ICD-SN/FDF	Interface Control Document between the Space Network and the Flight Dynamics Facility		Original	
454-KP-SYS-ICD-001	TDRS K Program Spacecraft / Ground Segment RF ICD		A	03/14/2008
458-IDD-0001	Space Network Ground Segment Sustainment (SGSS) Antenna Mechanical Systems (AMS) Interface Definition Document (IDD)		Baseline	09/2009
458-IDD-0002	Space Network Ground Segment Sustainment (SGSS) Australia TDRS Facility (ATF) Interface Definition Document (IDD)		Baseline	09/2009
458-IDD-0003	Space Network Ground Segment Sustainment (SGSS) Bilateration Ranging Transponder System (BRTS) Interface Definition Document (IDD)		Baseline	09/2009
458-IDD-0004	Space Network Ground Segment Sustainment (SGSS) Deep Space Network (DSN) Interface Definition Document (IDD)		Baseline	09/2009
458-IRD-0001	Space Network Ground Segment Sustainment (SGSS) NASA Integrated Services Network (NISN) Interface Requirements Document		Baseline	09/2009

Document No.	Document Title	Volume	Revision	Release Date
	(IRD)			
458-IRD-0002	Space Network Ground Segment Sustainment (SGSS) NASCOM Operations Management Center (NOMC) Interface Requirements Document (IRD)		Baseline	09/2009
458-IRD-0003	Space Network Ground Segment Sustainment (SGSS) Flight Dynamics Facility (FDF) Interface Requirements Document (IRD)		Baseline	09/2009
458-IRD-0004	Space Network Ground Segment Sustainment (SGSS) User Mission Operations Center (MOC) Interface Requirements Document (IRD)		Baseline	09/2009
458-IRD-0005	Space Network Ground Segment Sustainment (SGSS) User Local Equipment (ULE) Interface Requirements Document (IRD)		Baseline	09/2009
458-IRD-0006	Space Network Ground Segment Sustainment (SGSS) Near Earth Network (NEN) Interface Requirements Document (IRD)		Baseline	09/2009
458-IRD-0009	Space Network Ground Segment Sustainment (SGSS) Space Network Expansion East (SNE-E) Interface Requirements Document (IRD)		Baseline	09/2009
458-MAR-0001	SGSS Mission Assurance Requirements (MAR)		Baseline	09/2009
CCSDS 131.0-B-1	TM Synchronization and Channel Coding			September 2003
CCSDS 131.1-O-2	Low Density Parity Check Codes for Use in Near-Earth and Deep Space			
CCSDS 133.1-B-1	Encapsulation Service Blue Book Issue 1		Technical Corrigendum 1: October 2006	June 2006
CCSDS 503.0-B-1	Tracking Data Message Blue Book Issue 1			11/2007
CCSDS 702.1-R-3	IP over CCSDS Space Links Red Book Issue 3			09/2008
CCSDS 732.0-B-2	AOS Space Data Link Protocol			July 2006

Document No.	Document Title	Volume	Revision	Release Date
CCSDS 910.11-B-1	Space Communication Cross Support--Service Management--Service Specification Blue Book Issue 1			August 2009
CCSDS 910.4-B-2	Cross Support Reference Model-Part 1: Space Link Extension Services Blue Book, Issue 2			October 2005
CCSDS 911.1-B-2	Space Link Extension - Return All Frames Service Specification Blue Book Issue 2			November 2004
CCSDS 911.2-B-1	Space Link Extension - Return Channel Frames Service Specification			November 2004
CCSDS 911.5-B-1	Space Link Extension – Return Operational Control Fields Service Specification			November 2004
CCSDS 912.1-B-2	Space Link Extension - Forward CLTU Service Specification			November 2004
CCSDS 914.0-M-1	Space Link Extension—Application Program Interface for Transfer Services—Core Specification. Magenta Book. Issue 1			10/2008
DS80409-H00-003	TDRS H,I,J Space/Ground ICD		D	10/27/2000
GPD 7120.1A	Goddard Space Flight Center (GSFC) Space Asset Protection Policy			07/19/2008
GPR 1600.1	Goddard Security Requirements			04/03/2008
GPR 1860.3	Radio Frequency Radiation Safety			01/26/2005
GPR 2570.1A	Radio Frequency (RF) Equipment Licensing			01/05/2005
GPR 2800.1	GSFC Section 508 Web Compliance			10/06/2005
GSFC-STD-1000	Goddard Space Flight Center Rules for the Design, Development, Verification, and Operations of Flight Systems		D	06/02/2008
GSFC-STD-9001	Spread Spectrum Modulation Formats for NASA Links			11/20/2007
GSFC-STD-9100	Low Density Parity Check Code for Rate 7/8			03/19/2008
NPR 2810.1A	Security of Information Technology			
OSHA 3092	Working Safely with Video Display Terminals			1997

Document No.	Document Title	Volume	Revision	Release Date
STDN No.220.29	Interface Control Document for the TDRSS Spacecraft/Ground Segment, STDN No. 220.29			02/1988

2.2 Information Documents

Document No.	Document Title	Volume	Revision	Release Date
452-PRS-BRTSA	Spread Spectrum Transponder for Use in the Bilateration Ranging Transponder System Augmentation (BRTSA) Functional and Performance Requirements Specification			04/04
452-SRD-SNAS	Space Network Access System (SNAS) System Requirements Document		DCN03	February 2009
452-SRD-USA	Space Network User Service Access (USA) System Requirements Document (SRD)			08/08
453-SRD-DAS	Demand Access System Systems Requirements Document, DCN 01		DCN 01	01/15/01
454-KP-GRD-SPEC-001	Tracking and Data Relay Satellite		A	April 30, 2007
456-SRD-SNE	System Requirements Document for the Space Network Expansion Ground System		DCN 03	September 2006
456-SRD-SNE-E	System Requirements Document for the Space Network Expansion Ground System - East			May 2008
530-RSD-WSC	Requirements Specification for the White Sands Complex (WSC)		1 DCN-06	June 1, 1997
531-TR-001	User Spacecraft Clock Calibration System User's Guide			
CSOC-GSFC-RD-002090	WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC) System Requirements Document			April 2003
CSOC-GSFC-REQ-003275	Data Services Management Center (DSMC) System Requirements Specification		DCN-001	01/10/07
CxP-70022-01	Constellation Program Command, Control,	1	Rev C,	02/2009

Document No.	Document Title	Volume	Revision	Release Date
	Communication, and Information (C3I) Interoperability Standards Book Volume 1: Interoperability Specification		Change 002	
FIPS PUB 140-2	Federal Information Processing Standards Publications - Security Requirements for Cryptographic Modules			December 2002
JSC-11534	External Interface Control Document: JSC-GSFC Operational Communications ICD for Mission Control Center Systems	1	F	March 2003
WSC-ATF-SRD	Australian TDRSS Facility (ATF) System Requirements Document		Rev 3	11/08/06

Section 3. Space Network Overview

3.1 Introduction to the Space Network

The NASA Space Network (SN) is a communication signal relay system which provides tracking and data transfer services between User platforms and User Mission Operations Centers (MOC). The SN was established in the early 1980s to replace NASA's worldwide network of ground tracking stations. The SN is comprised of a constellation of data relay and tracking satellites and associated ground systems. This space-based relay system can provide communication services over 100% of any customer platform orbit for altitudes ranging from 73km to 9000km, a capability that is unique within the civilian and commercial space industry. In addition to orbiting user platforms, limited communication services can also be provided for customer platforms located on the ground and ocean/sea surfaces (ex: ships) as well as airborne platforms (ex: atmospheric balloons).The fleet of Tracking and Data Relay Satellites (TDRS) in geosynchronous orbit serves as a data relay system between SN ground system and the User platforms. The TDRS fleet is separated into defined longitudinal regions around the Earth. These regions, known as the Pacific, Atlantic, and Indian Ocean Regions (POR, AOR, IOR), being nearly equally spaced, provide a geometry that allows complete global communications coverage. This is one of the primary advantages of the Space Network.

3.2 SN Functional Objectives

The primary functional objectives of the SN are listed below:

1. Monitor and Control the SN Flight and Ground Segments; including management of the configuration, health and safety of the TDRS spacecraft fleet and SN Ground Segment elements.
2. Provide SN user service planning and scheduling.
3. Relay user signals in forward and return directions between the ground and user platforms.
4. Distribute user data on the ground using NASA Integrated services Network (NISN) services, user-provided networks, or Local Interfaces (LIs).
5. Provide tracking services for TDRS and user spacecraft.
6. Provide sustaining engineering services for the flight and ground segments.
7. Provide operations training for the SN and user community.
8. Provide SN and user test and simulation capabilities.

3.3 SN High-Level Description and Architecture

The SN provides S-band, Ku and Ka telecommunications and tracking services for user satellites, launch vehicles, airborne vehicles, and ground-based systems. The SN relays user command and telemetry data between the user platforms and user control/data processing facilities via TDRS spacecraft and SN ground facilities. The SN also provides compatibility and performance test services to users. An interface is provided to users for service scheduling and status. The SN is managed from the Goddard Space Flight Center (GSFC) and maintains a remote engineering facility. Figure 3.3-1 depicts the conceptual SN constellation and the associated ground facilities. The facilities are further described in Sections 3.4 and 3.5.

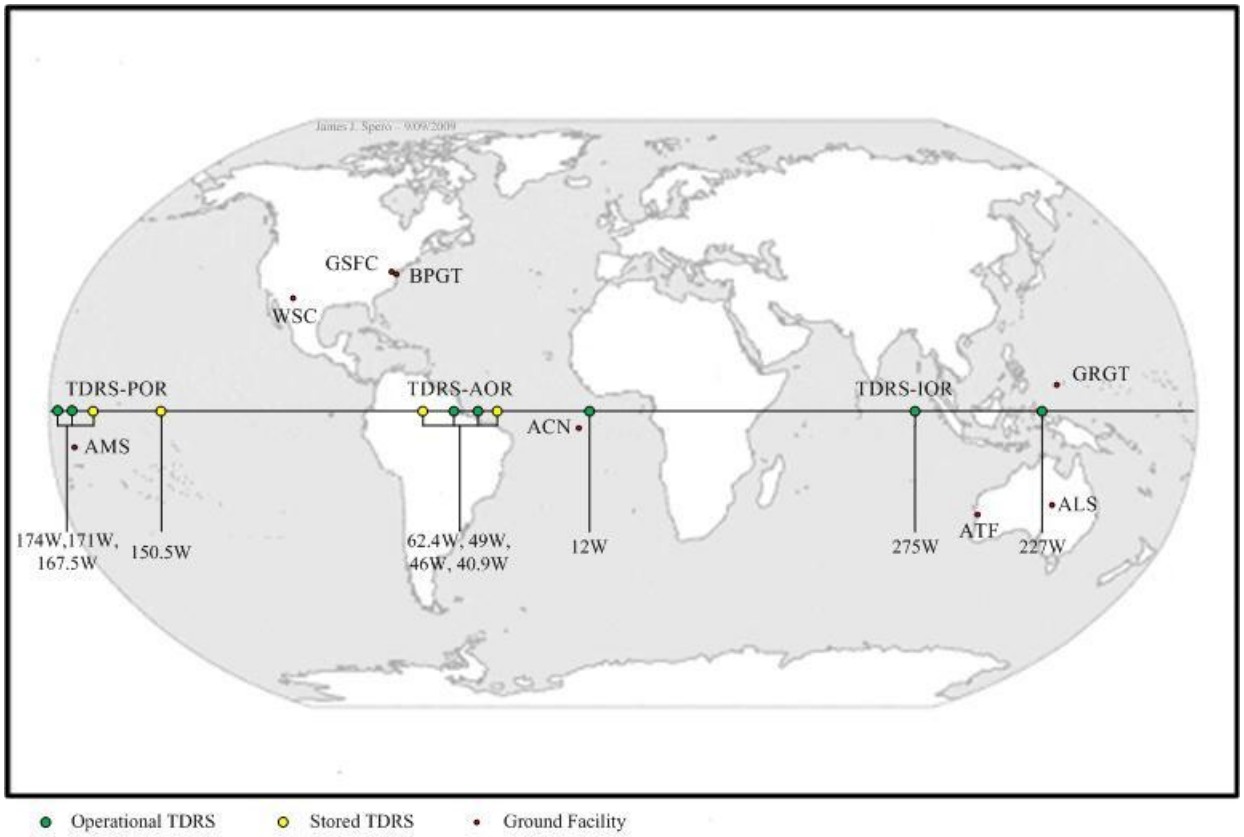


Figure 3.3-1 Conceptual SN Constellation

The SN includes the following principal components:

1. The Space Segment, comprised of a geosynchronous constellation of TDRS spacecraft capable of providing mission services.
2. The Ground Segment, comprised of various ground stations and elements used to monitor and control TDRS spacecraft and provide user services, as well as bilateration ranging transponders, backup monitor and control facilities, and specialized facilities for launch support and polar user support.

3.4 The SN Ground Segment Sustainment (SGSS) Project

The current SNGS originated in the early 1980's with the building of the White Sands Ground Terminal (WSGT). In 1994, WSC was augmented with a Second TDRSS Ground Terminal (STGT), and then in 1996 WSGT was upgraded using STGT technology (Figure 3.4-1).

The current system uses equipment and communications protocols that are becoming obsolete and difficult to operate, maintain, and replace since vendors no longer support a majority of these system hardware and software. Spares inventory on many items are at levels that pose risks to the ability to maintain the system, and some online systems have been cannibalized to repair other failed systems to full function. As new systems are acquired to perform upgrades and implement new requirements, it is becoming increasingly difficult to interface those systems with the older systems already in place.

The age of the SN ground segment and the risks associated with operating and maintaining the system led the Office of Space Communications and Navigation (SCaN) to initiate a sustainment effort for the core

elements of the SNGS. Table 3.4-1 differentiates the "in-scope" and "out of scope" elements for the SGSS implementation contractor.

Table 3.4-1 SGSS Scope

WITHIN SCOPE	OUT OF SCOPE
SN and SNE Fleet and Ground Management	BRTS(except monitor & control interface)
SN Services (User Service, Operational Test Services, etc.)	Existing Antenna Mechanical Systems(except monitor & control interface)
Service Management	Facility Physical Plant (except monitor interface)
User Data Management (Routing, Recording, Translation, etc.)	TDRS and User Spacecraft
SN Data Management, Storage and Archive	RFSOC/CTV
Enterprise Services (Internal Communications, Security, System Administration, etc.)	User MOCs, FDF, NEN, DSN, SPRT/MRTS
SN Maintenance	MILA
SN Testing	GSFC NIC
SN Training	User Local Equipment (ULE) (except monitor interface)
Continuity Of Operations	SNE-East (except monitor & control interface)
External Interfaces	ATF(except monitor & control interface)
	Collimation equipment (Blue Mesa) (except monitor & control interface)

The SGSS Project is tasked with determining the appropriate method of sustaining SN operations for a minimum of 25 additional years of service. This includes defining a system meeting current and projected SN Operations and SN User requirements and sustainment goals of operability, scalability, flexibility, extendibility, maintainability, reliability, and availability. These requirements and goals must be met within the environmental constraints of the current SN and provide for smooth transition to operations without interruption to on-going SN operations.

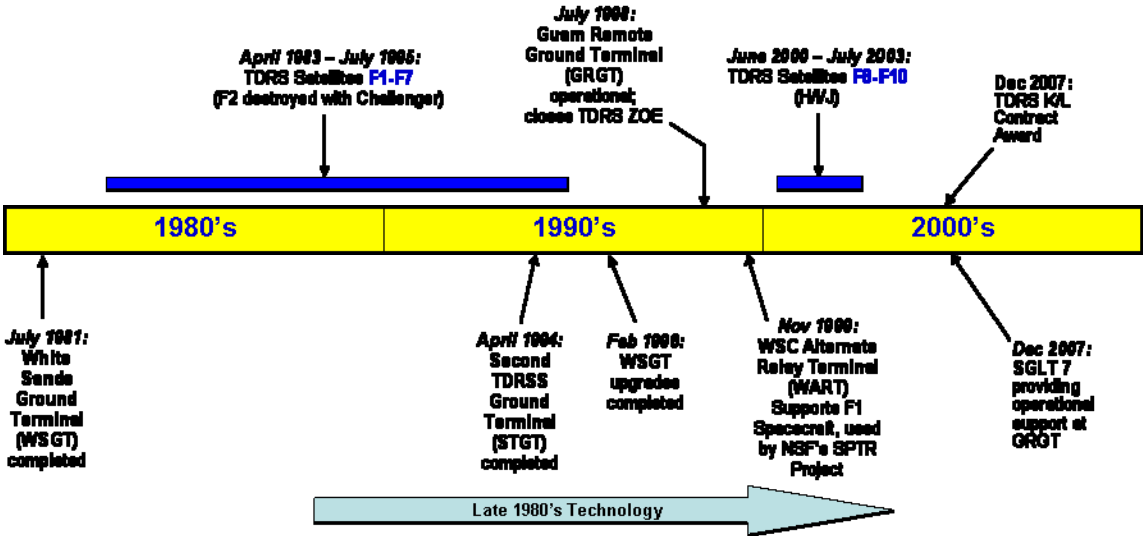


Figure 3.4-1 SN History Summary

3.5 SN Ground Segment Definition

The SN maintains multiple ground facilities providing various functions as part of SN operations. This section defines the projected SN ground assets, including facilities and antenna sites, available at the time of SGSS deployment to the operational environment. It identifies the high-level functions of SN facilities and the assignment of those functions to a facility.

NOTE: Facilities and antenna sites are assumed to be fixed and not subject to change as part of the SGSS Project implementation. Functions assigned to each facility are NOT assumed to be fixed and should not be taken as direction for implementation.

3.5.1 SN Ground Facilities

Table 3.5-1 identifies projected SN ground facilities, their geographic locations, and the expected function(s) at the time of SGSS deployment.

Table 3.5-1 SN Ground Facilities and Functions

Facility	Location	Functions
STGT	Las Cruces, New Mexico (WSC)	Primary SN Operations, AOR and POR General User Services, SN HW/SW Maintenance, SN HW/SW Test , SN Operations Training
WSGT	Las Cruces, New Mexico (WSC)	Redundant Local Operation, AOR and POR General User Services
ETGT	Las Cruces, New Mexico (WSC)	AOR and POR TDRS TT&C
GRGT[1]	Guam	IOR User Services
BPGT(SNE-E)	Blossom Point, Maryland	AOR Dedicated User Services
ATF	Western Australia	IOR TDRS TT&C
SNEF	Greenbelt, Maryland (GSFC)	SN Remote Engineering Support
BRTS Relay	Alice Springs, Australia (ALS), American Samoa (AMS), Ascension Island (ACN), and the WSC	TDRS Signal Relay

Note 1: GRGT is the combination of existing SN facilities located on Guam including SNE-W.

3.5.2 SN Ground Antennas

Table 3.5-2 identifies the projected locations of SN Space-Ground Link (SGL) antennas at the time of SGSS deployment. These locations are fixed and not subject to change within the SGSS implementation time frame.

Table 3.5-2 SN SGL Antenna Sites

Site	Dual Band Ku/S	Ku-Band	S-Band
STGT[1]	3	0	1
WSGT[1]	0	3	1
ETGT	0	0	2
GRGT	3[2]	0	0
BPGT (SNE-E)	2	0	0
ATF	0	0	1
SNEF	0	0	0

Note 1: A new dual band Ku/S SGL antenna is planned for WSC. Location within WSC is pending engineering study.
Note 2: 1 antenna is assigned to general IOR SN Services, 1 antenna is assigned to dedicated IOR SN services, and 1 is a spare shared between them.

Table 3.5-3 defines the projected locations of SN test service antennas at the time of SGSS implementation. These locations are fixed and not subject to change within the SGSS implementation and transition to operations time frame.

Table 3.5-3 SN Test Antennas

Site	Dual Band Ku/S	Ka-Band
STGT	3	1
WSGT	2	1
ETGT	0	0
GRGT[1]	2	1
BPGT (SNE-E)	1	0
ATF	0	0
SNEF	0	0

Note 1: GRGT is the combination of existing SN facilities located on Guam including SNE-W.

3.5.3 SNGS Functional Summary

The SNGS provides spacecraft telecommunications services in conjunction with the TDRS satellites. It also provides operational test services, service management, a user services "gateway" to facilitate the transfer of telecommunications services products, fleet and ground management, a suite of maintenance and training capabilities, an enterprise infrastructure within which all the other functions operate, and an operator interface.

Spacecraft Telecommunications Services include forward and return data relay services and radiometric tracking services to SN User platforms via the TDRS satellites. Also included are telemetry, tracking and command services for the TDRS satellites; emergency backup support to the NASA Near Earth Network (NEN) and Deep Space Network (DSN); internal performance measurement, monitoring and calibration capabilities, and provision of time and frequency references.

Operational Test Services (OTS) provide the ability to test the integrity of a data path, including the RF signal, travelling though the SN system. These services consist chiefly of loop testing within the SN ground system and end-to-end relay testing which includes the TDRS spacecraft in the loop. Test services run in conjunction with, and are complementary to, the SN User Services (return, forward, and tracking). Pre-service loop testing may be performed before User Service events or to troubleshoot and test the integrity of the SN ground system by looping RF or IF through a short, medium or long path. Also provided are end-to-end relay testing that can provide simultaneous forward and return communications from the customer MOC through the SN ground system, up to the TDRS spacecraft and back to the user without the use of a user satellite.

Service Management operates within the context of time-sequenced scheduling phases (planning, active, operational, real-time, and post-event). Service Management includes:

- Validation and maintenance of User Profiles based on approved service agreements.

- Receipt and validation of specific user service and internal system activity requests.
- Development of planning schedules to facilitate 'what-if' analyses and optimize logical allocation of SN assets.
- Development and "publication" of de-conflicted active schedules.
- Processing of changes to the published schedule.
- Generating schedules to facilitate physical allocation and configuration of assets.
- Coordination to support schedule changes based on emergency or critical schedule requests.
- Generation of service accounting reports and invoices.

The User Services Gateway provides the remote data interface to SN User services and includes all processing needed to transform baseband space link data into forms suitable for ground transport (SLE, NASCOM Blocks, or direct IP packets), and to support the CCSDS ENCAP protocol. It provides a remote user interface for access to forward and return service streams as well as service monitoring data. It also includes baseband user data processing to and from frame formats compatible with space telecommunications, and the generation of Tracking and Clock Correlation Data Messages. Also included are the Line Outage Recording (LOR) functionality for SN Users and playback options per CCSDS SLE services.

Fleet and Ground Management provides control and monitoring of SN assets. This includes tracking, telemetry and commanding of the TDRS fleet as well as configuration and monitoring of ground equipment. Fleet and Ground Management acts on approved schedules, along with user platform vectors and SNGS asset status, and properly configures the space and ground segments to provision the service. Typically this provisioning enables the flow of data between a user control center and a user platform. Also included are monitoring the execution and performance of each user service event, and the capability to reconfigure on-going events as needed to facilitate the successful acquisition, retention and completion of each event. Fleet and Ground Management includes monitoring of the SN as a whole, and situational awareness of the entire system, detecting anomalous or erroneous conditions and alerting the operators to take appropriate action. It provides the capability to analyze, calibrate and detect trends in critical components in both the space and ground segments of the SN.

Maintenance and Training provides capabilities for Hardware Maintenance and Test, Software Development and Maintenance, Off-Line Software Testing, System Configuration and Maintenance Management, Simulator/Model Development and Maintenance, and Training. Environments necessary to provide these functions exist separately and distinctly to avoid contention for resources among Software Development/Hardware Integration, Test, Training and Simulation. Exact hardware duplicates of some of the elements of the operational environment appear within the MTF where it is necessary for fidelity purposes.

Enterprise Infrastructure (EI) provides the critical Information Technology (IT) functionality throughout the SGSS architecture. These functions are categorized within four major areas: Communications Infrastructure, Data Management & Storage, IT Security, and TDRS Encrypt/Decrypt. Communications

Infrastructure includes provision of networking services within and between SNGS sites, IP LANs within sites, high-speed data switching, and voice and enterprise messaging. Data Management & Storage provides a centralized repository for the storage, backup, and retrieval of SN data (files, logs, databases, etc). The IT Security functions are closely related to Communications Infrastructure through enforcement of boundaries and appropriate protection of systems and data flows within and between relevant boundaries. The TDRS encrypt/decrypt functions provide security of the data link between the SNGS and the TDRS fleet and are distinct from the IT Security functions.

3.6 SN External Supporting Elements

The SNGS requires support from several external elements. This section identifies those elements and describes the required support.

3.6.1 NASA Integrated Service Network

Managed by GSFC, NISN is a global system of communications transmission, switching, and terminal facilities that provides NASA with wide area network communications services. NISN services that support SN include real-time and mission critical Internet Protocol (IP) routed data (as defined in NISN-001-001: NISN Services Document), as well as high-rate data and video services that connect the SN ground facilities. Inter-Center mission voice communications services are also provided for management of the network and support of user missions.

3.6.2 Flight Dynamics Facility

Located at GSFC, the Flight Dynamic Facility (FDF) provides support to the SN and NASA approved user platform missions for acquisition data generation, orbit determination, and orbit maneuver support. The FDF validates and calibrates SN and ground station tracking data for TDRS spacecraft. The FDF also controls and provides schedule requests for the BRTS passes.

3.6.3 NASA Deep Space Network

Managed by the Jet Propulsion Laboratory (JPL), the Deep Space Network (DSN) is comprised of three ground tracking stations at strategic positions around the Earth. The DSN provides emergency support in the event of a user contingency or degraded SNGS support. It also provides telecommunications and tracking support during TDRS launch and subsequent transfer operations, and TDRS longitude location changes.

3.6.4 NASA Near Earth Network (NEN)

Managed by GSFC, NASA's Near Earth Network (NEN) is comprised of ground stations in MILA and Ponce de Leon (PDL), Florida; McMurdo, Antarctica; White Sands, New Mexico and Wallops Island, Virginia. Under contract are commercial operators at Spitsbergen, Norway; Poker Flat Research Range and the Alaska Satellite Facility (ASF) in Fairbanks, Alaska; Santiago, Chile; South Point, Hawaii, North Pole, Alaska, and Dongara, Australia. These stations provide orbital communications support for Near-Earth orbiting user platforms. Additionally, the MILA and Wallops stations provide pre-launch, launch, and landing communications support for the Space Transportation System (STS).

Section 4. General

4.1 Requirements, Directives, Standards, and Guidelines

SGSS.001000 GSFC Requirements, Directives, and Standards
The SNGS shall comply with the GSFC standards, procedures, guidelines, and directives listed in Table 4.1-1.

Table 4.1-1 GSFC Requirements, Directives, and Standards

Document Number	Document Name
GSFC-STD-1000	Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems
GSFC-STD-9001	Spread Spectrum Modulation Formats for NASA Links
GPD 7120.1A	Goddard Space Flight Center Protection Policy (GSFC) Space Asset
GPR 1600.1	Goddard Security Requirements
GPR 1860.3	Radio Frequency Radiation Safety
GPR 2570.1A	Radio Frequency (RF) Equipment Licensing
GPR 2800.1	GSFC Section 508 Web Compliance

Rationale: GSFC has mandated that the SN must comply with applicable standards, procedures, and guidelines.

4.2 General Requirements

SGSS.001003 Data Routing
The SNGS shall route user data from the point of data ingest to the point of transfer to an external network or system.
Rationale: The SNGS must route user data as appropriate throughout SN ground systems and equipment. This requirement pertains to SNGS-owned equipment ONLY. It does not include NISN-owned or NISN-controlled lines between SN ground facilities and external entities (see SNGS-NISN IRD). It also does not cover the SN flight segment.

SGSS.001004 Time Stamp Resolution
The SNGS shall time stamp SN data and products with Universal Time Coordinated (UTC) to a resolution of 1 millisecond.
Rationale: SN Ground Segment data (including events and reports), TDRS spacecraft commands, telemetry and selected users data need to have a ground time stamp and a single correlated time reference across the system for activities such as trending and analysis, and anomaly investigation.

SGSS.001005 Time Stamp Accuracy
The SNGS shall time stamp SN data and products with UTC to an accuracy of 0.5 millisecond.

Rationale: SN Ground Segment data (including events and reports), TDRS spacecraft commands, telemetry and selected users data need to have a ground time stamp and a single correlated time reference across the system for activities such as trending and analysis, and anomaly investigation.

SGSS.001032 Digitized Downlink Data Time Reference Accuracy

The SNGS shall time reference all digitized downlink data (MA, SSA & KSA) with a timing resolution of 10 nanoseconds or better to the internal Timing and Frequency reference specified in SGSS.005079.
Rationale: Accuracy of 10 nanoseconds or better is required to support multi-TDRS arraying and to support current customer requirements. Accuracy includes timing distribution, residual instantaneous uncertainty between UTC and USNO, and error contribution going through GPS to WSC.

SGSS.001006 Monitor Data Provision

Each SNGS hardware and software configuration item shall generate status and performance data.
Rationale: Operations requires the ability to monitor system components for operational status and configuration.

SGSS.001007 Control Data Reaction

The SNGS shall assure hardware and software configuration item reaction to configuration and control commands.
Rationale: Operations required the ability to control SNGS components.

SGSS.001027 Maximum Pre-service Configuration Time for MA

The SNGS shall provide a maximum of 10 seconds for MA service configuration.
Rationale: This is consistent with SCaN parent requirements for MA service provisioning performance and allows time for configuration of the ground based beamformers. Multiple MA services can be going on in parallel for any given TDRS.

SGSS.001028 DELETED

SGSS.001029 DELETED

SGSS.004032 Inter Service Optimization

The SNGS shall optimize the configuration time between service instances.
Rationale: In order to maximize the overall utilization of the SN network the SNGS control system needs to be designed to optimize the inter-service shutdown and set up execution, without perturbing on going services running in parallel.

SGSS.004117 Maximum Pre-service Configuration Time for TDRS

The SNGS shall allow a maximum of 2 minutes for service configuration when consecutive events require the use of the same SA antenna on TDRS.
Rationale: This facilitates optimization of SN resources use while not exceeding the constraints of TDRS spacecraft.

SGSS.004116 Maximum Pre-service Configuration Time for Extended View Angle on TDRS F8 and Later

The SNGS shall allow a maximum of 6 minutes for service configuration when consecutive events require the use of the same SA antenna and utilize the extended view angle on TDRS F8 and later spacecraft.
Rationale: This facilitates optimization of SN resource use while not exceeding constraints of this generation of TDRS spacecraft. The additional pre-service configuration time is due to the extended viewing angles of the SA antennas for this generation of TDRS. However, the use of these extended viewing angles are outside the normal performance envelope of near earth orbiting (or lower) User platforms and therefore 2 minutes would be the expected maximum pre-service configuration time under these conditions.

SGSS.001030 Legacy External Interface Support

The SNGS shall allow the use of legacy electronic interfaces to external entities.

Rationale: In order to minimize impact to exiting SN Users and support facilities (such as FDF, NEN, and DSN), the SN must allow those external entities to use existing electronic interfaces. The term "legacy" means "existing at the time of SGSS deployment" (see glossary).

4.3 Design Requirements

SGSS.001008 Minimum System Life
The SNGS shall be designed to accommodate technology upgrades and functional enhancements on a five year cycle to support a minimum system life of 25 years.
Rationale: The SN will be required to support the existing TDRS spacecraft (F1-F10) and future TDRS spacecraft (TDRS-K, TDRS-L) until the projected end of life for each spacecraft. Given the projected life span of existing TDRS spacecraft and planned TDRS spacecraft, the ground segment must be designed for a minimum of 25 years of additional support. This will be supported via management direction for "planned obsolescence" and periodic technology refresh cycles.

SGSS.001009 SGL Equipment Life
The SNGS shall be designed for a minimum 10 year life for SGL processing equipment.
Rationale: RF processing equipment is defined as baseband through the LNAs/HPAs. Ten years was selected based on life cycles of current signal processing hardware and cost/benefit ratio.

SGSS.001010 SNGS Equipment Design Life
The SNGS shall be designed for a minimum 5 year life for all operational ground equipment except SGL equipment.
Rationale: This includes all equipment not in the baseband to RF signal processing chains. Five years was selected based on the life cycles of current computing and networking technology and Project philosophy of a 5-year planned obsolescence.

SGSS.001031 Initial WSC TDRS Support
The SNGS shall initially support five (5) operational TDRS and four (4) stored TDRS at WSC
Rationale: Operational TDRS are any TDRS available to provide User services communicating with the ground over a Ku-Band RF link. Operational TDRS may temporarily switch to an S-Band RF link in contingency or anomaly situations. Stored TDRS are any TDRS not providing User services communicating with the ground over an S-Band RF link only.

SGSS.001034 WSC Operational TDRS Support Scalability
The SNGS shall be scalable to support 14 operational TDRS at WSC.
Rationale: The SNGS must be scalable from its initial design.

SGSS.001037 WSC Stored TDRS Support Scalability
The SNGS shall be scalable to support eight (8) stored TDRS at WSC.
Rationale: The SNGS must be scalable from its initial design.

SGSS.001035 Initial GRGT TDRS Support
The SNGS shall initially support two (2) operational TDRS at GRGT.
Rationale: Based on current loading and resource availability predictions, the SN will require 2 operational TDRS spacecraft in the IOR to meet User needs. GRGT is defined to include all SN and SNE facilities on Guam.

SGSS.001036 GRGT TDRS Support Scalability
The SNGS shall be scalable to support four (4) operational TDRS at GRGT.
Rationale: The SNGS must be scalable from its initial design.

SGSS.001025 SNGS Extensibility

The SNGS shall accommodate the inclusion of the legacy capabilities and interfaces currently provided by the component networks (SN, NEN, DSN) until they are decommissioned at the dates mutually agreed to by the SCaN and legacy User missions.

Rationale: The SNGS needs to provide the hooks to allow for the incorporation of additional planning, service management, and service provisioning functions provided by NEN and DSN and to extend service support to those Users.

SGSS.001033 SNGS Design Scalability

The SNGS shall initially support 25 User platforms, scalable to 200.

Rationale: The SN currently supports 18 User platforms and is projected to support approximately 25 (assuming Cx and possible NEN/DSN user support) at the time of SGSS deployment. It is unlikely that the SN will be required to support more than 200 User platforms in the design life of the SGSS.

SGSS.001026 New and Repaired Resource Validation

The SNGS shall allow validation of SN resources in the operational environment prior to use in SN service support.

Rationale: The system should be sufficiently modular such that a new or repaired component can be introduced without severely impacting the management or performance of the system as a whole. The system should provide the ability to validate the operation of the new or repaired resource in the operational environment before committing it to the support of user services or system support.

SGSS.004112 Ground Segment Scalability

The SNGS shall allow the addition and removal of homogeneous components to the ground segment without any application software changes.

Rationale: The addition or removal of similar resources must not severely impact the management or performance of the system as a whole and should be sufficiently modular such that software changes, especially those that require broad shutdown or reconfiguration, are not necessary. Changes to SN resources should not require changes to code in order to expand or reduce the system's capacity.

Section 5. Spacecraft Telecommunications Services

The TDRS System provides two categories of spacecraft telecommunications. There are space-to-space links (SSL) between the TDRS and the moving user platform, and there are space-to-ground links (SGL) between the TDRS and the fixed ground terminal. The user platform has the option of communicating with the TDRS in one of three frequency bands, S-band, Ku-band or Ka-band. The TDRS communications payload translates these signals to the SGL trunk frequencies which occupy Ku-band only. Command and monitoring of the TDRS is normally carried out over the same Ku-band SGL trunk, but can optionally be performed at S-band, although the use of S-band TT&C precludes the carrying of user services.

For clarity, the Space-to-Space links are described as Forward and Return links, with Forward being the direction from the TDRS to the user, and Return being the direction from the user to the TDRS. The Space-to-Ground links are described as Uplinks and Downlinks, where the uplink is from the ground to the TDRS and the downlink is from the TDRS to the ground.

User Services are named for the SSL frequency band and the access mode. Single Access service is available in all three user frequency bands. This service normally dedicates the entire link bandwidth to a single user. Multiple Access service is available only at S-band, and the link bandwidth can be shared among many simultaneous users.

5.1 User Data Relay and Ranging Services

5.1.1 User Forward Data Services

SGSS.002001 S-band Single-Access Forward Service (SSAF)
The SNGS shall transmit user data on two Frequency Division Multiplexed (FDM) channels per operational TDRS of the Ku-band uplink designated in Table 5.1-1 for SSAF user service traffic.
Rationale: This is constrained by the transponder design of the TDRS communications payload.

Table 5.1-1 Uplink Frequency Plan

Service	SGL Uplink			SSL Forward		
	Center Freq (MHz)	POL	BW (MHz)	Center Freq (MHz)	POL	BW (MHz)
User Services						
KaSAF-1	14,625.00	1	50	22,555 to 23,545 (1)	LHC/RHC	50
KaSAF-2	15,200.00	1	50	22,555 to 23,545 (1)	LHC/RHC	50
KuSAF-1	14,625.00	1	50	13,775.00	LHC/RHC	50
KuSAF-2	15,200.00	1	50	13,775.00	LHC/RHC	50
SSAF-1	14,679.50	1	20	2,030 to 2,113.5 (2)	LHC/RHC	20
SSAF-2	14,719.50	1	20	2,030 to 2,113.5 (2)	LHC/RHC	20
MAF-1	14,826.40	1	6	2,106.406	LHC	6
MAF-2	14,816.40	1	6	2,106.406	LHC	6
TDRS Support						
Ku-Band CMD 1	14,780.4375					
Ku-Band CMD 2	14,785.9625					
Ku-Band Pilot (F1-F7 only)	15,150.00					
S-Band CMD 1	2,030.4375	RHC	3			
S-Band CMD 2	2,035.9625	RHC	3			

NOTES:
1. Tunable in 5 MHz steps.
2. Tunable in 0.5 MHz steps.

SGSS.002012 Multiple Access Forward (MAF) Service
The SNGS shall transmit user data on two FDM channels per operational TDRS of the Ku-band uplink designated in Table 5.1-1 for Multiple Access Forward (MAF) user service traffic.
Rationale: This is constrained by the transponder design of the TDRS communications payload.

SGSS.002023 Ku-band Single-Access Forward (KuSAF) Service
The SNGS shall transmit user data on two FDM channels per operational TDRS of the Ku-band uplink designated in Table 5.1-1 for KuSAF user service traffic.
Rationale: This is constrained by the transponder design of the TDRS communications payload.

SGSS.002033 Ka-band Single-Access Forward (KaSAF) Service
The SNGS shall transmit user data on two FDM channels per operational TDRS of the Ka-band uplink designated in Table 5.1-1 for KuSAF user service traffic.
Rationale: This is constrained by the transponder design of the TDRS communications payload.

SGSS.005132 Forward Service Status Measuring and Monitoring
The SNGS shall provide RF and baseband equipment and service performance status data every second including the following:

a. Status Measuring and Monitoring. During service, the Forward Service equipment shall provide equipment and service performance status data every second. This data shall include the following:

1. Service Performance Parameters.

   a) Service (e.g., Baseband, IF, performance test or other)
   b) Modulation (e.g., PM, BPSK, QPSK, etc.)
   c) PN Enable (e.g., I and Q enable or I and Q disable, etc.)
   d) Coding (e.g., convolutional, rate ½ LDPC, concatenated, etc.)
   e) Randomization (e.g., enable, bypass)
   f) Block interleaving (e.g., bypass, I=1, I=2, etc.)
   g) Periodic Convolutional Interleaving (e.g., enable, bypass)
   h) Carrier Frequency.
   i) I/Q Channel Power Ratio.
   j) ASM Pattern.

2. Equipment Status.

   a) Power Supply Status.
   b) Power Settings.

3. Data Presence Monitoring. Continuously monitor the data and clock channels to determine:

   a) Clock Presence.
   b) Data Transition Density.

b. Front Panel Capabilities. All equipment, down to the LRU level, shall incorporate front panel controls, status indicators, and test and monitoring points including:

   1. Visual on/off status indication..
   2. Access to input/output baseband, IF and RF signals and selected voltage levels.
   3. ON/OFF controls.
   4. Test mode selects.

c. BIT/BITE Monitoring. Provide BIT/BITE monitoring data.

Rationale: Will be baseline capability at SGSS deployment.

5.1.1.1 Forward Service Signal Parameters

SGSS.005133 Forward Service Break-Lock

The SNGS shall provide a break-lock function which is used to break the forward service signal lock when it is suspected that the user transponder has false locked

Rationale: The break lock command will knock the user transponder off the false lock point and enable another attempt at successful acquisition.

SGSS.005134 Forward Service Idle Pattern

The SNGS shall insert a baseband idle pattern in lieu of user data when user services are not scheduled. Idle pattern data is defined as PN code assignment 48 in the 451-PN-Code-SNIP.

Rationale: The idle pattern is required in order to prevent an unmodulated carrier which could cause interference to other authorized users of the frequency band.

5.1.1.1.1 Forward Service Modulation

SGSS.005006 User Selectable Forward Service Modulation
The SNGS shall modulate user data by user-selectable methods identified in Table 5.1-2.
Rationale: Modulation and demodulation are complementary functions that are required to transport data over a physical medium. There are many methods of doing this and a selection must be provided to meet specific user requirements.

Table 5.1-2 Forward Service Uncoded Data Rates

Modulation Scheme	Data Rate, Kbit/s (Uncoded)			
	MAF/SMAF	SSAF	KuSAF	KaSAF
Direct PM	n/a	0.125 – 1,000	n/a	n/a
PSK Subcarrier PM	n/a	0.125 – 8	n/a	n/a
BPSK	n/a	1 – 7,000	300 – 25,000	300 – 25,000
PN-Spread BPSK	0.1 – 300	0.1 – 300	1 – 300	1 – 300
QPSK	0.1 – 300	1 – 14,000	600 – 50,000	600 – 50,000
SQPSK	n/a	1 – 14,000	600 – 50,000	600 – 50,000
Unbalanced QPSK	n/a	0.1 – 300	1 – 300	1 – 300
Balanced QPSK	n/a	300 – 7,000	n/a	n/a

SGSS.005008 Binary Phase Shift Keying (BPSK) Modulation
The SNGS shall provide BPSK modulation at the rates identified in Table 5.1-2.
Rationale: Binary Phase Shift Keying (BPSK) is a robust and simple digital modulation scheme that is widely used for satellite communications, especially when link conditions are challenging. This is a legacy requirement.

SGSS.005009 PN Spread BPSK Modulation
The SNGS shall provide PN Spread BPSK modulation at the rates identified in Table 5.1-2.
Rationale: PN-spreading of the BPSK signal allows that signal to occupy a wider bandwidth at a lower power. It reduces interference, both given and received, provides a means of spectrum re-use, and provides a means of PN ranging.

SGSS.005010 SQPSK Modulation
The SNGS shall provide SQPSK modulation at the rates identified in Table 5.1-2.
Rationale: Staggered QPSK (also called Offset QPSK or OQPSK) provides more optimal symbol transitions than QPSK by delaying one of the quadrature elements by half a symbol period with respect to the other. The average magnitude of the phase transitions is smaller with SQPSK than with conventional QPSK, resulting in improved error performance.

5.1.1.1.2 Forward Service FEC Encoding

SGSS.005012 User Selectable FEC Encoding
The SNGS shall provide Forward Error Correction encoding of user data by user-selectable methods identified in Table 5.1-3.
Rationale: Forward Error Correction coding is an industry best practice that is used to achieve low bit error rates over an error-prone channel. Many coding techniques exist and a selection must be provided to meet specific user requirements.

Table 5.1-3 Forward Error Correction Codes

Code	Rates
Convolutional	Rate 1/2
Convolutional	Rate 1/3
Reed-Solomon	255,233
Convolutional+Reed-Solomon	(255,233) RS + Rate 1/2 Conv
Convolutional+Reed-Solomon	(252,220) RS + Rate 1/2 Conv
Turbo Product Code	Rate 7/8
Low Density Parity Check **AR4JA**	Rate 1/2 **(2048, 1024)**
Low Density Parity Check	Rate 7/8 **(8160, 7136)**

SGSS.005013 Convolutional Encoding
The SNGS shall provide Convolutional encoding on forward links at rates identified in Table 5.1-3.
Rationale: Convolutional encoding is an early method of Forward Error Correction that has low complexity and low delay, and is still widely used. This is a legacy requirement.

SGSS.005014 Convolutional+Reed Solomon Encoding
The SNGS shall provide encoding that employs a Convolutional outer code concatenated with a Reed Solomon inner code on forward links at rates identified in Table 5.1-3.
Rationale: Convolutional codes have an error floor that impacts high data rates in a bursty noise environment, such as a satellite link. To mitigate this a Reed-Solomon block code is often used as an outer code. This is a legacy requirement.

SGSS.005015 Turbo Product Encoding
The SNGS shall provide Turbo Product encoding on forward links at rates identified in Table 5.1-3.
Rationale: Turbo product codes in most cases provide higher FEC performance than RS+Convolutional concatenated codes.

SGSS.005016 LDPC Encoding
The SNGS shall offer Low Density Parity Check encoding on forward links at rates identified in Table 5.1-3.
Rationale: LDPC is a highly complex, but highly efficient FEC code. With modern computing power the complexity is no longer a limiting issue. LDPC can offer improvement even over highly efficient Turbo codes. It has been widely adopted throughout the satellite industry, and was the FEC selected for the commercial Digital Video Broadcasting – Satellite (DVB-S2) standard.

GSFC-STD-9100 specifies one implementation of LDPC Encoding. CCSDS 131.1-O-2 provides a recommended implementation that has been adopted by the DSN and is preferred by European Space Agency missions. A specific implementation of LDPC is required by Constellation Program. It is expected that several variants of LDPC Encoding will be necessary in the SGSS implementation.

A specific implementation of LDPC is required by Constellation Program.

5.1.1.1.3 KaSAF Signal Parameters

SGSS.002034 KaSAF Data Rates
The SNGS shall provide KaSA forward data rates as defined in Table 5.1-4.
Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-4 Ka-band Single Access Forward (KaSAF) User Services

Service	Data Rates	Coding	Modulation	Ranging (Y/N)
KaSAF	300 kbps – 25 Mbps	Uncoded	**Non-Spread BPSK**	**N**
	150 kbps – 12.5 Mbps	R 1/2 Convolutional		**N**
	150 kbps – 12.5 Mbps	R 1/2 LDPC		**N**
	262.5 kbps – 21.875 Mbps	R 7/8 LDPC		**N**
	262.3 kbps–21.8 Mbps	(255,223) Reed–Solomon		**N**
	131.2 kbps–10.9 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	1 – 300 kbps	Uncoded	**PN-Spread BPSK**	**N**
	1 – 150 kbps	R 1/2 Convolutional		**N**
	1 – 150 kbps	R 1/2 LDPC		**N**
	1 – 262.5 kbps	R 7/8 LDPC		**N**
	1 – 262.3 kbps	(255,223) Reed–Solomon		**N**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	600 kbps – 50 Mbps	Uncoded	**Non-Spread QPSK/SQPSK**	**N**
	300 kbps – 25 Mbps	R 1/2 Convolutional		**N**
	300 kbps – 25 Mbps	R 1/2 LDPC		**N**
	525 kbps – 43.75 Mbps	R 7/8 LDPC		**N**
	524.7 kbps –43.73 Mbps	(255,223) Reed–Solomon		**N**
	262.3 kbps–21.8 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	1 – 300 kbps	Uncoded	**Unbalanced QPSK with PN-Spread Range on Q channel**	**Y**
	1 – 150 kbps	R 1/2 Convolutional		**Y**
	1 – 150 kbps	R 1/2 LDPC		**Y**
	1 – 262.5 kbps	R 7/8 LDPC		**Y**
	1 – 262.4 kbps	(255,223) Reed–Solomon		**Y**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**

SGSS.002035 KaSAF Coding
The SNGS shall provide KaSA forward coding as defined in Table 5.1-4.
Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002036 KaSAF Modulation
The SNGS shall provide KaSA forward modulation as defined in Table 5.1-4.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002083 KaSA Forward Service Signal Parameters
The SNGS shall provide KaSA forward service signal parameters as defined in Table 5.1-5.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

Table 5.1-5 KaSA Forward Service Signal Parameters

Parameter (note 1)	Description					
Carrier frequency sweep range (SR) (note 2)	±10 Hz to ±52.40 kHz					
Carrier frequency sweep duration (SD) (note 1)	1 to 120 seconds					
QPSK (PN modulation enabled; Unbalanced QPSK; Range on Q channel)						
$\frac{\text{Command Channel Radiated Power}}{\text{Range Channel Radiated Power}}$	+10 dB					
QPSK Command Channel						
PN code modulation	PSK, ± π/2 radians					
Carrier suppression	30 dB minimum					
PN code length (chips)	2^{10} - 1					
PN code epoch reference	Refer to 451-PN CODE-SNIP					
PN code family	Gold codes					
PN code chip rate (chips/sec) (note 3)	$\frac{31}{1469\times 96}\times\left(\frac{F}{10^9}-8.78-0.005K\right)\times 10^9$					
Data modulation	Modulo-2 added asynchronously to PN code					
Data format	NRZ-L,M,S (note 4)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional Code	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions (note 5,6)	1 kbps - 300 kbps	1 kbps – 150 kbps	1 kbps – 150 kbps	1 – 262.5 kbps	1 – 262.4 kbps	1 – 131.2 kbps
Symbol Format	NRZ (note 4)					
QPSK Range Channel						
Carrier	Command channel carrier frequency delayed π/2 radians					
PN code modulation	PSK, ± π/2 radians					
Carrier suppression	30 dB minimum					
PN code chip rate	Synchronized to command channel PN code chip rate					
PN code length (chips)	(2^{10} - 1) x 256					
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.					
PN code family	Truncated 18-stage shift register sequences					
QPSK (PN modulation disabled)						
Data modulation	PSK, ±π/2 radians					
Carrier suppression	30 dB minimum					
Data format	NRZ-L,M,S (note 4)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional Code(7)	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions (notes 5,6)	600 kbps - 50 Mbps	300 kbps – 25 Mbps	300 kbps – 25 Mbps	525 kbps – 43.75 Mbps	524.7 kbps – 43.7 Mbps	262.3 kbps – 21.8 Mbps
Symbol Format	NRZ (note 4)					
BPSK (PN modulation enabled; also referred to as Spread Spectrum BPSK (SS-BPSK))						

Parameter (note 1)	Description					
PN code modulation	PSK, ± π/2 radians					
Carrier suppression	30 dB minimum					
PN code length (chips)	210 - 1					
PN code epoch reference	Refer to 451-PN CODE-SNIP					
PN code family	Gold codes					
PN code chip rate (chips/sec) (note 3)	$\frac{31}{1469\times 96}\times\left(\frac{F}{10^9}-8.78-0.005K\right)\times 10^9$					
Data modulation	Modulo-2 added asynchronously to PN code					
Data format	NRZ-L,M,S (note 4)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional Code	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions (note 5,6)	1 kbps - 300 kbps	1 kbps – 150 kbps	1 kbps – 150 kbps	1 – 262.5 kbps	1 - 262.3 kbps	1 - 131.2 kbps
Symbol Format	NRZ (note 4)					
BPSK (PN modulation disabled)						
Data modulation	PSK, ±π/2 radians					
Carrier suppression	30 dB minimum					
Data format	NRZ-L,M,S (note 4)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional Code(7)	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions (notes 5,6)	300 kbps - 25 Mbps	150 kbps – 12.5 Mbps	150 kbps – 12.5 Mbps	262.5 kbps – 21.875 Mbps	262.3 kbps – 21.8 Mbps	131.2 kbps – 10.9 Mbps
Symbol Format	NRZ (note 4)					

NOTES:

1. All forward service signal parameters shall be supported for a single data channel alternating symbols
2. The KaSA forward service frequency sweep shall be initiated by the SN ground terminal at f_o-SR and linearly swept to f_o+SR in SD seconds and held at f_o+SR thereafter. The KaSA forward service frequency sweep shall not impact simultaneous SN ground terminal Doppler compensation of the KaSA forward service carrier and PN code rate (if applicable).
3. "K" = $\frac{\frac{f_o}{10^6}-22555}{5}$ Rounded to the nearest integer if K ≠ integer and 0 < K < 198. f_o is the nominal center frequency in Hz of the customer platform receiver as defined by the customer MOC.
4. Data format at the baseband data interface will be NRZ-L. Data format conversion from NRZ-L to NRZ-M,S may be scheduled. Symbol format conversion is not required.
5. The forward data rate in this table is the rate prior to encoding.
6. The customer-supplied Schedule Order (SHO) will define a forward service data rate which is consistent with the customer-provided data clock at the start of service.
7. For the rate ½ convolutional coded case, a single encoder service shall be supported and a "stacked" encoder service shall be supported and a "stacked" encoder service shall be supported. Appendix A defines the stacked encoder service.

SGSS.002084 KaSA Forward Service Constraints

The SNGS shall provide KaSA forward service meeting the constraints defined in Table 5.1-6.

Rationale: The constraints are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-6 Signal Constraint Requirements for KSAF Service Equipment

Parameter	Requirement
Command Channel Radiated Power / Range Channel Radiated Power	10 ± 0.5 dB or 0 ± 0.5 dB
Modulator Gain Imbalance (Peak)	± 0.25 dB
Relative Phase Between I/Command And Q/Range Channels (Peak)	90 ± 3°
Symbol Asymmetry (Peak)[2]	± 3%
Symbol Transition Time (90% of Initial State To 90% of Final State)[2]	≤ 5% of Symbol Duration But Not Less Than 4 nanoseconds
Phase Nonlinearity (Peak), Best Straight Line (BSL)	± 4.25° over ± 17.5 MHz
Gain Flatness (Peak), RSS	± 0.4 dB over ± 17.5 MHz
Gain Slope (Peak)	± 0.1 dB/MHz over ± 17.5 MHz
AM/AM	≥ 0.0 and ≤ 1.0 dB/dB
AM/PM	≤ 5°/dB
PN code chip jitter (RMS) (including effects of Doppler compensation)	≤ 1°
Data Bit Jitter (Peak)[2]	≤ 0.1%
Spurious PM (RMS)	≤ 0.8° over ± 25.0 MHz
Spurious outputs (sum of all in-band spurs from all transmit sources)	≥ 30 dBc over ± 25.0 MHz
Incidental AM (peak)[3] (excluding TWT HPA ionic relaxation pulses)	≤ 1.5% over ± 25.0 MHz
Phase noise (rms) -Total 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 25 MHz	 ≤ 1.4° ≤ 1.4° ≤ 3.9° ≤ 1.0°
Phase noise (rms) -Component not coherent with TTCS pilot signal 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 25 MHz	 ≤ 0.8° ≤ 0.7° ≤ 1.8° ≤ 1.0°
I//QPN code chip skew (peak)	≤ 0.01 chip
PN code chip asymmetry (peak)	≤ 0.01 chip
PN code chip rate (peak) relative to absolute coherence with carrier rate	≤ 0.01 chips/sec at PN code chip rate
Symbol rate tolerance	≤ 0.1%

NOTES:

1. Signal constraint definitions are provided in SNUG rev. 9, Appendix E.
2. These values are the SNGS contributions to data asymmetry, data transition time, and data bit jitter, assuming perfect forward service input data.
3. Incidental AM pulses due to TWT HPA ionic relaxation shall be less than 10 milliseconds in duration and 1.5% (peak) in amplitude. Therefore, the worst case total value for incidental AM will be less than 3% (peak).

SGSS.002085 KaSA Forward Service Signal Performance Requirements

The SNGS shall provide KaSA forward service meeting the performance defined in Table 5.1-7.

Rationale: The constraints are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-7 KaSAF Signal Performance Requirements

Parameter	Requirement
RF carrier frequency, F_o	KSA1 14625.0 MHz KSA2 15200.0 MHz
RF bandwidth (1.0 dB)	50 MHz minimum, each channel
Output carrier frequency and phase stability	Carrier frequency stability shall be determined by the TFR. The carriers shall be phase coherent with the TFR frequency standard to the extent specified in the specifications governing phase noise.
Output carrier power level stability	± 0.5 dB per 24 hours
Carrier and PN code frequency generation	RF carrier and PN code clock shall be coherently derived from the TFR
Signal-to-Noise ratio (thermal)	≥ 43 dB in RF bandwidth
Out-of-band spurs	Greater than or equal to 40 dB below the unmodulated carrier (up to 30 GHz)

5.1.1.1.4 KuSAF Signal Parameters

SGSS.002024 KuSAF Data Rates

The SNGS shall provide KuSA forward data rates as defined in Table 5.1-8.

Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-8 Ku-band Single Access Forward (KuSAF) User Services

Service	Data Rates	Coding	Modulation	Ranging (Y/N)
KuSAF	300 kbps – 25 Mbps	Uncoded	**Non-Spread BPSK**	**N**
	150 kbps – 12.5 Mbps	R 1/2 Convolutional		**N**
	150 kbps – 12.5 Mbps	R 1/2 LDPC		**N**
	262.5 kbps – 21.875 Mbps	R 7/8 LDPC		**N**
	262.3 kbps–21.8 Mbps	(255,223) Reed–Solomon		**N**
	131.2 kbps–10.9 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	1 – 300 kbps	Uncoded	**PN-Spread BPSK**	**N**
	1 – 150 kbps	R 1/2 Convolutional		**N**
	1 – 150 kbps	R 1/2 LDPC		**N**
	1 – 262.5 kbps	R 7/8 LDPC		**N**
	1 – 262.3 kbps	(255,223) Reed–Solomon		**N**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	600 kbps – 50 Mbps	Uncoded	**Non-Spread QPSK/SQPSK**	**N**
	300 kbps – 25 Mbps	R 1/2 Convolutional		**N**
	300 kbps – 25 Mbps	R 1/2 LDPC		**N**
	525 kbps – 43.75 Mbps	R 7/8 LDPC		**N**
	524.7 kbps –43.73 Mbps	(255,223) Reed–Solomon		**N**
	262.3 kbps–21.8 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	1 – 300 kbps	Uncoded	**Unbalanced QPSK with PN-Spread Range on Q channel**	**Y**
	1 – 150 kbps	R 1/2 Convolutional		**Y**
	1 – 150 kbps	R 1/2 LDPC		**Y**
	1 – 262.5 kbps	R 7/8 LDPC		**Y**
	1 – 262.4 kbps	(255,223) Reed–Solomon		**Y**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**

SGSS.002025 KuSAF Coding
The SNGS shall provide KuSA forward coding as defined in Table 5.1-8.
Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002026 KuSAF Modulation
The SNGS shall provide KuSA forward modulation as defined in Table 5.1-8.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002086 KuSA Forward Service Signal Parameters
The SNGS shall provide KuSA forward service signal parameters as defined in Table 5.1-9.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

Table 5.1-9 KuSAF PSK Service Signal Parameters

Parameter (note 1)	Description					
Carrier frequency sweep range (SR) (note 2)	±10 to ±30 kHz					
Carrier frequency sweep duration (SD) (note 1)	1 to 120 seconds					
QPSK/SQPSK (PN modulation enabled; Unbalanced QPSK; Range on Q Channel)						
$\frac{\text{Command Channel Radiated Power}}{\text{Range Channel Radiated Power}}$	+10 dB					
QPSK Command Channel						
PN code modulation	PSK, ± π/2 radians					
Carrier suppression	30 dB minimum					
PN code length (chips)	2^{10} - 1					
PN code epoch reference	Refer to 451-PN CODE-SNIP					
PN code family	Gold codes					
PN code chip rate (chips/sec)	$\frac{31}{1469 \times 96} \times F$					
Data modulation	Modulo-2 added asynchronously to PN code					
Data format	NRZ-L,M,S (note 3)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions, kbit/s (note 4,5)	1 - 300	1 – 150	1 – 150	1 – 262.5	1 – 262.4	1 – 131.2
Symbol Format	NRZ (note 3)					
QPSK Range Channel						
Carrier	Command channel carrier frequency delayed π/2 radians					
PN code modulation	PSK, ± π/2 radians					
Carrier suppression	30 dB minimum					
PN code chip rate	Synchronized to command channel PN code chip rate					
PN code length (chips)	(2^{10} - 1) x 256					
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.					
PN code family	Truncated 18-stage shift register sequences					
QPSK/SQPSK (PN modulation disabled)						
Data modulation	PSK, ±π/2 radians					
Carrier suppression	30 dB minimum					
Data format	NRZ-L,M,S (note 3)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional(6)	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenate d RS+CC
Data rate restrictions, Mbit/s (notes 4,5)	0.600 – 50	0.300 – 25	0.300 – 25	0.525 – 43.75	0.5247 – 43.73	0.2623 – 21.86
Symbol Format (note 3)	NRZ (note 3)					
BPSK (PN modulation enabled; also referred to as Spread Spectrum BPSK (SS-BPSK))						
PN code modulation	PSK, ± π/2 radians					
Carrier suppression	30 dB minimum					
PN code length (chips)	2^{10} - 1					

Parameter (note 1)	Description					
PN code epoch reference	Refer to 451-PN CODE-SNIP					
PN code family	Gold codes					
PN code chip rate (chips/sec)	$\frac{31}{1469 \times 96} \times F$					
Data modulation	Modulo-2 added asynchronously to PN code					
Data format	NRZ-L,M,S (note 3)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional Code	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions, kbit/s (note 4,5)	1 - 300	1 – 150	1 – 150	1 – 262.5	1 - 262.3	1 - 131.2
Symbol Format (note 3)	NRZ (note 3)					
BPSK (PN modulation disabled)						
Data modulation	PSK, $\pm\pi/2$ radians					
Carrier suppression	30 dB minimum					
Data format	NRZ-L,M,s (note 3)					
Forward Error Correction Coding	Uncoded	R ½ Convolutional Code(6)	R ½ LDPC	R 7/8 LDPC	(255,223) Reed-Solomon	Concatenated RS+CC
Data rate restrictions, Mbit/s (notes 4,5)	0.300 – 25	0.150 – 12.5	0.150 – 12.5	0.2625 – 21.875	0.2623 – 21.8	0.1312 – 10.9
Symbol Format	NRZ (note 3)					

NOTES:

1. All forward service signal parameters shall be supported for a single data channel alternating symbols unless otherwise stated.
2. The KuSA forward service frequency sweep will be initiated by the SNGS at f_o-SR and linearly swept to f_o+SR in SD seconds and held at f_o+SR thereafter. The KuSA forward service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the KuSA forward service carrier and PN code rate (if applicable). The frequency sweep range can be a little bit higher or lower than the stated SR in order to be an integer multiple of the coherent forward factor 1469 Hz.
3. The data format at the baseband data interface will be NRZ-L. Data format conversion from NRZ-L to NRZ-M,S may be scheduled. Symbol format conversion is not required.
4. The forward data rate in this table is the rate prior to encoding.
5. For the rate ½ convolutional coded case, both a single encoder and a "stacked" encoder service shall be supported.

SGSS.005151 KuSA Forward Service Constraints

The SNGS shall provide KuSA forward service meeting the constraints defined in Table 5.1-10

Rationale: The constraints are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-10 Signal Constraint Requirements for KuSAF Service Equipment

Parameter	Requirement
Command Channel Radiated Power / Range Channel Radiated Power	10 ± 0.5 dB or 0 ± 0.5 dB
Modulator Gain Imbalance (Peak)	± 0.25 dB
Relative Phase Between I/Command And Q/Range Channels (Peak)	90 ± 3°
Symbol Asymmetry (Peak)[2]	± 3%
Symbol Transition Time (90% of Initial State To 90% of Final State)[2]	≤ 5% of Symbol Duration But Not Less Than 4 nanoseconds
Phase Nonlinearity (Peak), Best Straight Line (BSL)	± 4.25° over ± 17.5 MHz
Gain Flatness (Peak), RSS	± 0.4 dB over ± 17.5 MHz
Gain Slope (Peak)	± 0.1 dB/MHz over ± 17.5 MHz
AM/AM	≥ 0.0 and ≤ 1.0 dB/dB
AM/PM	≤ 5°/dB
PN code chip jitter (RMS) (including effects of Doppler compensation)	≤ 1°
Data Bit Jitter (Peak)[2]	≤ 0.1%
Spurious PM (RMS)	≤ 0.8° over ± 25.0 MHz
Spurious outputs (sum of all in-band spurs from all transmit sources)	≥ 30 dBc over ± 25.0 MHz
Incidental AM (peak)[3] (excluding TWT HPA ionic relaxation pulses)	≤ 1.5% over ± 25.0 MHz
Phase noise (rms) - Total 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 25 MHz	 ≤ 1.4° ≤ 1.4° ≤ 3.9° ≤ 1.0°
Phase noise (rms) -Component not coherent with TTCS pilot signal 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 25 MHz	 ≤ 0.8° ≤ 0.7° ≤ 1.8° ≤ 1.0°
I//QPN code chip skew (peak)	≤ 0.01 chip
PN code chip asymmetry (peak)	≤ 0.01 chip
PN code chip rate (peak) relative to absolute coherence with carrier rate	≤ 0.01 chips/sec at PN code chip rate
Symbol rate tolerance	≤ 0.1%

NOTES:
1. Signal constraint definitions are provided in SNUG rev. 9, Appendix E.
2. These values are the SNGS contributions to data asymmetry, data transition time, and data bit jitter, assuming perfect forward service input data.
3. Incidental AM pulses due to TWT HPA ionic relaxation shall be less than 10 milliseconds in duration and 1.5% (peak) in amplitude. Therefore, the worst case total value for incidental AM will be less than 3% (peak).

SGSS.005152 KuSA Forward Service Signal Performance Requirements

The SNGS shall provide KuSA Forward service meeting the performance defined in Table 5.1-11

Rationale: The performance requirements are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-11 KuSAF Signal Performance Requirements

Parameter	Requirement
RF carrier frequency, F_o	KSA1 14625.0 MHz KSA2 15200.0 MHz
RF bandwidth (1.0 dB)	50 MHz minimum, each channel
Output carrier frequency and phase stability	Carrier frequency stability shall be determined by the TFR. The carriers shall be phase coherent with the TFR frequency standard to the extent specified in the specifications governing phase noise.
Output carrier power level stability	± 0.5 dB per 24 hours
Carrier and PN code frequency generation	RF carrier and PN code clock shall be coherently derived from the TFR
Signal-to-Noise ratio (thermal)	≥ 43 dB in RF bandwidth
Out-of-band spurs	Greater than or equal to 40 dB below the unmodulated carrier (up to 30 GHz)

5.1.1.1.5 SSAF PSK Signal Parameters

SGSS.002002 SSAF Data Rates

The SNGS shall provide S-band Single Access (SSA) forward data rates as defined in Table 5.1-12.

Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-12 S-Band Single Access Forward (SSAF) User Services

Service	Data Rates	Coding	Modulation	Ranging (Y/N)
SSAF	1 kbps – 7 Mbps	Uncoded	**Non-Spread BPSK**	**N**
	1 kbps – 3.5 Mbps	R 1/2 Convolutional		**N**
	1 kbps – 3.5 Mbps	R 1/2 LDPC		**N**
	1 kbps – 6.125 Mbps	R 7/8 LDPC		**N**
	1 kbps – 3 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	0.1 – 300 kbps	Uncoded	**PN-Spread BPSK**	**N**
	1 – 150 kbps	R 1/2 Convolutional		**N**
	1 – 150 kbps	R 1/2 LDPC		**N**
	1 – 262.5 kbps	R 7/8 LDPC		**N**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	1 kbps – 14 Mbps	Uncoded	**Non-Spread QPSK/SQPSK**	**N**
	1 kbps – 7 Mbps	R 1/2 Convolutional		**N**
	1 kbps – 7 Mbps	R 1/2 LDPC		**N**
	1 kbps – 12.25 Mbps	R 7/8 LDPC		**N**
	1 kbps – 6.1 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	0.1 – 300 kbps	Uncoded	**Unbalanced QPSK with PN-Spread Range on Q channel**	**Y**
	1 – 150 kbps	R 1/2 Convolutional		**Y**
	1 – 150 kbps	R 1/2 LDPC		**Y**
	1 – 262.5 kbps	R 7/8 LDPC		**Y**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**
	300 kbps – 7 Mbps	Uncoded	**Balanced QPSK with non-Spread data on I and Range code only on Q**	**Y**
	150 kbps – 3.5 Mbps	R 1/2 Convolutional		**Y**
	150 kbps – 3.5 Mbps	R 1/2 LDPC		**Y**
	262.5 kbps – 6.215 Mbps	R 7/8 LDPC		**Y**
	131.2 kbps – 3 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**
	0.125 kbps – 6 Mbps	Uncoded	**Direct PM**	**N**
	0.125 kbps – 3 Mbps	R 1/2 Convolutional		**N**
	0.125 kbps – 2.62 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	0.125 kbps - 1 Mbps	Uncoded	**PSK Subcarrier PM**	**N**
	0.125 kbps – 0.5 Mbps	R 1/2 Convolutional		**N**
	0.125 kbps – 0.44 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**

SGSS.002003_SSAF Coding

The SNGS shall provide SSA forward coding as defined in Table 5.1-12.

Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002004_SSAF Modulation

The SNGS shall provide SSA forward modulation as defined in Table 5.1-12.

Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002080_SSAF PSK Signal Parameters

The SNGS shall provide a SSAF PSK signal with parameters given in Table 5.1-13.

Rationale: These signal parameters are required to support the capabilities of existing SN customers.

Table 5.1-13 SSAF PSK Signal Parameters

Parameter	Description				
Data Source	Single Data Source				
Carrier frequency sweep range (SR) (note 1)	±10 Hz to ±37 kHz				
Carrier frequency sweep duration (SD) (note 1)	1 to 120 seconds				
QPSK/SQPSK (PN modulation enabled; Unbalanced QPSK; Range on Q channel)					
$\frac{\text{Command Channel Radiated Power}}{\text{Range Channel Radiated Power}}$	+10 dB				
Command Channel					
PN code modulation	PSK, +π/2 radians				
Carrier suppression	30 dB minimum				
PN code length (chips)	$2^{10} - 1$				
PN code epoch reference	Refer to 451-PN CODE-SNIP				
PN code family	Gold codes				
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$				
Data modulation	Modulo-2 added asynchronously to PN code				
Data format	NRZ-L,M,S (note 2)				
Forward Error Correction Coding	Uncoded	Rate ½ Convolutional	Rate ½ LDPC	Rate 7/8 LDPC	Concatenated RS+CC
Data rate restrictions, kbit/s (note 3)	0.1 - 300	1 – 150	1 – 150	1 – 262.5	1 – 131.2
Symbol Format	NRZ (note 2)				
Range Channel					
Carrier	Command channel carrier frequency delayed π/2 radians				
PN code modulation	PSK + π/2 radians				
Carrier suppression	30 dB minimum				
PN code chip rate	Synchronized to command channel PN code chip rate				
PN code length (chips)	$(2^{10} - 1) \times 256$				
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.				
PN code family	Truncated 18-state shift register sequences				
QPSK/SQPSK (PN modulation disabled)					
I:Q Channel Power Ratio	1:1				
Data modulation	PSK, +π/2 radians				
Carrier suppression	30 dB minimum				
Data format	NRZ-L,M,S (note 2)				
Forward Error Correction Coding	Uncoded	Rate ½ Convolutional	Rate ½ LDPC	Rate 7/8 LDPC	Concatenated RS+CC
Data rate restrictions, Mbit/s (note 3)	0.001 - 14	0.001 – 7	0.001 – 7	0.001 - 12.25	0.001 – 6.1
Symbol Format	NRZ (note 2)				
BPSK (PN modulation enabled; also referred to as Spread Spectrum BPSK (SS-BPSK))					
PN code modulation	PSK, +π/2 radians				
Carrier suppression	30 dB minimum				

Parameter	Description				
PN code length (chips)	$2^{10} - 1$				
PN code epoch reference	Refer to 451-PN CODE-SNIP				
PN code family	Gold codes				
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$				
Data modulation	Modulo-2 added asynchronously to PN code				
Data format	NRZ-L,M,S (note 2)				
Forward Error Correction Coding	Uncoded	Rate ½ Convolutional	Rate ½ LDPC	Rate 7/8 LDPC	Concatenated RS+CC
Data rate restrictions, kbit/s (note 3)	0.1 - 300	1 – 150	1 – 150	1 – 262.5	1 – 131.2
Symbol Format	NRZ (note 2)				
BPSK (PN modulation disabled)					
Data modulation	PSK, +π/2 radians				
Carrier suppression	30 dB minimum				
Data format	NRZ-L,M,S (note 2)				
Forward Error Correction Coding	Uncoded	Rate ½ Convolutional	Rate ½ LDPC	Rate 7/8 LDPC	Concatenated RS+CC
Data rate restrictions, Mbit/s (note 3)	0.001 – 7.0	0.001 – 3.5	0.001 – 3.5	0.001 - 6.125	0.001 – 3.0
Symbol Format	NRZ (note 2)				

NOTES:

1. The SSA forward service frequency sweep shall be initiated by the SNGS at f_o - SR and linearly swept to fo + SR in SD seconds and held at f_o + SR thereafter, where fo is the center frequency, SR is the sweep range, and SD is the sweep duration. The SSA forward service frequency sweep shall not impact simultaneous SNGS Doppler compensation of the SSA forward service carrier and PN code rate (if applicable). The frequency sweep range can be a little bit higher or lower than the stated SR in order to be an integer multiple of the coherent forward factor 221 Hz.
2. The data format at the baseband data interface will be NRZ-L. Data format conversion from NRZ-L to NRZ-M,S may be scheduled. Symbol format conversion is not required.
3. The forward data rate restrictions in this table are applicable prior to SNGS encoding.

SGSS.005111 Forward Service Signal Constraints

The SNGS shall provide a SSAF signal which meets the signal constraint requirements of Table 5.1-14.
Rationale: The signal constraints help to assure that the system will be compatible with existing user platforms.

Table 5.1-14 SSAF Signal Constraints

Parameter	PSK Modulation		PM Modulation	
	QPSK/SQPSK	BPSK	Direct Data	PSK Subcarrier
$\frac{\text{I or Command channel radiated power}}{\text{Q or Range channel radiated power}}$	+10 ± 0.5 dB or 0 + 0.5 dB	NA	NA	
Modulation index accuracy	NA		±10% of the modulation index	
Subcarrier frequency accuracy	NA		NA	+0.5 Hz

Parameter	PSK Modulation		PM Modulation	
	QPSK/SQPSK	BPSK	Direct Data	PSK Subcarrier
Data transition and subcarrier coherency	NA		NA	Transitions occur at subcarrier zero crossings within +1 degree
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)		NA	
Modulator gain imbalance (peak)	±0.25 dB		±0.25 dB	
Relative phase between I and Q channels	90 ±3 degrees	NA	NA	
Symbol Rate Tolerance	≤ 0.1%		≤ 0.1%	
Symbol asymmetry (peak)[2]	±3 percent		±3 percent	
Symbol transition time (90% of initial state to 90% of final state)[2]	<5 percent of symbol duration		<5 percent of symbol duration	
Phase nonlinearity (peak), Best Straight Line (BSL)	± 4.25° over ± 7.0 MHz		± 4.25° over ± 7.0 MHz	
Gain flatness (peak)	± 0.4 dB over ± 7.0 MHz		± 0.4 dB over ± 7.0 MHz	
Gain slope (peak)	± 0.1 dB/MHz over ± 7.0 MHz		± 0.1 dB/MHz over ± 7.0 MHz	
AM/AM	≥ 0.0 and ≤ 1.0 dB/dB		≥ 0.0 and ≤ 1.0 dB/dB	
AM/PM	≤ 5°/dB		≤ 5°/dB	
PN code chip jitter (rms) (including effects of Doppler compensation)	≤ 1°		NA	
Data bit jitter (peak)[2]	≤ 0.1%		≤ 0.1%	
Spurious PM (rms)	≤ 0.8° over ± 10.0 MHz		≤ 0.8° over ± 10.0 MHz	
Spurious outputs (sum of all in-band spurs from all transmit sources)	≥ 30 dBc over ± 10.0 MHz		≥ 30 dBc over ± 10.0 MHz	
Incidental AM (peak)[3] (Excluding TWT HPA IONIC Relaxation Pulses)	≤ 1.5% over ± 10.0 MHz		≤ 1.5% over ± 10.0 MHz	
Phase Noise (rms) Total				
1 Hz – 10 Hz	<1.4°		<1.4°	
10 Hz – 32 Hz	<1.4°		<1.4°	
32 Hz – 1 KHz	<3.9°		<3.9°	
1 kHz – 10 MHz	<1.0°		<1.0°	
Phase Noise (RMS) -component not coherent with TTCS pilot signal				
1 Hz – 10 Hz	≤ 0.8°		≤ 0.8°	
10 Hz – 32 Hz	≤ 0.7°		≤ 0.7°	
32 Hz – 1 KHz	≤ 1.8°		≤ 1.8°	
1 kHz – 10 MHz	≤ 1.0°		≤ 1.0°	
I/Q PN code chip skew (peak)	<0.01 chip	NA	NA	
PN chip asymmetry (peak)	<0.01 chip	NA	NA	

NOTES:

1. Signal constraint definitions are provided in SNUG Rev.9, Appendix E.
2. These values are the SNGS contributions to data asymmetry, data transition time, and data bit jitter, assuming perfect forward service input data.
3. Incidental AM pulses due to TWT HPA ionic relaxation will be less than 10 milliseconds in duration and 1.5% (peak) in amplitude. Therefore, the worst case total value for incidental AM will be less than 3% (peak).

SGSS.005153 SSA Forward Service Signal Performance Requirements
The SNGS shall provide SSA Forward service meeting the performance defined in Table 5.1-15
Rationale: The constraints are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-15 SSAF Signal Performance Requirements

Parameter	Requirement
RF Carrier Frequency, Fo	SSA1 14679.5 MHz SSA2 14719.5 MHz
RF Bandwidth (1.0 dB)	20 MHz minimum, each channel
Output Carrier Frequency and Phase Stability	Carrier frequency stability shall be determined by the TFR. the carriers shall be phase coherent with the TFR frequency standard to the extent specified in the specifications governing phase noise.
Output Carrier Power Level Stability	± 0.5 dB per 24 hours
Carrier and PN Code Frequency Generation	RF carrier and PN code clock shall be coherently derived from the TFR
Signal-to-Noise Ratio (Thermal)	≥ 43 dB in RF bandwidth
Out-of-Band-Spurs	Greater than or equal to 40 dB below the unmodulated carrier (up to 30 GHz)

5.1.1.1.6 SSAF PM Signal Parameters

SGSS.005077 PM Modulation
The SNGS shall provide Phase Modulation (PM) at the rates identified in Table 5.1-1 and 5.1-13.
Rationale: Phase Modulation is required for NEN user support.

SGSS.005110 SSAF PM Signal Parameters
The SNGS shall provide a SSAF Phase Modulated signal with parameters given in Table 5.1-16.
Rationale: These signal parameters are required to support the capabilities of existing SN and NEN customers.

Table 5.1-16 SSAF Phase Modulation (PM) Service Signal Parameters

SSAF Phase Modulation (PM) Service Signal Parameters			
Parameter		**Description**	
Carrier Frequency Sweep (note 1)		±10 Hz to ±600 kHz	
Carrier Frequency Sweep Duration (note 1)		1 to 120 seconds	
Direct Phase Modulation			
Modulation index		0.2 to 1.5 radians, or π/2 radians	
Data modulation		Data directly phase modulates the carrier	
Data format		NRZ-L,M,S (note 2)	
Symbol format		NRZ (note 2)	Biphase (note 2)
Data rate restrictions (note 3)	Uncoded	0.125 kbps - 1 Mbps	0.125 kbps - 500 kbps
	R ½ Convolutional	0.125 kbps -500 kbps	0.125 kbps - 250 kbps
	Concatenated RS + CC	0.125 kbps -437 kbps	0.125 kbps - 218 kbps
PSK Subcarrier Phase Modulation			
Data modulation		Data PSK modulates a subcarrier	
Subcarrier Type		Squarewave or Sinusoidal	

SSAF Phase Modulation (PM) Service Signal Parameters			
Parameter		**Description**	
Subcarrier Frequency		2, 4, 8, or 16 kHz	
Carrier modulation		Linearly phase modulated by the subcarrier	
Carrier Modulation index		0.2 to 1.8 radians	
Data format		NRZ-L,M,S (note 2)	
Symbol format		NRZ (note 2)	Biphase (note 2)
Data rate restrictions (note 3) and subject to subcarrier to data rate ratio restrictions below)	Uncoded	0.125 kbps - 8 kbps	0.125 kbps - 4 kbps
	R ½ Convolutional	0.125 kbps - 4 kbps	0.125 kbps - 2 kbps
	Concatenated RS + CC	0.125 kbps - 3.5 kbps	0.125 kbps - 1.75 kbps
Subcarrier to Data Rate Ratio (R)		$R=2^n$, where n=1, …7	$R=2^n$, where n=2, …7

NOTES:

1. After the start of an SSAF PM service, the carrier frequency shall sweep plus and minus the Sweep Range (SR) around the center frequency (CF) in a triangle-wave pattern, sweeping from CF to either extreme in Sweep Duration (SD). At sweep start, all modulation (including subcarrier, when applicable) shall be removed. The carrier shall sweep from CF to (CF – SR) in SD seconds. The sweep shall reverse, sweeping from (CF – SR) to CF in SD seconds; then continue sweeping from CF to (CF + SR), again in SD seconds. The sweep shall continue in alternating directions (triangle-wave pattern) until a termination request is received. Upon receipt of the termination request, the sweep shall continue until its next arrival at CF and the frequency profile shall continue to follow the Doppler compensated frequency profile (if enabled). At sweep termination, modulation shall be applied. The SSAF PM service frequency sweep does not impact simultaneous SN ground terminal Doppler compensation of the SSAF service carrier.
2. The data format at the baseband data interface will be NRZ-L. Data format conversion from NRZ-L to NRZ-M,S may be scheduled. Symbol format conversion from NRZ to Biphase may also be scheduled.
3. The forward data rate restrictions in this table are applicable to the uncoded data rate.

5.1.1.1.7 MAF Signal Parameters

SGSS.002013 S-band Multiple Access Forward (MAF) Data Rates

The SNGS shall provide SMA forward data rates as defined in Table 5.1-17.

Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-17 S-Band Multiple Access Forward (MAF) Data Rates

Service	Data Rates	Coding	Modulation	Ranging (Y/N)
MAF	0.1 kbps – 300 kbps	Uncoded	**PN-Spread BPSK**	**N**
	1 kbps – 150 kbps	R 1/2 Convolutional		**N**
	1 kbps – 150 kbps	R 1/2 LDPC		**N**
	1 kbps – 262.5 kbps	R 7/8 LDPC		**N**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**N**
	0.1 kbps – 300 kbps	Uncoded	**Staggered Quadriphase Pseudorandom Noise (SQPN) (Range on the Q channel)**	**Y**
	1 kbps – 150 kbps	R 1/2 Convolutional		**Y**
	1 kbps – 150 kbps	R 1/2 LDPC		**Y**
	1 kbps – 262.5 kbps	R 7/8 LDPC		**Y**
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**

SGSS.002014 SMAF Coding

The SNGS shall provide SMA forward coding as defined in Table 5.1-17.

Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002015 SMAF Modulation
The SNGS shall provide SMA forward modulation as defined in Table 5.1-17.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002119 MA Forward Service Signal Constraints
The SNGS shall provide MA forward service meeting the signal constraints defined in Table 5.1-18.
Rationale: The constraints are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-18 Signal Constraint Requirements for MAF Service

Parameter	Requirement
I or Command Channel Radiated Power / Q or Range Channel Radiated Power	+10 ± 0.5 dB
Modulator gain imbalance (peak)	±0.25 dB
Relative phase between I and Q channels	90 ±3 degrees
Symbol Rate Tolerance	≤ 0.1%
Symbol asymmetry (peak)[1]	±3 %
Symbol transition time (90% of initial state to 90% of final state)[1]	≤ 5 % of symbol duration
Phase nonlinearity (peak), Best Straight Line (BSL)	± 4.25° over ± 2.1 MHz
Gain flatness (peak), RSS	± 0.4 dB over ± 2.1 MHz
Gain slope (peak)	± 0.1 dB/MHz over ± 7.0 MHz
AM/AM	≥ 0.0 and ≤ 1.0 dB/dB
AM/PM	≤ 4°/dB
PN code chip jitter (rms) (Including effects of Doppler compensation)	≤ 1°
Data bit jitter (peak)[1]	≤ 1%
Spurious PM (rms)	≤ 0.8° over ± 3.0 MHz
Spurious outputs (Sum of all in-band spurs from all transmit sources)	≥ 30 dBc over ± 3.0 MHz
Incidental AM (peak)	≤ 1.4% over ± 3.0 MHz
Phase Noise (rms) − Total 1 Hz – 10 Hz 10 Hz – 32 Hz 32 Hz – 1 KHz 1 kHz – 10 MHz	 ≤1.4° ≤1.4° ≤3.9° ≤1.0°
Phase Noise (rms) − Component not coherent with TTCS pilot signal 1 Hz – 10 Hz 10 Hz – 32 Hz 32 Hz – 1 KHz 1 kHz – 10 MHz	 ≤ 0.8° ≤ 0.7° ≤ 1.8° ≤ 1.0°
I/Q PN code chip skew (peak)	<0.01 chip
PN chip asymmetry (peak)	<0.01 chip
PN code chip rate (peak) relative to absolute coherence with carrier rate	< 0.01 chips/sec at PN code chip rate

NOTES:
(1) These values are the SNGS contributions to symbol asymmetry, symbol transition time, and data bit jitter, assuming perfect forward service input data.

SGSS.005154 MA Forward Service Signal Performance Requirements
The SNGS shall provide MA Forward service meeting the performance defined in Table 5.1-19.
Rationale: The constraints are imposed to maintain compatibility with existing SN user platforms.

Table 5.1-19 MAF Signal Performance Requirements

Parameter	Requirement
RF Carrier Frequency, Fo	MA1 14,826.4 MHz MA2 14,816.4 MHz
RF Bandwidth (1.0 dB)	6 MHz minimum, each channel
Output Carrier Frequency and Phase Stability	Carrier frequency stability shall be determined by the TFR. the carriers shall be phase coherent with the TFR frequency standard to the extent specified in the specifications governing phase noise.
Output Carrier Power Level Stability	± 0.5 dB per 24 hours
Carrier and PN Code Frequency Generation	RF carrier and PN code clock shall be coherently derived from the TFR
Signal-to-Noise Ratio (Thermal)	≥ 43 dB in RF bandwidth
Out-of-Band-Spurs	Greater than or equal to 40 dB below the unmodulated carrier (up to 30 GHz)

5.1.1.2 Forward Service IF Transport

SGSS.005017 Accept IF Forward signals from ULE
The SNGS shall accept IF signals from User Local Equipment for the transmission of Forward user services.
Rationale: Some users opt to bypass SN modems and simply provide an IF signal for upconversion and transmission.

5.1.1.3 Forward Service Doppler Compensation

SGSS.005118 Doppler Compensation
The SNGS shall provide Doppler compensation as described in Table 5.1-20, upon scheduled request.
Rationale: An adjustment of the forward link frequency, to compensate for Doppler shift induced by relative spacecraft motion, makes signal acquisition easier for the user platform. The calculation of this frequency adjustment is based on the knowledge of the user platform orbit.

Table 5.1-20 Doppler Compensation Requirements

Doppler Compensation Performance	User Service			
Parameter	**KaSA**	**KuSA**	**SSA**	**MA**
Maximum carrier frequency dynamics before compensation				
Max Doppler (kHz)	±943.7	± 552	± 85	± 85
Max Freq Rate (Hz/sec)	± 1196.7	± 700	± 360	± 110
Max Freq Acceleration (Hz/sec^2)	±17.1	± 1.0	± 15	± 0.15
PN chip rate dynamics before compensation				
Max Doppler (kchip/sec)	± 0.13	± 0.13	± 0.13	± 0.13
Max Freq Rate (chip/sec^2)	± 0.13	± 0.16	± 0.53	± 0.16
Max Freq Acceleration (chip/sec^3)	± 0.00022	± 0.00022	± 0.022	± 0.00022

Doppler Compensation Performance	User Service			
Parameter	**KaSA**	**KuSA**	**SSA**	**MA**
Other Parameters				
Doppler Compensation Frequency Error[1]	≤ 530 Hz	≤ 325 Hz	≤ 50 Hz	≤ 50 Hz
Frequency Residual Rate of Change due to SNGS error. (Increase over Doppler-free carrier frequency, at the user platform)	≤ 500 Hz/s	≤ 330 Hz/s	≤ 30 Hz/s	≤ 30 Hz/s
Frequency Residual Rate of Change due to ephemeris uncertainty	≤ 5 Hz/s	≤ 5 Hz/s	≤ 2.5 Hz/s	≤ 2.5 Hz/s
Compensation Characteristic	Straight line (linear chord) plot of frequency vs. time, using a series of phase-continuous frequency steps.			
Dynamic conditions under which performance must be met				
User platform velocity (km/sec)	12	12	12	12
User platform acceleration (m/sec^2)	15	15	50	15
User platform jerk, sustained indefinitely (m/s^3)	0.02	0.02	2	0.02
User platform jerk, sustained ≤ 1 second (m/s^3)	n/a	n/a	5	n/a
User platform jerk, sustained ≤ 50 milliseconds (m/s^3)	n/a	n/a	70	n/a
User platform ephemeris uncertainty (sec)	≤ ± 4.5	≤ ± 4.5	≤ ± 9	≤ ± 4.5
TDRS Inclination (degrees)	15	15	15	15

Notes:

1. The requirement value specified is the maximum allowable SNGS contribution only to total Doppler compensation error, and does not include errors related to the accuracy of user platform and TDRS state vectors. The total Doppler compensation error is equal to E+C, where:
   - E is the error due to the ephemeris uncertainty "e" inherent in the user and TDRS vectors provided to the WSC. $E \leq e(f_0/c)\ddot{R}$, where f_0 is the nominal center frequency of the user spacecraft defined in the event schedule, c is the free space speed of light in m/sec, $\ddot{R}$ is the range acceleration between the TDRS and the user platform, and e is the ephemeris epoch time uncertainty. For SSA service user, $\ddot{R} \leq 50$ m/sec^2 and $e \leq \pm 9$ sec.
   - C is the SNGS-induced Doppler compensation frequency error

5.1.2 User Return Data Services

Return services originate at the user platform and are relayed to the user Mission Operations Center through the SN. Some return services use Pseudorandom Noise (PN) codes that spread the signal; these services are called Data Group 1 (DG1). The spread signals may be used to perform ranging services, to reduce power flux density, or to support multiple users (with different PN codes). Data Group 1 is further divided into three Modes, depending on whether the PN code is used to spread both I and Q channels, or just the I channel; and whether the user platform coherently derives its transmit frequency from the receive frequency. I and Q refer to the In-phase and the Quadrature-phase components of the PSK modulated signal, and may be treated as distinct data channels. The Data Groups and Modes are defined in Table 5.1-21. Return services that are not spread are called Data Group 2 (DG2).

Table 5.1-21 Data Group and Mode Descriptions

Data Group and Mode	PN Code	Coherency
DG1 Mode 1	I and Q	Coherent
DG1 Mode 2	I and Q	Non-Coherent
DG1 Mode 3	I only	Coherent
DG2	None	Either Coherent or Non-Coherent

SGSS.002068 PN Spreading of Return Links

The SNGS shall provide PN spreading and de-spreading of baseband data in compliance with ITU, FCC and NTIA constraints on spectral occupancy.

Rationale: PN spreading is required to limit interference of the TDRS space-to-space links with other spacecraft and terrestrial users of the same frequencies.

SGSS.002005 S-band Single-Access Return Service (SSAR)

The SNGS shall receive user data on two FDM channels per operational TDRS of the Ku-band downlink designated in Table 5.1-22 for SSAR traffic.

Rationale: This is constrained by the transponder design of the TDRS communications payload.

Table 5.1-22 Downlink Frequency Plan

Service	SGL Downlink			SSL Return		
	Center Freq (1) (MHz)	POL	BW (MHz)	Center Freq (2) (MHz)	POL	BW (MHz)
User Services						
KaSAR-1	13,528.40	1	225	25,253.4 to 27,478.4 (3)	LHC/RHC	225
KaSAR-2	13,928.40	2	225	25,253.4 to 27,478.4 (3)	LHC/RHC	225
KaSAR-3	13,720.00	1	650	25,545.0 to 27,195.0 (3)	LHC/RHC	650
KuSAR-1	13,528.40	1	225	15,003.40	LHC/RHC	225
KuSAR-2	13,928.40	2	225	15,003.40	LHC/RHC	225
SSAR-1	13,677.50	2	10	2204.52 to 2295.20 (4)	LHC/RHC	10
SSAR-2	13,697.50	2	10	2204.52 to 2295.20 (4)	LHC/RHC	10
MAR-1 through MAR-30	30 Channels, 13405.0 MHz to 13622.5 MHz in 7.5 MHz steps	2	6	2287.5	LHC	6
TDRS Support						
Ku-Band TLM-1	13,725.00	2	3			
Ku-Band TLM-2	13,731.00	2	3			
S-Band TLM-1	2,205.0	RHC	3			
S-Band TLM-2	2,211.0	RHC	3			

NOTES:

1. Frequency plan shown for the F8 - L spacecraft. For the F1-F7 spacecraft, the frequency plan is similar except only the high TT&C frequencies are supported.
2. For coherent operation, forward-return turnaround ratios are:
   - S-Band: 240/221
   - Ku-Band: 1600/1469
   - Ka-Band: 3344/3599
3. The Ka-Band SA Return service center frequency is tunable in 25 MHz steps on the TDRS spacecraft by telecommand.
4. The S-Band SA Return service center frequency is tunable in 0.5 MHz steps on the TDRS spacecraft by telecommand.

SGSS.002011 SSAR Aperture Combining
The SNGS shall have the capability to combine the signals received from a single customer spacecraft through both SSA return services using the same TDRS.
Rationale: Provides a customer spacecraft with a nominal 2.5 dB increase in return service performance.

SGSS.002016 Multiple Access Return Service -GBBF
The SNGS shall receive user data on thirty FDM channels per operational TDRS of the Ku-band downlink designated in Table 5.1-22 for MAR traffic with Ground-Based Beam Forming (GBBF).
Rationale: This is constrained by the transponder design of the first-generation TDRS communications payload.

SGSS.002017 Multiple Access Return Service-SBBF
The SNGS shall receive user data on six FDM channels per operational TDRS of the Ku-band downlink designated in Table 5.1-22 for MAR traffic with Satellite-Based Beam Forming (SBBF).
Rationale: This is constrained by the transponder design of the second-generation TDRS communications payload. One of the six channels is used for a phased-array calibration signal.

SGSS.002027 Ku-band Single-Access Return (KuSAR) Service
The SNGS shall receive user data on two FDM channels per operational TDRS of the Ku-band downlink designated in Table 5.1-22 for KuSAR user service traffic.
Rationale: This is constrained by the transponder design of the TDRS communications payload.

SGSS.002037 Ka-band Single-Access Return Service
The SNGS shall receive user data on two channels per operational TDRS of the Ku-band downlink designated in Table 5.1-22 for KaSAR traffic.
Rationale: This is constrained by the transponder design of the TDRS communications payload.

SGSS.002108 Return Link Bit Slippage

The SNGS shall meet the Return Link Bit Slippage specifications as follows:

a. Normal Transition Density
    1. For convolutionally coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1010 clock cycles, whichever is greater, for the C/No required for 10-5 PE performance. This requirement applies for transition densities of at least 40% for NRZ symbols and any transition density for biphase symbols.
    2. For LDPC and concatenated coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1012 clock cycles, whichever is greater, for the C/No required for 10-8 PE performance. This requirement applies for transition densities of at least 40% for NRZ symbols.
b. Low Transition Density
    1. For convolutionally coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1010 clock cycles, whichever is greater, for 1.0 dB more C/No than required for 10-5 PE performance. This requirement applies for NRZ symbol transition densities between 25% and 40%.
    2. For LDPC and concatenated coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1012 clock cycles, whichever is greater, for 1.0 dB more C/No than required for 10-8 PE performance. This requirement applies for NRZ symbol transition densities between 25% and 40%.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002109 Return Link Cycle Slippage

The SNGS shall meet the Return Link The mean time-to-cycle slip in tracking the carrier shall be greater than or equal to 90 minutes for 3 dB less C/No than required for the worst-case required BER operating point.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002114 Return Service Status Measuring and Monitoring

The SNGS shall provide RF and baseband equipment and service performance status data every second including the following:

1. Service Performance.
    - a) PN Lock.
    - b) Carrier Lock.
    - c) Symbol Lock.
    - d) Decoder Lock (when applicable).
    - e) KSA Autotrack Status.
    - f) C/No estimate.
    - g) Eb/No estimate.
    - h) Service (e.g., Baseband, IF, performance test or other)
    - i) Demodulation (e.g., PM, BPSK, QPSK, etc.)
    - j) PN Enable (e.g., I and Q enable or I and Q disable, etc.)
    - k) Decoding (e.g., convolutional, rate ½ LDPC, concatenated, etc.)
    - l) Derandomization (e.g., enable, bypass)
    - m) Block deinterleaving (e.g., bypass, I=1, I=2, etc.)
    - n) Periodic Convolutional deinterleaving (e.g., enable, bypass)
    - o) Real-time uncorrectable code block notification to user
    - p) Tuning Range up to 2.5 MHz.
    - q) Power ratio (I/Q) predict.
    - r) Bit Error Rates (I&Q; total for 8PSK)
    - s) Symbol rates (I&Q, total for 8PSK)
    - t) Equalizer selected.
    - u) Data format(s) selected.
    - v) Local/Remote
    - w) Operational Modes:
        - (1) Online
        - (2) Standby
        - (3) Maintenance-Test Mode
    - x) Configuration status
    - y) Summary fault(s)
    - z) Data filter
    - aa) Carrier Tracking Loop Bandwidth
    - bb) Bit Synchronizer Loop Bandwidth
    - cc) ABBE (On/Bypass)
    - dd) ASM pattern
    - ee) Data Service (AOS-framed, bit stream, etc.)
2. Equipment Status.
    - a) Power supply status.
    - b) AGC status.
3. Data Quality Monitoring.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002118 Return Service Status Monitor and Control

The SNGS shall provide the following monitor and control capabilities for the Return Service RF and baseband equipment:

a. Front Panel Capabilities. All equipment, down to the LRU level, shall incorporate front panel controls, status indicators, and test and monitoring points that include:
    1. Visual on/off status indication.
    2. Access to input/output baseband, IF and RF signals and selected voltage levels.
    3. All status.
    4. On/off controls.
    5. Test mode selects.
b. BIT/BITE Testing.
c. BIT/BITE Monitoring.
d. The Return Service equipment shall be controllable remotely.
e. The Return Service equipment shall support maintenance commands to perform self-test for the purpose of isolating any defective LRUs
    1. When commanded to fault isolate, the Return Service equipment shall identify any defective LRUs.
    2. Upon command, the Return Service equipment shall report the identification (ID) number of fault LRU for at least 90% of LRU faults.
    3. Upon command, the Return Service equipment shall report the ID number of the faulty LRU with a maximum false detect probability of 5%.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002116 Return Link Normal Transition Density Bit Slippage

The SNGS shall meet Return link bit slippage for Normal Transition Density

1. For convolutionally coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1010 clock cycles, whichever is greater, for the C/No required for 10-5 PE performance. This requirement applies for transition densities of at least 40% for NRZ symbols and any transition density for biphase symbols.
2. For LDPC and concatenated coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1012 clock cycles, whichever is greater, for the C/No required for 10-8 PE performance. This requirement applies for transition densities of at least 40% for NRZ symbols.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002117 Return Link Low Transition Density Bit Slippage

The SNGS shall meet Return Link bit slippages for Low Transition Density

1. For convolutionally coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than 1010 clock cycles, whichever is greater, for 1.0 dB more C/No than required for 10-5 PE performance. This requirement applies for NRZ symbol transition densities between 25% and 40%.
2. For LDPC and concatenated coded service, the mean time between slips caused by a cycle slip in the symbol clock recovery loop shall be either no less than 90 minutes or no less than

1012 clock cycles, whichever is greater, for 1.0 dB more C/No than required for 10-8 PE performance. This requirement applies for NRZ symbol transition densities between 25% and 40%.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002112 Return Link Reacquisition

The SNGS shall automatically initiate reacquisition using predrop-lock data to aid in the reacquisition in the case of loss of lock condition and as follows:

a. If signal (carrier and/or PN) tracking is lost and the user signal is present, autotracking shall continue during signal (carrier and/or PN) reacquisition.
b. If the KSAR user signal is lost during autotrack, the autotrack logic shall utilize the most current autotrack information to maintain SA antenna pointing. If the signal is absent for greater than 60 seconds, SA antenna pointing shall revert to open loop pointing.
c. Reacquisition time shall be at least two times faster than that for initial acquisition.
d. If reacquisition fails, the SNGS shall automatically revert to the initial acquisition process and provide notification to operations.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002110 False Acquisition Mitigation

The SNGS Return services shall be protected against false carrier acquisition and false acquisition to PN code sidebands during signal acquisition and signal tracking.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002111 Symbol Synchronization

SNGS Return Link Symbol synchronization shall be maintained if the mean clock cycle slip rate is ≤ 1 clock cycle slip in 106 clock cycles and under the following conditions:

a. Normal Transition Density. Symbol synchronization shall be maintained for 3 dB less C/No than required for the worst-case required BER operating point. This requirement applies for transition densities of at least 40% for NRZ symbols and any transition density for biphase symbols.

b. Low Transition Density. Symbol synchronization shall be maintained for 2 dB less C/No than required for the worst-case required BER operating point. This requirement applies for NRZ symbol transition densities between 25% and 40%.

Rationale: Will be baseline capability at SGSS deployment.

SGSS.002113 C/No Variation

The SNGS Returns services shall accommodate an input C/No variation of 12 dB, at a rate not to exceed 10 dB/sec, without requiring a reconfiguration.

Rationale: Needed to provide the dynamic range or the receivers.

5.1.2.1 Return Service Signal Parameters

5.1.2.1.1 Return Service Demodulation

SGSS.005023 User Selectable Return Service Demodulation

The SNGS shall provide demodulation of user data by user-selectable methods identified in Table 5.1-23.

Rationale: Modulation and demodulation are complementary functions that are required to transport data over a physical medium. There are many methods of doing this and a selection must be provided to meet specific user requirements.

Table 5.1-23 Return Service Uncoded Data Rates

Modulation Scheme	Data Rate, Kbit/s (Uncoded)				
	MAR/SMAR	SSAR	KuSAR	KaSAR (225 MHz)	KaSAR (650 MHz)
Direct PM	n/a	1 – 3,000	n/a	n/a	n/a
PSK Subcarrier PM	n/a	1 – 3,000	n/a	n/a	n/a
PN-Spread BPSK	0.1 – 300	0.1 – 300	1 – 300	n/a	n/a
BPSK	1 – 3,000	1 – 6,000	1 – 150,000	1 – 150,000	n/a
QPSK	1 – 3,000	1 – 12,000	1 – 300,000	1 – 300,000	n/a
SQPSK	1 – 3,000	1 – 12,000	1 – 300,000	1 – 300,000	300,000 – 850,000
SQPN	0.1 – 300	1 – 300	1 – 600	n/a	n/a
8PSK	n/a	12,000 – 24,000	300,000 – 600,000	300,000 – 600,000	1,000 – 1,500,000

8PSK 8-Phase Shift Keying
BPSK Binary Phase Shift Keying
PM Phase Modulation
QPSK Quadrature Phase Shift Keying
SQPN Staggered Quadriphase Pseudorandom Noise
SQPSK Staggered Quadrature Phase Shift Keying

SGSS.005024 SQPN Demodulation
The SNGS shall provide SQPN demodulation at the rates identified in Table 5.1-23.
Rationale: Staggered Quadrature Pseudo Noise (SQPN) modulation is similar to SQPSK, with the difference that the data is spread using a PN sequence.

SGSS.005025 BPSK Demodulation
The SNGS shall provide BPSK demodulation at the rates identified in Table 5.1-23.
Rationale: Binary Phase Shift Keying (BPSK) is a robust and simple digital modulation scheme that is widely used for satellite communications, especially when link conditions are challenging. This is a legacy requirement.

SGSS.005026 PN Spread BPSK Demodulation
The SNGS shall provide PN Spread BPSK demodulation at the rates identified in Table 5.1-23.
Rationale: PN-spreading of the BPSK signal allows that signal to occupy a wider bandwidth at a lower power. It reduces interference, both given and received, provides a means of spectrum re-use, and provides a means of PN ranging.

SGSS.005027 SQPSK Demodulation
The SNGS shall provide SQPSK demodulation at the rates identified in Table 5.1-23.
Rationale: Staggered QPSK (also called Offset QPSK or OQPSK) provides more optimal symbol transitions than QPSK by delaying one of the quadrature elements by half a symbol period with respect to the other. The average magnitude of the phase transitions is smaller with SQPSK than with conventional QPSK, resulting in improved error performance.

SGSS.005028 8PSK Demodulation
The SNGS shall provide 8PSK demodulation at the rates identified in Table 5.1-19.23
Rationale: 8PSK is a higher-order modulation (3 bits/symbol) that can provide increased throughput in a bandwidth-limited link.

5.1.2.1.2 Return Service FEC Decoding

SGSS.005029 User Selectable FEC Decoding
The SNGS shall provide decoding of user data transmitted over satellite links, using user-selectable Forward Error Correction (FEC) codes.
Rationale: Forward Error Correction coding is an industry best practice that is used to achieve low bit error rates over an error-prone channel. Many coding techniques exist and a selection must be provided to meet specific user requirements.

SGSS.005030 Convolutional Decoding
The SNGS shall provide Convolutional decoding on return links at rates identified in Table 5.1-3.
Rationale: Convolutional encoding is an early method of Forward Error Correction that has low complexity and low delay, and is still widely used. This is a legacy requirement.

SGSS.005031 Convolutional + Reed Solomon Decoding
The SNGS shall provide decoding that employs a Convolutional outer code concatenated with a Reed Solomon inner code on return links at rates identified in Table 5.1-3.
Rationale: Convolutional codes have an error floor that impacts high data rates in a bursty noise environment, such as a satellite link. To mitigate this, a Reed-Solomon block code is often used as an outer code. This is a legacy requirement.

SGSS.005032 Turbo Product Decoding
The SNGS shall provide Turbo Product decoding on return links at rates identified in Table 5.1-3.
Rationale: Turbo product codes in most cases provide higher FEC performance than RS+Convolutional concatenated codes.

SGSS.005033 Low Density Parity Check Decoding
The SNGS shall offer Low Density Parity Check decoding on return links at rates identified in Table 5.1-3.
Rationale: Required by Constellation Program. Low-Density Parity Check is a highly complex, but highly efficient FEC code. With modern computing power the complexity is no longer a limiting issue. LDPC can offer improvement even over highly efficient Turbo codes. It has been widely adopted throughout the satellite industry, and was the FEC selected for DVB-S2.

5.1.2.1.3 KaSAR Signal Parameters

SGSS.002038 KaSAR Data Rates
The SNGS shall provide KaSAR data rates as defined in Table 5.1-24.
Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-24 Ka-band Single Access Return (KaSAR) User Services

Service	Data Rates	Coding	Modulation	Tracking (Y/N)	Coherent/ Noncoherent
KaSAR – 225 MHz DG2	1 kbps – 150 Mbps	Uncoded	**BPSK**	**Y**	Non-Coherent
	1 kbps – 75 Mbps	R 1/2 Convolutional		**Y**	Non-Coherent
	1 kbps – 300 Mbps	Uncoded	**(QPSK), SQPSK**	**Y**	Non-Coherent
	1 kbps – 150 Mbps	R 1/2 Convolutional		**Y**	Non-Coherent
	1 kbps – 200 Mbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 kbps – 410 Mbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 kbps – 410 Mbps	R 7/8 TPC		**Y**	Non-Coherent
	1 kbps – 262.3 Mbps	(255,223) Reed–Solomon		**Y**	Non-Coherent
	1 kbps – 131.2 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
	150 – 300 Mbps	JPL R 1/2 LDPC	**8PSK**	**Y**	Non-Coherent
	150 – 600 Mbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	150 – 600 Mbps	R 7/8 TPC		**Y**	Non-Coherent
KaSAR – 650 MHz DG2	300 – 800 Mbps	Uncoded	**SQPSK**	**Y**	Non-Coherent
	300 – 575 Mbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	300 – 1000 Mbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	300 – 1000 Mbps	R 7/8 TPC		**Y**	Non-Coherent
	300 – 850 Mbps	JPL R 1/2 LDPC	**8PSK**	**Y**	Non-Coherent
	300 – 1500 Mbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	300 – 1500 Mbps	R 7/8 TPC		**Y**	Non-Coherent

SGSS.002039 KaSAR Decoding
The SNGS shall provide KaSAR decoding as defined in Table 5.1-24.
Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002040 KaSAR Demodulation
The SNGS shall provide KaSAR demodulation as defined in Table 5.1-24.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002100 KaSAR Data Formatting
The SNGS shall support KaSAR NRZ-L, M, or S Data formats.
Rationale: Required for types of data formatting supported by the SN.

SGSS.002101 KaSAR Symbol Formatting
The SNGS shall support KaSAR NRZ or Biphase Symbol formats.
Rationale: Required for types of symbol formatting supported by the SN.

SGSS.005138 KaSAR Return Service Configurations
The SNGS shall be capable of processing KaSAR input signals for the data configurations described in Table 5-25 and 5-26.
Rationale: Will be baseline capability at SGSS deployment.

Table 5.1-25 KaSA Return 225 MHz Service Configurations

Return Service Configuration[5]				Source Data Rate Restrictions and Availability[3,4]			
				DG1 Mode 1, 2, 3 and DG2 Coherent		DG2 Noncoherent[1,2]	
				Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		-	-	NRZ	1 kbps – 75 Mbps
		Uncoded		-	-	NRZ	1 kbps – 150 Mbps
	QPSK, SQPSK	Alternate I/Q encoded symbols	Rate ½ coded	-	-	NRZ	1 kbps – 150 Mbps
			Uncoded	-	-	NRZ	1 kbps – 300 Mbps
			Rate ½ LDPC	-	-	NRZ	1 kbps – 200 Mbps
			Rate 7/8 LDPC	-	-	NRZ	150 – 410 Mbps
			Rate 7/8 TPC	-	-	NRZ	150 – 410 Mbps
			(255,223) Reed-Solomon	-	-	NRZ	1 kbps – 277.52 Mbps
			Concatenated RS+ CC	-	-	NRZ	1 kbps – 131.2 Mbps
	SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	-	-	NRZ	1kbps – 150 Mbps
			Uncoded	-	-	NRZ	1 kbps – 300 Mbps
	8PSK	Alternate Encoded Symbols	Rate ½ LDPC	-	-	NRZ	150 – 300 Mbps
			Rate 7/8 LDPC	-	-	NRZ	150 – 600 Mbps
			Rate 7/8 TPC	-	-	NRZ	150 – 600 Mbps
Dual Data Sources (data rates are for each source separately)	QPSK[1] or SQPSK[1]	Rate 1/2 coded		-	-	NRZ	1 kbps – 75 Mbps
		Uncoded		-	-	NRZ	1 kbps – 150 Mbps[(6)]
		(255,223) Reed-Solomon		-	-	NRZ	138.76 Mbps[(6)]

NOTES:

- Configuration not supported

1. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently and differentially formatted (-M,-S).
   c. Dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels; QPSK is used for all other configurations; for both SQPSK and QPSK, an I:Q power ratio of 1:1 is supported.
2. Noncoherent configurations require a customer transmit frequency uncertainty of ± 55 kHz.
3. Data rates and modulation schemes are based upon support through the KaSAR 225 MHz SN ground terminal receivers.
4. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates.
5. For a channel with rate ½ coding and data rates greater than 10 Mbps, the "stacked" encoder/decoder is supported by the SN.
6. Support of modulo-4 differentially encoded service is required for the service modes described in Appendix F. Appendix F also provides a description of modulo-4 differential encoding / decoding.

Table 5.1-26 KaSA Return 650 MHz Service Configurations

Return Service Configuration				Source Data Rate Restrictions and Availability[1,2]			
				DG1 Mode 1, 2, 3 and DG2 Coherent		DG2 Noncoherent[1,2]	
				Data format	Data rate	Data format	Data rate
Single Data Source	QPSK/ SQPSK	Alternate I/Q encoded symbols	Rate ½ LDPC	-	-	NRZ	300 – 575 Mbps
			Rate 7/8 LDPC	-	-	NRZ	300 – 1000 Mbps
			Rate 7/8 TPC	-	-	NRZ	300 – 1000 Mbps
	SQPSK[1]	Alternating I/Q data	Uncoded	-	-	NRZ	300 – 800 Mbps
	8PSK	Alternate Encoded Symbols	Rate ½ LDPC	-	-	NRZ	400 – 850 Mbps
			Rate 7/8 LDPC	-	-	NRZ	400 – 1500 Mbps
			Rate 7/8 TPC	-	-	NRZ	400 – 1500 Mbps

NOTES:
- Configuration not supported
1. Data rates and modulation schemes are based upon support through the KaSAR 650 MHz SN ground terminal receivers.
2. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates.

SGSS.005139 ALOS Return Service
The SNGS shall provide Ka-Band Return data service for the Advanced Land Observing Satellite (ALOS) mission, as defined in Appendix F.
Rationale: NASA has a commitment to support the ALOS mission.

5.1.2.1.4 KuSAR Signal Parameters

SGSS.002028 KuSAR Data Rates
The SNGS shall provide KuSAR data rates as defined in Table 5.1-27.
Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-27 Ku-band Single Access Return (KuSAR) User Services

Service	Data Rates	Coding	Modulation	Tracking (Y/N)	Coherent/ Non coherent
KuSAR DG1 Mode 1	1 – 300 kbps	Uncoded	**PN-Spread BPSK**	**Y**	Coherent
	1 – 150 kbps	R 1/2 Convolutional		**Y**	Coherent
	1 – 150 kbps	JPL R 1/2 LDPC		**Y**	Coherent
	1 – 262.5 kbps	GSFC R 7/8 LDPC		**Y**	Coherent
	1 – 262.3 kbps	(255,223) Reed–Solomon		**Y**	Coherent
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
	1 – 600 kbps	Uncoded	**SQPN**	**Y**	Coherent
	1 – 300 kbps	R 1/2 Convolutional		**Y**	Coherent
	1 – 300 kbps	JPL R 1/2 LDPC		**Y**	Coherent
	1 – 525 kbps	GSFC R 7/8 LDPC		**Y**	Coherent
	1 – 525 kbps	(255,223) Reed–Solomon		**Y**	Coherent
	1 – 262.4 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
DG1 Mode 2	1 – 300 kbps	Uncoded	**PN-Spread BPSK**	**Y**	Non-Coherent
	1 – 150 kbps	R 1/2 Convolutional		**Y**	Non-Coherent
	1 – 150 kbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 – 262.5 kbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
	1 – 600 kbps	Uncoded	**SQPN**	**Y**	Non-Coherent
	1 – 300 kbps	R 1/2 Convolutional		**Y**	Non-Coherent
	1 – 300 kbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 – 525 kbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 – 262.4 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
DG2	1 kbps – 150 Mbps	Uncoded	**BPSK**	**Y**	Either
	1 kbps – 75 Mbps	R 1/2 Convolutional		**Y**	Either
	1 kbps – 300 Mbps	Uncoded	**(QPSK), SQPSK**	**Y**	Either
	1 kbps – 150 Mbps	R 1/2 Convolutional		**Y**	Either
	1 kbps – 200 Mbps	JPL R 1/2 LDPC		**Y**	Either
	1 kbps – 410 Mbps	GSFC R 7/8 LDPC		**Y**	Either
	1 kbps – 410 Mbps	R 7/8 TPC		**Y**	Either
	1 kbps – 262.3 Mbps	(255,223) Reed–Solomon		**Y**	Either
	1 kbps – 131.2 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Either
	150 – 300 Mbps	JPL R 1/2 LDPC	**8PSK**	**Y**	Non-Coherent
	150 – 600 Mbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	150 – 600 Mbps	R 7/8 TPC		**Y**	Non-Coherent

SGSS.002029 KuSAR Decoding

The SNGS shall provide KuSAR decoding as defined in Table 5.1-25.

Rationale: Forward Error Correction coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002030 KuSAR Demodulation

The SNGS shall provide KuSAR demodulation as defined in Table 5.1-25.

Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002032 KuSAR Coherency
The SNGS shall allow KuSAR coherent and non-coherent modes as defined in Table 5.1-25.
Rationale: For coherent modes, the customer's return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform's received forward link carrier frequency. Two-way Doppler measurements and range measurements (if PN spread) are available only in coherent mode.

SGSS.002102 KuSAR Data Formatting
The SNGS shall support KuSAR NRZ-L,M, or S Data formats.
Rationale: Required for types of data formatting supported by the SN.

SGSS.002103 KuSaR Symbol Formatting
The SNGS shall support KuSAR, NRZ or Biphase Symbol formats.
Rationale: Required for types of symbol formatting supported by the SN.

SGSS.005097 K-band Return Services Performance
The SNGS K-band return services shall meet probability of bit error (PE) requirements, for each data channel at the decoder output, for the range of error probabilities as specified in Table 5.1-28:

C/No = Eb/No + 10 log Rb + L(PE, Rb) where:

- 10E-8 ≤ PE ≤ 10E-5.
- Rb is the bit rate of the data channel.
- L(PE, Rb) is the allowable implementation loss given in Table 5.1-28.

Rationale: Eb/No is the theoretically required value to achieve a given PE in an additive white Gaussian noise (AWGN) channel (Table 5.1-33). See Appendix D Aggregate Signal Distortion Characteristics for estimated Return Service aggregate signal distortion characteristics up to the receiver input.

Table 5.1-28 Ku and Ka-band SAR Allowable Implementation Loss, L(PE,Rb)

Coding			Data Rate R_b (Mbps)	Allowable Implementation Loss, $L(P_E, R_b)^{(1,2,3,4)}$, dB			
				$P_E = 10^{-5}$	$P_E = 10^{-6}$	$P_E = 10^{-7}$	$P_E = 10^{-9}$
Uncoded	225-MHz Channel	QPSK/ SQPSK	0.001	3.0	3.4	3.8	N/A
			0.01	3.0	3.4	3.7	N/A
			0.1	3.0	3.4	3.7	N/A
			1	2.5	2.9	3.2	N/A
			10	2.5	2.9	3.2	N/A
			100	2.7	3.1	3.7	N/A
			150	3.0	3.5	4.2	N/A
			300	3.2	3.7	4.4	N/A
Rate 1/2 convolutional coding	225-MHz Channel	QPSK/ SQPSK	0.001	3.0	3.2	3.5	N/A
			0.01	3.0	3.2	3.4	N/A
			0.1	3.0	3.2	3.4	N/A
			1	2.5	2.7	2.9	N/A
			10	2.5	2.7	3.1	N/A
			75	3.0	3.2	3.7	N/A
			150	3.2	3.4	3.9	N/A
(255,223) Reed-	225-MHz Channel	QPSK/ SQPSK	0.001	3	3.2	3.5	N/A
			0.525	3	3.2	3.5	N/A

Coding			Data Rate R_b (Mbps)	Allowable Implementation Loss, $L(P_E, R_b)$[1,2,3,4], dB			
				$P_E = 10^{-5}$	$P_E = 10^{-6}$	$P_E = 10^{-7}$	$P_E = 10^{-9}$
Solomon			275	3.2	3.4	3.9	N/A
			277.52	3.2	N/A	N/A	N/A
Concatenated RS+CC (No Interleave)	225-MHz Channel	QPSK/ SQPSK	0.001	N/A	N/A	N/A	3.5
			131.2	N/A	N/A	N/A	3.9
Rate 1/2 LDPC[5]	225-MHz Channel	QPSK/ SQPSK	25	1.9	N/A	2.1	2.4
			150	1.9	N/A	2.1	2.4
			200	2.8	N/A	3.0	3.3
		8PSK	150	2.2	N/A	2.3	2.5
			300	3.0	N/A	3.1	3.3
	650-MHz Channel	QPSK/ SQPSK	300	1.9	N/A	2.1	2.4
			575	3.3	N/A	3.5	3.8
		8PSK	450	2.7	N/A	3.0	3.3
			700	4.2	N/A	4.5	4.8
Rate 7/8 LDPC[5]	225-MHz Channel	QPSK/ SQPSK	150	2.0	N/A	2.1	2.3
			200	2.0	N/A	2.1	2.3
			300	2.9	N/A	3.0	3.3
			400	4.0	N/A	4.2	4.6
		8PSK	150	2.2	N/A	2.3	2.5
			400	2.2	N/A	2.3	2.5
			450	2.5	N/A	2.6	2.8
			500	2.7	N/A	2.8	3.0
			550	3.4	N/A	3.5	3.8
			600	4.2	N/A	4.4	4.7
	650-MHz Channel	QPSK/ SQPSK	300	2.2	N/A	2.3	2.5
			450	2.2	N/A	2.3	2.5
			600	2.4	N/A	2.5	2.7
			800	3.0	N/A	3.1	3.3
			1000	3.9	N/A	4.1	4.4
		8PSK	400	2.6	N/A	2.9	3.2
			450	2.6	N/A	2.9	3.2
			600	2.7	N/A	3.0	3.3
			800	2.7	N/A	3.0	3.3
			1000	2.7	N/A	3.0	3.3
			1200	3.8	N/A	4.1	4.5
Rate 7/8 TPC[5]	225-MHz Channel	QPSK/ SQPSK	150	2.0	N/A	2.1	2.3
			200	2.2	N/A	2.3	2.5
			300	2.7	N/A	2.8	3.0
			400	4.0	N/A	4.2	4.6
		8PSK	150	1.9	N/A	2.0	2.2
			400	1.9	N/A	2.0	2.2
			450	2.4	N/A	2.5	2.7
			500	2.5	N/A	2.6	2.9
			550	3.0	N/A	3.1	3.4
			600	3.6	N/A	3.7	3.9
	650-MHz Channel	QPSK/ SQPSK	300	2.3	N/A	2.4	2.55
			450	2.3	N/A	2.4	2.55
			600	2.5	N/A	2.6	2.75
			800	3.1	N/A	3.2	3.4

Coding			Data Rate R_b (Mbps)	Allowable Implementation Loss, $L(P_E, R_b)^{(1,2,3,4)}$, dB			
				$P_E = 10^{-5}$	$P_E = 10^{-6}$	$P_E = 10^{-7}$	$P_E = 10^{-9}$
			1000	4.0	N//A	4.1	4.3
		8PSK	400	2.4	N/A	2.5	2.7
			450	2.4	N/A	2.5	2.7
			600	2.4	N/A	2.5	2.7
			800	2.5	N/A	2.6	2.8
			1000	2.5	N/A	2.6	2.8
			1200	3.2	N/A	3.3	3.5

NOTES:
1. For all per channel symbol rates ≤ 300 ksym/s, implementation loss requirements specified for PN-spread case.
2. For NRZ-M and NRZ-S data formats, an additional implementation loss of 0.1 dB shall be allowed.
4. BPSK shall be compliant with all QPSK/SQPSK implementation loss requirements except for the applicable data rates that will be one half that stated in this table.

SGSS.005140 KuSAR Return Service Configurations

The SNGS shall be capable of processing KuSAR input signals for the data configurations described in Table 5.1-29.

Rationale: Will be baseline capability at SGSS deployment.

Table 5.1-29 KuSA Return Service Configurations

Return Service Configuration[6]				Source Data Rate Restrictions and Availability[5]			
				DG1 Mode		DG2 Mode	
				1[1] and 2[1,4]		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		NRZ	1 - 150 kbps[1]	NRZ	1 kbps – 75 Mbps
		Uncoded		NRZ	1 - 300 kbps[1]	NRZ	1 kbps – 150 Mbps
		Rate ½ LDPC		NRZ	1 - 150 kbps[1]	-	
		Rate 7/8 LDPC		NRZ	1 – 262.5 kbps	-	
		Rate 7/8 TPC		NRZ	1 – 262.5 kbps	-	
		(255,223) Reed-Solomon		NRZ	1 – 262.3 kbps	-	
		Concatenated RS+ CC		NRZ	1 – 131.2 kbps	-	
		Identical I & Q channel data	Rate 1/2 coded	NRZ	1 - 300 kbps	-	-
			Uncoded	NRZ	1 - 600 kbps	-	-
	SQPN, QPSK, SQPSK[3]	Alternate I/Q encoded symbols	Rate 1/2 coded	NRZ	1 - 300 kbps	NRZ	1 kbps – 150 Mbps
			Uncoded	NRZ	1 - 600 kbps	NRZ	1 kbps – 300 Mbps
			Rate ½ LDPC	NRZ	1 – 300 kbps	NRZ	1 kbps – 200 Mbps
			Rate 7/8 LDPC	NRZ	1 – 525 kbps	NRZ	150 – 410 Mbps
			Rate 7/8 TPC		-	NRZ	150 – 410 Mbps
			(255,223) Reed-Solomon	NRZ	1 – 525 kbps	NRZ	1 – 275 Mbps
			Concatenated RS+ CC	NRZ	1 – 262.4 kbps	NRZ	1 kbps – 131..2 Mbps
		Alternating I/Q data	Individually rate 1/2 coded	NRZ	1 – 300 kbps	NRZ	1 kbps – 150 Mbps

Return Service Configuration[6]				Source Data Rate Restrictions and Availability[5]			
				DG1 Mode		DG2 Mode	
				1[1] and 2[1,4]		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate
			Uncoded	NRZ	1 – 600 kbps	NRZ	1 kbps – 300 Mbps
	8PSK	Alternate I/Q Encoded Symbols	Rate ½ LDPC	-	-	NRZ	150 – 300 Mbps
			Rate 7/8 LDPC	-	-	NRZ	150 – 600 Mbps
			Rate 7/8 TPC	-	-	NRZ	150 – 600 Mbps
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded		NRZ	1 – 150 kbps	NRZ	1 kbps – 75 Mbps
		Uncoded		NRZ	1 – 300 kbps	NRZ	1 kbps – 150 Mbps
		Rate ½ LDPC		-	-	-	-
		Rate 7/8 LDPC		-	-	-	-
		Concatenated RS+ CC		-	-	-	-

NOTES:

- Configuration not supported

1. For DG1 mode 1 and 2 configurations:
   a. Data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. Data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 shall be supported.
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at +π/2 radians.
3. I:Q power ratios of 1:1 shall be supported.
4. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation is used and an I:Q power ratio of 1:1 shall be supported. For the alternate I/Q bit configuration, the I and Q channels will be independently differentially formatted (-M,-S).
   c. Dual data source configurations: SQPSK will be used when there are identical baud rates on the I and Q channels; QPSK is used for all other configurations; for both SQPSK and QPSK, an I:Q power ratio of 1:1 shall be supported.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require the customer transmit frequency uncertainty of ± 55 kHz
6. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates.
7. For a channel with rate ½ coding and data rates greater than 10 Mbps, the "stacked" encoder/decoder is supported by the SN.

SGSS.005141 KuSAR Service Signal Parameters

The SNGS shall accept and process return link signals with the parameters as specified in Table 5.1-30.

Rationale: Required to support existing users and services.

Table 5.1-30 KuSAR Service Signal Parameters

Parameter	Value			
	Data Group 1 (DG1)[1]		Data Group 2 (DG2)[1]	
	Mode 1	Mode 2	Coherent Mode	Noncoherent Mode
User Carrier Frequency, F_1 [2]	$\frac{1600}{1469} x F_R$	User Spacecraft Oscillator	$\frac{1600}{1469} x F_R$	User Spacecraft Oscillator
PN Code Modulation	SQPN, BPSK	SQPN, BPSK		
PN Chip Rate (chips/second)	$\frac{31}{1600x96} x F_1$			
PN Code Length (chips)	$(2^{10} - 1) \times 256$	$2^{11} - 1$		
PN Code Epoch Reference				
I channel:	Epoch (all 1's condition) synchronized to Epoch (all 1's condition) of user spacecraft received forward service range channel PN Code	User Spacecraft Transmitter Oscillator		
Q channel[3]:	Epoch delayed X + 1/2 PN chips relative to I channel PN Code Epoch	Epoch delayed 1/2 PN chip relative to I channel PN Code Epoch		
PN Code Family	Truncated 18 stage shift register sequences, (per 451-PN CODE-SNIP).	Gold codes; (per 451-PN CODE-SNIP).		
Symbol PCI Interleaving	Per SNUG Rev. 9, Appendix F			
R-S Symbol Block Interleaving	Per CCSDS 131.0-B-1			
Symbol Format	NRZ			
Data Randomization	Per CCSDS 131.0-B-1			
Data Format	NRZ-L,M,.S[(4)]			
Data Modulation[(5)]				
I Channel:	Modulo-2 added asynchronously to the PN code on each channel; SQPN		SQPSK, 8PSK, BPSK (Single Data Channel), or QPSK (Dual Data Channel)	
Q Channel:				
Data Rate Restrictions[(6,7)]				
Uncoded	1-600 kbps	1-600 kbps	1 kbps - 300 Mbps	
Rate ½ Convolutional[8]				
Total:	1-300 kbps	1-300 kbps	I (max) + Q(max)	
I Channel:	1-150 kbps	1-150 kbps	1 kbps – 75 Mbps	
Q Channel:	1-150 kbps	1-150 kbps	1 kbps - 75 Mbps	
Rate ½ LDPC				
Total:	1-300 kbps	1-300 kbps	I (max) + Q(max) (SQPSK); 150 - 300 Mbps (8PSK)	
I Channel:	1-150 kbps	1-150 kbps	1 kbps - 100 Mbps (SQPSK)	
Q Channel:	1-150 kbps	1-150 kbps	1 kbps - 100 Mbps (SQPSK)	
Rate 7/8 LDPC				
Total:	1- 525 kbps	1-525 kbps	150 - 410 Mbps (SQPSK); 150 - 600 Mbps (8PSK)	
I Channel:	1-262.5 kbps	1-262.5 kbps	75 – 205 Mbps (SQPSK)	
Q Channel:	1-262.5 kbps	1-262.5 kbps	75 - 205 Mbps (SQPSK)	

Parameter	Value			
	Data Group 1 (DG1)[1]		Data Group 2 (DG2)[1]	
	Mode 1	Mode 2	Coherent Mode	Noncoherent Mode
Rate 7/8 TPC				
Total:	Not Supported	Not Supported	150 - 410 Mbps (SQPSK); 150 - 600 Mbps (8PSK)	
I Channel:	N/A	N/A	75 – 205 Mbps (SQPSK)	
Q Channel:	N/A	N/A	75 - 205 Mbps (SQPSK)	
(255,223) Reed-Solomon				
Total:	1 – 525 kbps	1 – 525 kbps	1 – 275 Mbps	
I Channel:	1 – 262.5 kbps	1 – 262.5 kbps	1 – 137.5 Mbps	
Q Channel:	1 – 262.5 kbps	1 – 262.5 kbps	1 – 137.5 Mbps	
Concatenated RS + CC				
Total:	1 – 262.4 kbps	1 – 262.4 kbps	1 - 131.2 Mbps	
I Channel:	1 – 131.2 kbps	1 – 131.2 kbps	1 – 65.6 Mbps	
Q Channel:	1 – 131.2 kbps	1 – 131.2 kbps	1 – 65.6 Mbps	

NOTES:
1. User spacecraft data service configurations are defined in section 5.1.2.1.4 *KuSAR Signal Parameters*.
2. F_R is the carrier frequency arriving at the user spacecraft; except during scheduled periods of doppler compensation inhibit, $F_R = f_o \pm E+C$, where f_o equals the nominal center frequency of the user spacecraft receiver as defined in the schedule and E+C is defined in Table 5.1-16 *Doppler Compensation Requirements*.
3. Q channel PN code is identical to I channel PN Code offset x + 1/2 PN Chips, where x ≥ 20,000. Value of x is determined by PN code assignments for a particular user spacecraft 451-PN Code-SNIP.
4. For an uncoded single data source service with SQPSK modulation, only NRZ-L will be used.
5. The *KuSA Return Service Configurations* table provides guidance regarding which modulations are required with the various coding options.
6. Data signals on I and Q channels may be independent and asynchronous. If the I and Q channel data signals are independent, the sum of the data rates on the I and Q channel shall not exceed the total maximum data rate. For Data Group 2, identical symbol rates on the I and Q channels, the I and Q channels will be offset relative to one another by one-half data bit period or, if convolutionally coded, one-half encoded data symbol period.
7. Data rate restrictions for BPSK are stated by the "I Channel" row.
8. For all rate ½ convolutional coded service modes, support shall be provided in a single symbol stream, single decoder manner and in a multiple symbol stream, stacked decoder manner.

SGSS.005142 KaSAR Service Signal Parameters

The SNGS shall accept and process return link signals with the parameters as specified in Table 5.1-31.
Rationale: Required to support existing users and services.

Table 5.1-31 KaSAR Service Signal Parameters

Parameter	Value	
	225 MHz	650 MHz
I/Q power ratio	1:1	
Data modulation	BPSK, QPSK, SQPSK, or 8PSK	SQPSK, 8PSK
Carrier Reference (F_2)	User Spacecraft Oscillator(1)	
Symbol PCI Interleaving	Per SNUG Rev. 9, Appendix F	
Symbol Block Interleaving	Per CCSDS 131.0-B-1	
Symbol Format	NRZ	
Data Randomization	Per CCSDS 131.0-B-1	
Data format	NRZ-L, M, S and modulo-4 differentially encoded(5)	NRZ-L, M, or S

Parameter	Value	
	225 MHz	650 MHz
Data rate(2)		
Uncoded(3)		
Total:	1 kbps – 300 Mbps	300 – 800 Mbps
I Channel:	1 kbps – 150 Mbps	150 – 400 Mbps
Q Channel:	1 kbps – 150 Mbps	150 – 400 Mbps
Rate ½ Convolutional (4)		
Total:	1 kbps – 150 Mbps	Not Supported
I Channel:	1 kbps – 75 Mbps	N/A
Q Channel:	1 kbps – 75 Mbps	N/A
Rate ½ LDPC		
Total:	1 kbps – 200 Mbps (SQPSK); 150 – 300 Mbps (8PSK)	300 Mbps – 575 Mbps (SQPSK); 400 Mbps – 850 Mbps (8QPSK)
I Channel:	1 kbps – 100 Mbps (SQPSK)	150 Mbps – 287.5 Mbps (SQPSK)
Q Channel:	1 kbps – 100 Mbps (SQPSK)	150 Mbps – 287.5 Mbps (SQPSK)
Rate 7/8 LDPC		
Total:	150 – 410 Mbps (SQPSK); 150 – 600 Mbps (8PSK)	300 – 1000 Mbps (SQPSK); 400 – 1500 Mbps (8PSK)
I Channel:	75 – 205 Mbps (SQPSK)	150 – 500 Mbps (SQPSK)
Q Channel:	75 – 205 Mbps (SQPSK)	150 – 500 Mbps (SQPSK)
Rate 7/8 TPC		
Total:	150 – 410 Mbps (SQPSK); 150 – 600 Mbps (8PSK)	300 – 1000 Mbps (SQPSK); 400 – 1500 Mbps (8PSK)
I Channel:	75 – 205 Mbps (SQPSK)	150 – 500 Mbps (SQPSK)
Q Channel:	75 – 205 Mbps (SQPSK)	150 – 500 Mbps (SQPSK)
(255,223) Reed-Solomon		
Total:	1 kbps – 277.52 Mbps	Not Supported
I Channel:	1 kbps – 138.76 Mbps	N/A
Q Channel:	1 kbps – 138.76 Mbps	N/A
Concatenated RS + CC		
Total:	1 kbps – 131.2 Mbps	Not Supported
I Channel:	1 kbps – 65.6 Mbps	N/A
Q Channel:	1 kbps – 65.6 Mbps	N/A

NOTES:

1. Carrier center frequency within the range 25,250 to 27,500 MHz. Data rates and carrier frequencies shall be constrained so that the first null of the spectrum for BPSK modulation (or the second null for QPSK) falls within the specified range.
2. Data signals on I and Q channels may be independent and asynchronous. If the I and Q channel data signals are independent, the sum of the data rates on the I and Q channels shall not exceed the total maximum data rate. For identical symbol rates on the I and Q channels, the I and Q channels will be offset relative to one another by one half symbol period.
3. The SNGS will ensure compatibility with the ALOS mission. The ALOS mission uses a balanced QPSK signal structure with modulo-4 differential encoding data formatting and no forward error correction coding signal which ultimately reduces to an uncoded QPSK signal structure with unique differential coding.
4. For all rate ½ convolutional coded service modes, support shall be provided in a single symbol stream, single decoder manner and in a multiple symbol stream, stacked decoder manner.
5. Support of modulo-4 differentially encoded service is only required for the service modes described in Appendix F. Appendix F also provides a description of modulo-4 differential encoding / decoding.

SGSS.005143 K-band User Satellite Signal Distortions

The SNGS K-band return services shall meet probability of bit error (PE) requirements when the signals at the LNA input contain the distortions identified in Appendix E Customer Signal Distortions Constraints.

Rationale: To meet the desired link performance one must take into account the contributions of allowed user spacecraft signal distortions.

5.1.2.1.5 SSAR Signal Parameters

SGSS.002006 SSAR Data Rates

The SNGS shall provide SSAR data rates as defined in Table 5.1-32.

Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-32 S-band Single Access Return (SSAR) User Services

Service	Data Rates	Coding	Modulation	Tracking (Y/N)	Coherent/ Non coherent
SSAR DG1 Mode 1	0.1 – 150 kbps	R 1/2 Convolutional	**PN-Spread BPSK**	**Y**	Coherent
	1 – 150 kbps	JPL R 1/2 LDPC		**Y**	Coherent
	1 – 262.5 kbps	GSFC R 7/8 LDPC		**Y**	Coherent
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
	0.1 – 300 kbps	R 1/2 Convolutional	**SQPN**	**Y**	Coherent
	1 – 300 kbps	JPL R 1/2 LDPC		**Y**	Coherent
	1 – 525 kbps	GSFC R 7/8 LDPC		**Y**	Coherent
	1 – 262.4 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
DG1 Mode 2	1 – 150 kbps	R 1/2 Convolutional	**PN-Spread BPSK**	**Y**	Non-Coherent
	1 – 150 kbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 – 262.5 kbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
	1 – 300 kbps	R 1/2 Convolutional	**SQPN**	**Y**	Non-Coherent
	1 – 300 kbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 – 525 kbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 – 262.4 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
DG1 Mode 3	I: 0.1 –150 kbps Q: 1 kbps – 3.0 Mbps	R 1/2 Convolutional	**QPSK**	**Y**	Coherent
	Q: 1 kbps – 2 Mbps	R 1/3 Convolutional		**Y**	Coherent
	I: 1 –150 kbps Q: 1 kbps – 4.5 Mbps	JPL R 1/2 LDPC		**Y**	Coherent
	I: 1 – 262.5 kbps Q: 1 kbps – 7.8 Mbps	GSFC R 7/8 LDPC		**Y**	Coherent
	I: 1 –131.2 kbps Q: 1 kbps – 2.62 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
DG2	1 kbps – 3 Mbps	R 1/2 Convolutional	**BPSK**	**Y**	Either
	1 kbps – 2 Mbps	R 1/3 Convolutional		**Y**	Either
	1 – 10 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Either
	1 kbps – 6 Mbps	R 1/2 Convolutional	**QPSK, SQPSK**	**Y**	Either
	1 kbps – 4 Mbps	R 1/3 Convolutional		**Y**	Either
	1 kbps – 9 Mbps	JPL R 1/2 LDPC		**Y**	Either
	1 kbps – 15.75 Mbps	GSFC R 7/8 LDPC		**Y**	Either
	1 kbps – 5.25 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Either

Service	Data Rates	Coding	Modulation	Tracking (Y/N)	Coherent/ Non coherent
	6 –12 Mbps	JPL R 1/2 LDPC	8PSK	Y	Either
	6 – 23.6 Mbps	GSFC R 7/8 LDPC		Y	Either
PM	0.125 kbps – 6 Mbps	Uncoded	Direct PM	Y	
	0.125 kbps – 3 Mbps	Rate ½ convolutional		Y	
	0.125 kbps – 2.62 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		Y	
	0.125 kbps – 1 Mbps	Uncoded	PSK Subcarrier PM	Y	
	0.125 kbps – 512 kbps	Rate ½ convolutional		Y	
	0.125 kbps – 440 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		Y	

SGSS.002007 SSAR Decoding
The SNGS shall provide SSAR decoding as defined in Table 5.1-32.
Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002008 SSAR Demodulation
The SNGS shall provide SSAR demodulation as defined in Table 5.1-32.
Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002010 SSAR Coherency
The SNGS shall allow SSAR coherent and non-coherent modes as defined in Table 5.1-32.
Rationale: For coherent modes, the customer's return link carrier frequency and Pseudo-random Noise (PN) code clock frequency (if applicable) are derived from the customer platform's received forward link carrier frequency. Two-way Doppler measurements and range measurements (if PN spread) are available only in coherent mode.

SGSS.002104 SSAR Data Formatting
The SNGS shall support SSAR NRZ-L, M, or S Data formats.
Rationale: Required for types of data formatting supported by the SN.

SGSS.002105 SSAR Symbol Formatting
The SNGS shall support SSA, NRZ or Biphase Symbol formats.
Rationale: Required for types of symbol formatting supported by the SN.

SGSS.005096 S-band Return Services Performance
The SNGS S-band return services shall meet probability of bit error (PE) requirements, for each data channel at the decoder output, for the range of error probabilities as specified below:

C/No = Eb/No + 10 log Rb + L(PE, Rb) where:

- $10E\text{-}8 \leq PE \leq 10E\text{-}5$
- Rb is the bit rate of the data channel.
- L(PE, Rb) is the allowable implementation loss given in Table 5.1-34.

Rationale: Eb/No is the theoretically required value to achieve a given PE in an additive white Gaussian noise (AWGN) channel (Table 5.1-33). See Appendix D Aggregate Signal Distortion Characteristics for estimated Return Service aggregate signal distortion characteristics up to the receiver input.

Table 5.1-33 Theoretical Required Values for PE in an AWGN Channel

MODULATION	CODING	REQUIRED E_b/N_o TO ACHIEVE Pe, dB				
		Pe = 10^{-5}	Pe = 10^{-6}	Pe = 10^{-7}	Pe = 10^{-8}	Pe = 10^{-9}
BPSK, QPSK, SQPSK	Uncoded	9.6	10.5	11.3	N/A	N/A
	Rate ½ Convolutional	4.2	4.8	5.4	N/A	N/A
	(255,223) Reed-Solomon	6.16	6.38	6.57	6.74	N/A
	Concatenated (255,223)RS + Rate ½ Conv. (I=0)	2.96	3.2	3.4	3.8	N/A
	(2048,1024) LDPC	1.74	1.89	2.03	2.17	2.29
	(8160,7136) LDPC	3.85	3.9	4.0	4.1	4.14
	$(128,120)^2$ TPC	3.65	3.72	3.78	3.90	4.0
8PSK	Uncoded	13.0	14.0	14.7	N/A	N/A
	(2048,1024) LDPC	3.43	3.65	3.78	4.0	4.2
	(8160,7136) LDPC	6.48	6.58	6.67	6.74	6.83
	$(128,120)^2$ TPC	6.4	6.48	6.55	6.65	6.75

Table 5.1-34 SSAR/MAR Allowable Implementation Loss, L(PE, Rb)

CODING		DATA RATE R_b (kbps)	CUSTOMER FREQUENCY ALLOCATION	ALLOWABLE IMPLEMENTATION LOSS, $L(P_E, R_b)$(1,2,3,4), dB			
				PE = 10^{-5}	PE = 10^{-6}	PE = 10^{-7}	PE = 10^{-8}
Rate 1/2 convolutional	QPSK/ SQPSK	.1	4.5 MHz	3.0	3.2	3.5	N/A
		1	4.5 MHz	3.0	3.2	3.4	N/A
		10	4.5 MHz	3.0	3.2	3.4	N/A
		100	4.5 MHz	3.0	3.2	3.4	N/A
		1000	2 MHz(4)	2.5	2.7	2.9	N/A
		3000	6 MHz(4)	3.0	3.2	3.7	N/A
		6000	10 MHz	3.2	3.4	3.9	N/A
Rate 1/3 convolutional	QPSK/ SQPSK	.1	4.5 MHz	3.0	3.2	3.5	N/A
		1	4.5 MHz	3.0	3.2	3.4	N/A
		10	4.5 MHz	3.0	3.2	3.4	N/A
		100	4.5 MHz	3.0	3.2	3.4	N/A
		1000	3 MHz(4)	2.5	2.7	2.9	N/A
		2000	6 MHz(4)	3.0	3.2	3.7	N/A
		4000	10 MHz	3.2	3.4	3.9	N/A
Rate 1/2 LDPC	QPSK/ SQPSK	24	4.5 MHz	2.3	N/A	N/A	2.4
		192	4.5 MHz	2.3	N/A	N/A	2.4
		300	4.5 MHz	2.2	N/A	N/A	2.3
		1,000	2 MHz(4)	1.9	N/A	N/A	2.1
		6,000	10 MHz	2.1	N/A	N/A	2.2
		8,000	10 MHz	2.4	N/A	N/A	2.5
		9,000	10 MHz	2.8	N/A	N/A	3.0
		9,600	10 MHz	3.3	N/A	N/A	3.5
	8PSK	6000	8 MHz	2.2	NA	NA	2.3
		12000	10 MHz	3.6	NA	NA	3.9
Rate 7/8 LDPC	QPSK/ SQPSK	525	4.5 MHz	2.4	N/A	N/A	2.6
		10,500	10 MHz	2.4	N/A	N/A	2.6
		14,400	10 MHz	2.9	N/A	N/A	3.2
		15,750	10 MHz	3.4	N/A	N/A	3.8
		16,000	10 MHz	3.6	N/A	N/A	4.0
	8PSK	6000	4.6 MHz	2.2	N/A	N/A	2.4
		12000	9.14 MHz	2.2	N/A	N/A	2.4
		23600	10 MHz	4.1	N/A	N/A	4.4
Concatenated RS+CC	QPSK/ SQPSK	1	4.5 MHz	2.5	N/A	N/A	3.2
		1000	2.3 MHz	2.2	N/A	N/A	2.8
		5000	10 MHz	3.2	N/A	N/A	4.1

NOTES:

1. For all per channel symbol rates ≤ 300 ksym/s, implementation loss requirements specified for PN-spread case.
2. For NRZ-M and NRZ-S data formats, an additional implementation loss of 0.1 dB shall be allowed.
3. BPSK shall be compliant with all QPSK/SQPSK implementation loss requirements except for the applicable data rates that will be one half that stated in this table.
4. 2x per channel symbol rate. Note that the maximum SSAR customer frequency allocation assumed in this document is 10 MHz, and even that requires a waiver.
5. For S-band Expendable Launch Vehicle (ELV) customer with BPSK or QPSK modulation, rate ½ convolutional coding, and baud rate between 12.5 ksym/s and 1024 ksym/s per channel, the implementation losses shall be reduced by 0.8 dB for BPSK and increased by 0.4 dB for QPSK. This applies only to ELV customers with bandwidth of 2x the I or Q channel baud rate, whichever is greater.

SGSS.005144 SSAR Return Service Configurations

The SNGS shall be capable of processing SSAR input signals for the data configurations described in Table 5.1-35.

Rationale: Will be baseline capability at SGSS deployment.

Table 5.1-35 SSA Return Service Configurations

Return Service Configuration				Source Data Rate Restrictions and Availability[6,7]					
				DG1 Mode				DG2 Mode	
				1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
				Symbol format[9]	Data rate	Symbol format[9]	Data rate	Symbol format[9]	Data rate
Single Data Source	BPSK	Rate 1/2 convolutional coded		NRZ	<150 kbps[1]	-	-	NRZ	1 kbps – 3 Mbps
								Biphase	1 kbps – 1.5 Mbps[5]
		Rate 1/3 convolutional coded		-	-	-	-	NRZ	1 kbps – 2 Mbps
								Biphase	1 kbps – 1 Mbps[5]
		Uncoded		[8]	≤ 300 kbps[(8)]	-	-	[8]	1 kbps – 6 Mbps[(8)]
		Rate ½ LDPC coded		NRZ	1 - 150 kbps	-	-	-	-
		Rate 7/8 LDPC coded		NRZ	1 - 262.5 kbps	-	-	-	-
		Concatenated RS+ CC coded		NRZ	1 - 131.2 kbps	-	-	NRZ	1 kbps – 2.6 Mbps
	SQPN[1], QPSK[2,3] or SQPSK[3]	Identical I & Q channel data	Rate 1/2 convolutional coded	NRZ	≤300 kbps	-	-	-	-
			Uncoded	[8]	≤300 kbps[(8)]	-	-	-	-
		Alternate I/Q encoded symbols	Rate 1/2 convolutional coded	-	≤300 kbps	-	-	NRZ	1 – 6 Mbps
			Rate 1/3 convolutional coded	-	-	-	-	NRZ	1 kbps – 4Mbps
			Rate ½ LDPC coded	NRZ	1 – 300 kbps	-	-	NRZ	1 kbps – 9Mbps
			Rate 7/8 LDPC coded	NRZ	1 – 525 kbps	-	-	NRZ	1 kbps – 16Mbps
			Concatenated RS+ convolutional coded	NRZ	1 – 262.4 kbps	-	-	NRZ	1 kbps – 5.25Mbps
		Alternating I/Q data	Individually rate 1/2 convolutional coded	NRZ	<300 kbps	-	-	NRZ	1 kbps – 6 Mbps[5]

Return Service Configuration				Source Data Rate Restrictions and Availability[6,7]					
				DG1 Mode				DG2 Mode	
				1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
				Symbol format[9]	Data rate	Symbol format[9]	Data rate	Symbol format[9]	Data rate
			Individually rate 1/3 convolutional coded	-	-	-	-	NRZ	1 kbps – 4 Mbps[5]
			Concatenated RS+ convolutional	NRZ	1 – 262.4 kbps	-	-	NRZ	1 kbps – 5.25Mbps
			Uncoded	[8]	≤600 kbps[(8)]	-	-	[8]	1 kbps – 12 Mbps[(8)]
	8PSK	Alternate I/Q Encoded Symbols	Rate ½ LDPC coded	-	-	-	-	NRZ	6 – 12 Mbps
			Rate 7/8 LDPC coded	-	-	-	-	NRZ	6 – 23.6 Mbps
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 convolutional coded		NRZ	<150 kbps	NRZ	I: 0.1-150 kbps Q: 1 kbps – 3 Mbps	NRZ	1 kbps – 3 Mbps[5,]
								Biphase	1 kbps – 1.5 Mbps[5,6,]
		Rate 1/3 convolutional coded		-	-	NRZ	Q: 1 kbps – 2 Mbps	NRZ	1 kbps – 2 Mbps
								Biphase	1 kbps – 1 Mbps[6]
		Rate ½ LDPC coded		-	-	NRZ	I: 1-150 kbps Q: 1 kbps – 4.5 Mbps	-	-
		Rate 7/8 LDPC coded		-	-	NRZ	I: 1-262.5 kbps Q: 1 kbps – 8 Mbps	-	-
		Concatenated RS+ convolutional coded		NRZ	1 – 131.2 kbps	NRZ	I: 1-131.2 kbps Q: 1 kbps – 2.62 Mbps	NRZ	1 kbps – 2.625Mbps

Return Service Configuration	Source Data Rate Restrictions and Availability[6,7]					
	DG1 Mode				DG2 Mode	
	1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
	Symbol format[9]	Data rate	Symbol format[9]	Data rate	Symbol format[9]	Data rate

NOTES:

- Configuration not supported:

1. For DG1 mode 1 and 2 configurations, where the minimum source data rates for rate ½ convolutional coding are 0.1 kbps for DG1 mode 1 and 1 kbps for DG1 mode 2:
   a. Data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. Data on both the I and Q channels: SQPN modulation is used and I:Q power ratios of 1:1 to 1:4 shall be supported.
   c. The alternating I/Q data bit configuration: the I channel will lead the Q channel by a half symbol. Similarly, the I and Q channels will be independently differentially formatted (-M,-S).
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at +π/2 radians.
   b. I:Q power ratios of 1:1 to 1:4 shall be supported.
   c. Rate 1/3 coding shall be supported for the Q channel. Rate 1/2 coding shall be supported on both the I and Q channels.
3. For DG2 configurations:
   a. Single data source configurations with data on one channel: BPSK modulation is used.
   b. Single data source configurations with data on both channels: SQPSK modulation is used and an I:Q power ratio of 1:1 shall be supported. For the alternate I/Q bit configuration, the I and Q channels will be independently differentially formatted (-M,-S).
   c. Dual data source configurations: SQPSK will be used when there are identical baud rates on the I and Q channels (; QPSK is used for all other configurations; for both SQPSK and QPSK, an I:Q power ratio of 1:1 or 4:1 shall be supported. For unbalanced QPSK, the I channel will contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate will not exceed 40 percent of the maximum allowable data rate on that Q channel.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require the customer to constraint the transmit frequency uncertainty to 35 KHz
5. Biphase symbol formats will not occur with PCI.
6. For all configurations and modes, the SNGS shall be capable of providing SSA support with decoding bypassed.
7. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates.
8. Uncoded service is effectively supported when the decoder is bypassed.
9. Data format is NRZ for every configuration.

SGSS.005145 S-Band User Satellite Signal Distortions

The SNGS S-band return services shall meet probability of bit error (PE) requirements when the signals at the LNA input contain the distortions identified in Appendix E Customer Signal Distortions Constraints.

Rationale: To meet the desired link performance one must take into account the contributions of allowed user spacecraft signal distortions.

5.1.2.1.6 MAR Signal Parameters

SGSS.002018 S-band Multiple Access Return (SMAR) Data Rates

The SNGS shall provide SMAR data rates as defined in Table 5.1-36.

Rationale: Data rates are chosen to satisfy many competing engineering constraints.

Table 5.1-36 S-band Multiple Access Return (MAR) User Services

Service	Data Rates	Coding	Modulation	Tracking (Y/N)	Coherent/ Non coherent
MAR DG1 Mode 1	0.1 – 150 kbps	R 1/2 Convolutional	**PN-Spread BPSK**	**Y**	Coherent
	1 – 150 kbps	JPL R 1/2 LDPC		**Y**	Coherent
	1 – 262.5 kbps	GSFC R 7/8 LDPC		**Y**	Coherent
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
	0.1 – 300 kbps	R 1/2 Convolutional	**SQPN**	**Y**	Coherent
	1 – 300 kbps	JPL R 1/2 LDPC		**Y**	Coherent
	1 – 525 kbps	GSFC R 7/8 LDPC		**Y**	Coherent
	1 – 262.4 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
DG1 Mode 2	1 – 150 kbps	R 1/2 Convolutional	**PN-Spread BPSK**	**Y**	Non-Coherent
	1 – 150 kbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 – 262.5 kbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 – 131.2 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
	1 – 300 kbps	R 1/2 Convolutional	**SQPN**	**Y**	Non-Coherent
	1 – 300 kbps	JPL R 1/2 LDPC		**Y**	Non-Coherent
	1 – 525 kbps	GSFC R 7/8 LDPC		**Y**	Non-Coherent
	1 – 262.4 kbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Non-Coherent
DG1 Mode 3	I: 0.1 –150 kbps Q: 1 kbps – 1.5 Mbps	R 1/2 Convolutional	**QPSK**	**Y**	Coherent
	Q: 1 kbps – 1Mbps	R 1/3 Convolutional		**Y**	Coherent
	I: 1 –150 kbps Q: 1 kbps – 1.5 Mbps	JPL R 1/2 LDPC		**Y**	Coherent
	I: 1 – 262.5 kbps Q: 1 kbps – 3.5 Mbps	GSFC R 7/8 LDPC		**Y**	Coherent
	I: 1 –131.2 kbps Q: 1 kbps – 1.31 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Coherent
DG2	1 kbps – 3 Mbps	R 1/2 Convolutional	**SQPSK**	**Y**	Either
	1 kbps – 1 Mbps	R 1/3 Convolutional		**Y**	Either
	1 kbps – 4 Mbps	JPL R 1/2 LDPC		**Y**	Either
	1 kbps – 7 Mbps	GSFC R 7/8 LDPC		**Y**	Either
	1 kbps – 2.62 Mbps	(255, 223) RS + R 1/2 Conv (Concatenated)		**Y**	Either

SGSS.002019 SMAR Decoding

The SNGS shall provide SMAR decoding as defined in Table 5.1-36.

Rationale: FEC coding methods are chosen to satisfy many competing engineering constraints.

SGSS.002020 SMAR Demodulation

The SNGS shall provide SMAR demodulation as defined in Table 5.1-36.

Rationale: Modulation methods are chosen to satisfy many competing engineering constraints.

SGSS.002022 SMAR Coherency
The SNGS shall allow SMAR coherent and non-coherent modes as defined in Table 5.1-36.
Rationale: For coherent modes, the customer's return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform's received forward link carrier frequency. Two-way Doppler measurements and range measurements (if PN spread) are available only in coherent mode.

SGSS.002106 MAR Data Formatting
The SNGS shall support MAR NRZ-L, M, or S Data formats.
Rationale: Required for types of data formatting supported by the SN.

SGSS.002107 MAR Symbol Formatting
The SNGS shall support MAR NRZ or Biphase Symbol formats.
Rationale: Required for types of symbol formatting supported by the SN.

SGSS.005036 MA Return Signal Splitting
The SNGS shall perform MA return signal splitting.
Rationale: The composite MA Return signal is provided to multiple signal processing strings for the simultaneous processing of multiple simultaneous MA Return user service flows.

SGSS.005037 MA Return Signal Recovery for Ground-Based Beamforming
The SNGS shall separate and recover received MA beam element waveforms for Ground-Based Beamforming
Rationale: The composite MA Return signal comprises up to 30 separate downlink carriers which must be recovered and provided to the beam former

SGSS.005038 MA Return Signal Recovery for Satellite-Based Beamforming
The SNGS shall separate and recover received MA beam element waveforms.
Rationale: The composite MA Return signal comprises 5 separate downlink carriers which must be recovered and provided to the Return signal processing function

SGSS.005039 MA Return Signal Processing
The SNGS shall perform MA return signal processing by applying beamforming phase and amplitude coefficients to recover user generated data.
Rationale: This is the ordinary method of recovering signals from a phased-array antenna. First generation TDRS (F1-F7) depend upon ground-based beamforming to provide MA service. Third-generation TDRS are also expected to have this feature.

SGSS.005040 MA Simultaneous Calibration/Service
The SNGS shall conduct simultaneous calibration of the MA system while providing user service.
Rationale: A continuous reference signal is needed to calibrate the phase and amplitude coefficients. One feed of the spacecraft MA array is always dedicated to calibration.

SGSS.005041 MA Return Multiuser Access Method
The SNGS shall offer Code Division Multiple Access (CDMA) as a multi-user access method for MA Return services.
Rationale: CDMA Spread Spectrum techniques are required to prevent interference with ground users in the same band. CDMA is also used to provide multi-user access to the MA frequency spectrum. This also serves to spread the signal so as to meet FCC interference limits.

SGSS.005042 MA Forward Multiuser Access Method
The SNGS shall offer Code Division Multiple Access (CDMA) as a multi-user access method for MA Forward services.

Rationale: CDMA Spread Spectrum techniques are required to prevent interference with ground users in the same band. CDMA is also used to provide multi-user access to the MA frequency spectrum. This also serves to spread the signal so as to meet FCC interference limits.

5.1.2.1.7 PM Return Service Signal Parameters

SGSS.005078 PM Demodulation

The SNGS shall provide demodulation of Phase Modulated signals at the rates identified in Table 5.1-1 and 5.1-13.

Rationale: Phase Modulation is required for NEN user support.

5.1.2.1.8 Performance Exceptions for Established Users

SGSS.002120 Supplemental Implementation Loss Specifications

The SNGS shall meet the supplemental performance requirements stated in Table 5.1-37.

Rationale: SNGS must provide support for all existing users, including those which do not meet the specifications published in the SNUG etc.

Table 5.1-37 Supplemental Implementation Loss Requirements for Select Noncompliance Scenarios

Customer	Service Description				Noncompliant Customer Distortion(1)	Value		Total Implemen-tation Loss(2,3)
	Service	Data Group (DG)	Mode	Data Rate		Noncompliant Value	SNUG Constraint	
Orion/CEV	SSAR	1	1 & 2	36 kbps and 192 kbps	Customer Frequency Allocation	3.6 MHz	4.5 MHz	≤ 2.5 dB
HST	MAR and SSAR	1	2	I: 4 kbps and Q: 32 kbps	I/Q Power Ratio Tolerance	≤ ± 0.5 dB	≤ ± 0.4 dB from nominal	≤ 3.9 dB
					Phase Nonlinearity (peak)	± 4 degrees	± 3 deg over ± 2.1 MHz	
					Gain Flatness (peak)	± 0.5 dB	± 0.3 dB over ± 2.1 MHz	
					Gain Slope	± 0.5 dB/MHz	0.1 dB/MHz	
					AM/PM	≤ ± 15 deg/dB	≤ ± 12 deg/dB	
					Incidental AM (peak)	18%	5%	
					Untracked Phase Noise	6.5 degrees rms	≤ 2 degrees rms	
					I/Q PN Skew (Relative to 0.5 chip)	≤ 0.03 chip	≤ 0.01 chip	
	SSAR	2	--	1024 kbps	Phase Imbalance	≤ ± 5 degrees	≤ ± 3 degrees	≤ 3.94 dB
					Symbol Asymmetry (peak)	5.19%	< 3 %	
					Symbol Rise Time	≤ 75 nsec (i.e., 7.7%)	≤ 5 % of symbol duration but > 17 nsec	
					In-band Spurious Outputs	≥ 22 dBc	≥ 30 dBc	
ISS	SSAR	1	2	192 kbps	Phase Imbalance	< 6°	< 5° (DG1 Mode 1 and 2)	≤3.12 dB

Customer	Service Description				Noncompliant Customer Distortion(1)	Value		Total Implemen-tation Loss(2,3)
	Service	Data Group (DG)	Mode	Data Rate		Noncompliant Value	SNUG Constraint	
					Phase Nonlinearity (peak)	≤ 5.0° over ± 3.5 MHz	≤ 3.0° over ± 3.5 MHz	
					Gain Flatness (peak)	≤ 0.6 dB over ± 3.5 MHz	≤ 0.4 dB over ± 2.1 MHz	
					Untracked Spurious PM	≤ 3.0° rms	≤ 2.0°rms	
	KuSAR	2	--	150 Mbps	Phase Imbalance	< 6°	< 3°	3.23 dB
					Phase Nonlinearity (peak)	≤ 3.0˚ over ± 40.0 MHz	≤ 3.0˚ over ± 80 MHz	
					Gain Flatness (peak)	≤ 0.45 dB over ± 40 MHz	≤ 0.3 dB over ±80 MHz	
					Untracked Spurious PM	≤ 3.0° rms	≤ 2.0° rms	
					Gain Slope	≤ 0.1 dB/MHz over ± 40 MHz	≤ 0.1 dB/MHz over ± 80 MHz	
					Symbol Rise Time	≤ 10%	≤ 5%	
					Incidental AM	10 Hz to 2 KHz: ≤ 2.84% 2 KHz to 10 KHz: ≤ 0.3% > 10 KHz: ≤ 5.0% Total: ≤ 8.14%	Open-loop Pointing At freq > 100 Hz: ≤5% For A/T perf: 10 Hz to 10 KHz: ≤3% 10 Hz to 2 KHz: ≤ 0.6%	
ALOS	KaSAR	2	--	114.5 Mbps	Phase Imbalance	± 5°	± 3°	5.0 dB
					Gain Flatness (peak)	≤ 0.6 dB over ± 98 MHz	≤ 0.3 dB over ± 80 MHz	
					Phase Nonlinearity (peak)	≤ 7 degrees over ± 98 MHz	≤ 3 degrees over ± 80 MHz	
					Gain Slope	≤ 0.2 dB/MHz over ± 98 MHz	≤ 0.1 dB/MHz over ± 80 MHz	
					Spurious PM	2.5° rms	2.0° rms	
					Spurious Outputs	≤ -27 dBc	≤ -30 dBc	
					I/Q Symbol Skew	7 %	3 %	
					Data Rise Time, (90 percent of initial state to 90 percent of final state)	27.7%	≤ 5 percent of symbol duration but > 800 psec	
					Symbol Asymmetry	5 % per channel	± 3 %	

Customer	Service Description				Noncompliant Customer Distortion(1)	Value		Total Implemen-tation Loss(2,3)
	Service	Data Group (DG)	Mode	Data Rate		Noncompliant Value	SNUG Constraint	
					Phase Noise	3.4 deg rms in 2 B_L = 600 kHz	1 Hz – 10 Hz: ≤ 50.0° rms 10 Hz – 100 Hz: ≤ 10.0° rms 100Hz – 1 kHz: ≤ 2.0° rms 1 kHz –150 MHz: ≤ 2.0° rms	
					Minimum 3-dB bandwidth prior to power amplifier	≥ 2 x maximum baud rate	Not specified	

Notes:
1. Only those constraints which are noncompliant are stated. All other customer hardware distortions are consistent with SNUG maximum-allowed values.
2. Total implementation loss in a customer hardware distortion environment as described in this table, a TDRS distortion environment consistent with that stated for the implementation loss specifications in the main body of this SRD, and a ground terminal distortion environment as defined by the USSR design.
3. Values based upon analyses performed in support of the particular mission RF ICD.

SGSS.002121 Noncompliant MA Return Service Users

The SNGS shall accommodate established noncompliant MA users by providing service to users that do not conform to existing specifications, as described in Table 5.1-38.

Rationale: The SNGS must provide support for all existing users, including those which do not meet the specifications published in the SNUG etc.

Table 5.1-38 MAR Customer Hardware Noncompliance

Mission / Service	Parameter	SNUG Value	Noncompliant Value
Aqua DG1 Modes 1 & 2 2.048 kbps	Symbol Jitter and Jitter Rate	≤ 0.1 %	< 5.9 % rms[1]
ATV DG1 Modes 1 & 2 16 kbps	Symbol Jitter and Jitter Rate	≤ 0.1 %	< 0.3 % [2]
	Phase Non-Linearity	≤ 3 degrees ± 2.1 MHz (MA)	< 7 degrees over + 2.1 MHz [3]
	Untracked Spurious PM	≤ 2 degrees (rms)	< 3.3 degrees (rms) [4]
	I/Q code chip skew	≤ 0.01 chip	< 0.03 chip
	PN Power Suppression	≤ 0.3 dB	< 0.4 dB [5]
HTV DG1 Mode 1 4 kbps	Phase Noise	1 Hz – 10 Hz: ≤1.0° rms 10 Hz – 1 kHz: ≤ 1.0° rms 1 kHz – 3 MHz: ≤ 1.5° rms	1 Hz – 10 Hz: 1.5° rms 10 Hz – 1 kHz: 3.5° rms 1 kHz – 3 MHz: 1.1° rms
	Phase Non-Linearity	≤ 4.0 degrees over ± 2.1 MHz	≤10.6 degrees over ± 1.7 MHz
	Gain Flatness	≤ 0.4 dB over ± 2.1 MHz	≤ 0.7 dB over ± 1.7 MHz
	Symbol Jitter and Jitter Rate	< 0.1%	< 1.0%
HST DG1 Modes 1 & 2 1 kbps; 8 kbps; 4 kbps (I-ch), 32 kbps (Q-ch)	Phase Imbalance	≤ ± 3 degrees	≤ ± 5 degrees
	Symbol Asymmetry (peak)	< 3 %	5.19% (for 1.024 Mbps only)
	I/Q Power Ratio Tolerance	≤ ± 0.4 dB from nominal	≤ ± 0.5 dB
	Symbol Rise Time	≤ 5 % of symbol duration but > 17 nsec	≤ 75 nsec
	Gain Flatness	± 0.3 dB over ± 2.1 MHz	± 0.5 dB
	In-band Spurious Outputs	≥ 30 dBc	≥ 22 dBc
	Untracked Phase Noise	≤ 2 degrees rms	6.5 degrees rms
	I/Q PN Skew Relative to 0.5 chip	≤ 0.01 chip	≤ 0.03 chip
LandSat-7 DG1 Modes 1 & 2 2.432 kbps	AM/PM	≤ 15 degrees/dB	≤ 18 degrees/dB

NOTES:

[1] We do not have specific insight into the characteristics of this noncompliance. It is recommended that a random jitter be assumed

[2] It is recommended that a random jitter be assumed

[3] Recommend assuming a ripple of period 2.1 MHz

[4] Recommend placing the spur at about 1 kHz or higher

[5] Recommend achieving PN power suppression via PN chip jitter (random)

5.1.2.2 Return Service Signal Acquisition

SGSS.005129 Signal Acquisition under Free Flight Dynamics

The SNGS shall acquire signals from user spacecraft having free flight dynamics characteristics given in Table 5.1-39.

Rationale: Waveform distortions due to spacecraft dynamics must be compensated in order for signal acquisition to succeed.

Table 5.1-39 User Platform Dynamics

Parameter	SSA	KSA	MA
Speed: $\dot{R} \leq$	12 km/sec	12 km/sec	12 km/sec
Acceleration: $\ddot{R} \leq$	50 m/sec^2	15 m/sec^2	15 m/sec^2
Jerk (sustained indefinitely): $\dddot{R} \leq$	2 m/sec^3	0.02 m/sec^3	0.02 m/sec^3
Jerk (sustained duration ≤ 1 second): $\dddot{R} \leq$	5 m/sec^3	n/a	n/a
Jerk (sustained duration ≤ 50 milliseconds): $\dddot{R} \leq$	70 m/sec^3	n/a	n/a

SGSS.005130 Signal Acquisition Definition

The SNGS shall complete the following actions as part of the signal acquisition process:

- Carrier synchronization
- PN code synchronization (if applicable)
- Symbol synchronization
- Beamformer stabilization (if applicable)
- Viterbi decoder synchronization (if applicable)
- Derandomizer synchronization (if applicable)
- Block code synchronization (if applicable)
- Data polarity ambiguity resolution (if applicable)
- Data channel ambiguity resolution (if applicable).

Rationale: Many aspects of the waveform must be synchronized and stable in order for mission data transport to begin.

SGSS.005131 Signal Acquisition Performance

The SNGS shall acquire signals with the performance given in Table 5.1-40.

Rationale: Signal acquisition performance must be within acceptable limits in order to maximize user platform contact time.

Table 5.1-40 Signal Acquisition(1) and Re-Acquisition Performance

Parameter	Value		
	SSAR	KuSAR or Kasar-225 MHz	KaSAR (650 MHz)
Acquisition			
C/N_o Threshold : greater of the stated value or that required to achieve the scheduled Pe	36 dB-Hz(1)	70 dB-Hz	86.5 dB-Hz
Total Search Range (kHz)	± 40	± 61.2	± 306.2
Probability of Acquisition (%)	≥ 90	≥ 90	≥ 90
Acquisition Time(2,3) (sec), maximum for given coding			
Uncoded(4)	--	$1 + \frac{3}{Rb}$	$1 + \frac{3}{Rb}$
Rate 1/2 Convolutional (4)	$1 + \frac{6.5}{Rb}$	$1 + \frac{6.5}{Rb}$	--
Rate 1/3 Convolutional(4)	$1 + \frac{6.5}{Rb}$	--	--
(255,223) Reed Solomon	--	$1 + \frac{7.5}{Rb}$	--

Parameter	Value		
	SSAR	KuSAR or Kasar-225 MHz	KaSAR (650 MHz)
Concatenated (255, 223) RS + Convolutional or Concatenated (252, 220) RS + Convolutional	$1 + \frac{10.3}{Rb}$	$1 + \frac{10.3}{Rb}$	--
(2048,1024) LDPC	$1 + \frac{13.8}{Rb}$	$1 + \frac{13.8}{Rb}$	$1 + \frac{13.8}{Rb}$
(8160,7136) LDPC	$1 + \frac{20.4}{Rb}$	$1 + \frac{20.4}{Rb}$	$1 + \frac{20.4}{Rb}$
(128,120) TPC	--	$1 + \frac{35.1}{Rb}$	$1 + \frac{35.1}{Rb}$
Reacquisition			
C/N_o Threshold : greater of the stated value or that required to achieve the scheduled Pe	36 dB-Hz(1)	70 dB-Hz	86.5 dB-Hz
Total Search Range (kHz)	Not Specified	Not Specified	Not Specified
Probability of Acquisition (%)	≥ 99	≥ 99	≥ 99
Re-Acquisition Time(sec), maximum for given coding			
Uncoded(4)	--	$0.5 + \frac{3}{Rb}$	$0.5 + \frac{3}{Rb}$ (note 4)
Rate 1/2 Convolutional (4)	$1 + \frac{6.5}{Rb}$	$0.5 + \frac{6.5}{Rb}$	--
Rate 1/3 Convolutional(4)	$1 + \frac{6.5}{Rb}$	--	--
(255,223) Reed Solomon	--	$0.5 + \frac{7.5}{Rb}$	--
Concatenated (255, 223) RS + Convolutional or Concatenated (252, 220) RS + Convolutional	$1 + \frac{10.3}{Rb}$	$0.5 + \frac{10.3}{Rb}$	--
(2048,1024) LDPC	$1 + \frac{13.8}{Rb}$	$0.5 + \frac{13.8}{Rb}$	$0.5 + \frac{13.8}{Rb}$
(8160,7136) LDPC	$1 + \frac{20.4}{Rb}$	$0.5 + \frac{20.4}{Rb}$	$0.5 + \frac{20.4}{Rb}$
(128,120) TPC	--	$0.5 + \frac{35.1}{Rb}$	$0.5 + \frac{35.1}{Rb}$

NOTES:

1. For SQPSK modulation with identical symbol rates and power levels on the I and Q channels, acquisition and reacquisition requirements are applicable for a minimum received C/No at the LNA output of 48 dB-Hz.
2. Signal acquisition time does not include the delays associated with PCI deinterleaving and block deinterleaving.
3. Rb is defined as the total single-stream uncoded data rate in kbps.
4. An additional F/Rb shall be allowed when randomization is scheduled, where F is the AOS transfer frame length including ASM bits.

5.1.2.3 Return Service IF Transport

SGSS.005034 Analog IF Return Signals to ULE

The SNGS shall provide analog IF return signals to ULE with no digitization in the return signal path.
Rationale: Analog return IF service without any digitization in the return signal path is required to support certain existing Users.

SGSS.005128 ULE Packetized Data Streams

The SNGS shall allow the delivery of packetized data streams to ULE via LAN connection.

Rationale: SN Users (SCaN) have requested to have the ability to receive packetized data streams at their ULE.

SGSS.005035 Intermediate Frequency Waveform Recording
The SNGS shall record a minimum of three (3)simultaneously received analog IF waveforms per Terminal of at least 225 MHz bandwidth, with 8 bits resolution, for a minimum duration of two (2) hours.
Rationale: IF recording is required for post-failure forensic analysis for manned spaceflight. It is a site-wide capability rather than a capability per TDRS. This requirement originated with the Constellation Program.

SGSS.005112 Recording of KaSAR IF Waveforms
The SNGS shall record KaSAR IF waveforms for manned spaceflight missions.
Rationale: KaSAR is one of the services used by the Constellation program.

SGSS.005113 Recording of SSAR IF Waveforms
The SNGS shall record SSAR IF waveforms for manned spaceflight missions.
Rationale: SSAR is one of the services used by the Constellation program.

5.1.2.4 Return Service Signal Arraying

SGSS.005114 Return Service Signal Arraying
The SNGS shall have the capability to combine the Return signals of all TDRS SSL relay antennas in view of a particular mission to achieve improved G/T.
Rationale: Combining of user return signals from multiple relay spacecraft antennas increases link performance; robustness; geometric diversity; interference suppression for return services. The expected G/T improvement is shown in Table 5.1-41. Routine combining of MA antenna signals enables a robust on demand MA return service. Combining of SA signals with each other, as well as with MA signals from several spacecraft is intended to provide a robust capability for spacecraft emergencies and high risk events such as launches and landings. This capability provides value to the User through both higher signal gain than can be achieved by a single antenna as well as providing diverse look angles to challenged links (such as tumbling spacecraft or launch vehicles).

Table 5.1-41 G/T Improvement with Relay Spacecraft Antenna Combining

	G/T Improvement (dB)				
# of Antenna signals combined	**1**	**2**	**3**	**4**	**5**
MA		2.8	4.5	5.5	6.7
SA		2.8	4.5	5.5	6.7
1-SA plus # of MA Apertures	0.7	1.7	2.2	2.8	3.3

5.1.3 Service Simultaneity

SGSS.005149 Simultaneity of User Services
The SNGS shall be capable of simultaneously providing the user services shown in Table 5.1-42, for each active TDRS.
Rationale: This requirement provides for the full utilization of TDRS payload capabilities.

Table 5.1-42 Active TDRS Simultaneous User Service Capabilities

User Service	Service Function	Service Type	Services per Active TDRS
Forward Data or IF	Data relay to user spacecraft	S-band Single Access (SSAF)	2 (SSA-1F, SSA-2F)
Forward Data or IF	Data relay to user spacecraft	S-band Multiple Access (MAF)	2 (MA-1F, MA-2F)
Forward Data or IF	Data relay to user spacecraft	K-band Single Access (KSAF)	2 (KSA-1F, KSA-2F)
Return Data or IF	Data relay from user spacecraft	S-band Single Access (SSAR)	2 (SSA-1R, SSA-2R)
Return Data or IF	Data relay from user spacecraft	S-band Multiple Access (MAR)	8 (MA-1R -to- MA-8R)
Return Data or IF	Data relay from user spacecraft	K-band single access (KSAR)	2 (KSA-1R, KSA-2R)
Tracking	User spacecraft range-rate	One-way or two-way Doppler	4 (2 SSA, 2 KSA(1))
Tracking	User spacecraft range	User spacecraft range	4 (2 SSA, 2 KuSA)
Tracking	Time transfer	Time transfer	4 (2 SSA, 2 KuSA)

NOTE:
1. For KaSA, only one-way return Doppler is applicable.

5.1.3.1 Forward Service Simultaneity

SGSS.002042 Forward Service Simultaneity

The SNGS shall be capable of transmitting simultaneous SA and Multiple Access (MA) Forward services to any TDRS, up to the maximum number of non-overlapping carriers in the Uplink Frequency Plan, Table 5.1-1.

Rationale: For efficient use of the space segment resources, the ground segment should have sufficient equipment to carry the maximum number of simultaneous services possible on a fully-functional TDRS. The Ku and Ka services are mutually exclusive.

SGSS.002044 Multiple User Platforms SA Forward Service

The SNGS shall be capable of providing simultaneous SA Forward services to two different user platforms, one S-band and the other K-band, within the view angle of a single TDRS SA antenna, within the link margin constraints of that TDRS SA link.

Rationale: This capability is required to support user on-orbit docking maneuvers or two user spacecraft in close on-orbit proximity. This is known as a “virtual platform” SAF service.

5.1.3.2 Return Service Simultaneity

SGSS.002043 Return Service Simultaneity

The SNGS shall be capable of receiving simultaneous SA and MA Return services from any TDRS, up to the maximum number of non-overlapping carriers in the Downlink Frequency Plan, Table 5.1-22.

Rationale: This is required to ensure the most efficient utilization of the TDRS communications payload.

SGSS.002045 Multiple User Platforms SA Return Service

The SNGS shall be capable of providing simultaneous SA Return services to two different user platforms one S-band and the other K-band, within the view angle of a single TDRS SA antenna, within the link margin constraints of that TDRS SA link.

Rationale: This capability is required to support user on-orbit docking maneuvers or two user spacecraft in close on-orbit proximity. This is known as a “virtual platform” SAR service.

5.1.3.3 Cross Support Service

SGSS.002046 MAF/SAR Cross-Support Service
The SNGS shall provide simultaneous MAF and SAR services to a single user platform.
Rationale: When the forward and return services are supplied by different TDRSS telecommunications services (e.g., MA forward and SSA return), the configuration is called a cross-support service.

SGSS.002076 SAF/MAR Cross-Support Service
The SNGS shall provide simultaneous SAF and MAR services to a single user platform.
Rationale: When the forward and return services are supplied by different TDRSS telecommunications services (e.g., SSA forward and MA return), the configuration is called a cross-support service.

5.1.4 CCSDS Advanced Orbiting Systems Protocols

SGSS.005115 CCSDS AOS Protocols
The SNGS shall implement the CCSDS Advanced Orbiting Systems (AOS) protocols as defined in CCSDS Recommendation 732.0-B-2.
Rationale: CCSDS 732.0-B-2 defines the AOS framing and multiplexing data units (M_PDU and B_PDU) required to support conventional CCSDS missions and the Cx Emergency Communications and Post-Landing Communications requirements. AOS is on the forward and return links for CxP.

SGSS.005116 Return AOS Frames
The SNGS shall accept and process Advanced Orbiting System (AOS) Frames in compliance with the Cx C3I Interoperability Specification (reference CxP 70022-01, Section 3).
Rationale: This is required by IRDs between CxP and SCaN, as specified in CxP 70022-1.

SGSS.005117 Forward AOS Frames
The SNGS shall process and transmit Advanced Orbiting System (AOS) Frames in compliance with the Cx C3I Interoperability Specification (reference CxP 70022-01, Section 3).
Rationale: This is required by IRDs between CxP and SCaN, as specified in CxP 70022-1.

5.1.5 User Tracking and Timing Services

5.1.5.1 Tracking Services

SGSS.002057 SSA Tracking
The SNGS shall provide SSA tracking services as defined in Table 5.1-43.
Rationale: Tracking is the means by which users determine the orbit of their spacecraft. Such knowledge is required to establish communications links, and may also be required as a part of the spacecraft mission support.

Table 5.1-43 Required Tracking Services for Service Support Configuration

Tracking Services	One Way Doppler	Two Way Doppler	Range and Time Correlation
S-BAND MULTIPLE ACCESS (MA)	DG1 MODE 2	DG1 MODE 1	DG1 MODE 1
S-BAND SINGLE ACCESS (SSA)	DG1 MODE 2 DG2 noncoherent	DG1 MODES 1,3 DG2 coherent	DG1 MODES 1,3
Ku-BAND SINGLE ACCESS (KuSA)	DG1 MODE 2 DG2 noncoherent	DG1 MODES 1,3 DG2 coherent	DG1 MODES 1,3
Ka-BAND SINGLE ACCESS (KaSA)	DG2 noncoherent	N/A	N/A

SGSS.002058 MA Tracking
The SNGS shall provide MA tracking services as defined in Table 5.1-43.
Rationale: Tracking is the means by which users determine the orbit of their spacecraft. Such knowledge is required to establish communications links, and may also be required as a part of the spacecraft mission support.

SGSS.002059 KuSAR Tracking
The SNGS shall provide KuSA tracking services as defined in Table 5.1-43.
Rationale: Tracking is the means by which users determine the orbit of their spacecraft. Such knowledge is required to establish communications links, and may also be required as a part of the spacecraft mission support.

SGSS.002060 KaSAR Tracking
The SNGS shall provide KaSA tracking services as defined in Table 5.1-39.
Rationale: Tracking is the means by which users determine the orbit of their spacecraft. Such knowledge is required to establish communications links, and may also be required as a part of the spacecraft mission support.

SGSS.002061 Tracking and Timing Simultaneity
The SNGS shall provide simultaneous tracking and timing services as indicated in Table 5.1-43.
Rationale: The SNGS must be capable of providing tracking and timing services on all active services simultaneously.

SGSS.002062 Range Measurement Service
The SNGS shall provide range measurements of the user platform using the PN code ranging method upon scheduled request.
Rationale: High precision range measurements are required for precise orbit determination (tracking) of the user platform. The PN ranging method is necessary for the required precision. This service is also used to provide precise orbit determination of each TDRS spacecraft by ranging to a BRTS transponder at well-known fixed location.

SGSS.002063 Data Sampling
The SNGS shall sample the Doppler measurement within ± 25 nanoseconds and the range measurement within ± 1microsecond of the with the T&FR timing epoch.
Rationale: The accuracy of the ranging measurement depends on the data measurement timing.

SGSS.002064 Doppler Measurement Service
The SNGS shall provide Doppler (Range Rate) measurements, upon scheduled request.
Rationale: Doppler measurements enable the correction of transmit and receive frequencies. This is a legacy requirement.

SGSS.002071 Range Measurement Accuracy
The SNGS shall provide range measurements of the user platform with error not exceeding 16 nanoseconds rms for measurement data rate less than 1000 bits/sec and not exceeding 8 nanoseconds rms otherwise.
Rationale: Accurate ranging is required for orbit determination.

SGSS.002072 Doppler Frequency Measurement Error
The SNGS shall provide Doppler frequency measurements of the user platform with rms error not exceeding 0.32 radians/sec rms for ADR ≤ 500 bits/sec , 0.24 radians/sec rms for 500 < ADR ≤ 1000 bits/sec and 0.16 radians/sec rms otherwise, for a one-second average Doppler frequency measurement, where ADR is the Achievable Data Rate in bits per second.
Rationale: Accurate Doppler is required for signal acquisition and orbit determination.

SGSS.002115 Range Systematic Error
The SNGS shall, after correction for transit delays, have the residual systematic range error contribution to the range measurement be less than ± 30 nanoseconds.
Rationale: To keep the range station delay from degrading the orbit determination.

5.1.5.2 Timing Services

SGSS.002065 Time Transfer Service
The SNGS shall provide clock calibration service for the user platform, upon scheduled request.
Rationale: Some missions require an accurate onboard clock. This is a legacy requirement.

SGSS.002066 Return Channel Time Delay Measurement Service
The SNGS shall provide Return Channel Time Delay measurements, upon scheduled request.
Rationale: This is a calibration measurement of the time delay from the SN ground station antenna input to the SN ground station baseband output at the point of time tagging within the data transport. In the legacy system it was dependent on the NASA Communications (NASCOM) 4800 bit block.

SGSS.002073 Time Transfer Measurement Accuracy
The SNGS shall provide time transfer measurements with systematic error of less than +5 microseconds of UTC.
Rationale: Accurate onboard time is required by some missions.

SGSS.002074 Time Transfer Measurement Jitter
The SNGS shall provide time transfer measurements having jitter within +25 nanoseconds rms.
Rationale: Accurate onboard time is required by some missions.

SGSS.002075 Return Channel Time Delay Measurement Accuracy
The SNGS shall provide Return Channel Time Delay measurements with the following accuracy: Data rates < 250 kbps: ±25% of the data bit period. Data rates ≥ 250 kbps: ±1 microsecond.
Rationale: This is a calibration measurement of the time delay from the SN ground station antenna input to the SN ground station baseband output at the point of time tagging within the data transport.

SGSS.005047 Return Channel Time Delay (RCTD) Measurement
The SNGS shall provide Return Channel Time Delay (RCTD) Measurements.
Rationale: RCTD measurements are available to any customer platform that transmits a return link signal. The reported value is the time delay from the range-to-zero set reference point in the WSC antenna input to the WSC baseband output reference point, where a UTC time tag is placed on the data stream.

SGSS.005048 Time Tagging
The SNGS shall time tag the baseband user return data within ±5 Microseconds accuracy.
Rationale: Highly accurate knowledge of the signal timing is needed in some applications.

5.1.5.3 PN Ranging

SGSS.005043 PN Ranging
The SNGS shall provide range measurements of the user platform using the PN ranging method.
Rationale: PN Ranging is the most accurate method available for determining the orbit of the user spacecraft.

5.1.5.4 Two-way Doppler

SGSS.005045 Two-Way Doppler Measurements
The SNGS shall provide two-way Doppler measurements.
Rationale: Two-way Doppler measurement uses a carrier on the return service that is synchronized with the forward service carrier. The measurement can be used for spacecraft orbit determination.

5.1.5.5 One-Way Doppler Measurements

SGSS.005044 One-Way Doppler Measurements
The SNGS shall provide one-way return link Doppler measurements.
Rationale: One-way Doppler is a measurement of the receive frequency, relative to the original transmit frequency of the user spacecraft return link. The measurement can be used for spacecraft orbit determination.

5.1.5.6 Clock Calibration

SGSS.005046 Time Transfer Measurements (Clock Calibration)
The SNGS shall provide Time Transfer measurements.
Rationale: Time transfer measurements provide the customer MOC with the ability to determine the time difference between the on-board platform clock and UTC. The Time Transfer measurement is available only with coherent services. The customer platform must also provide a time receipt of the PN epoch onboard.

5.2 Space-to-Ground Links

5.2.1 General SGL System Requirements

SGSS.005135 SGL Acquisition and Tracking
The SNGS shall acquire and track an assigned TDRS.
Rationale: The SGL antenna must be reliably pointed at the TDRS to enable RF link closure.

SGSS.005136 SGL Signal Reception
The SNGS shall receive and amplify dual polarization, Return user service signals and TDRS telemetry/ranging RF signals.
Rationale: Reception and amplification of the SGL downlink is the first step in the downlink signal processing chain.

SGSS.005137 SGL Signal Transmission
The SNGS shall transmit Forward user service signals, TDRS command/ranging RF signals, and an RF pilot signal (TDRS F1-F7 only) to the TDRS.
Rationale: Transmission of the SGL uplink is the final step in the uplink signal processing chain.

5.2.1.1 Frequency Plan

SGSS.002077 TDRS Uplink Frequency Plan
The SNGS shall comply with the uplink frequency plan shown in Table 5.1-1.
Rationale: Frequency allocations are constrained by the transponder design of the TDRS communications payload.

SGSS.002078 TDRS Downlink Frequency Plan
The SNGS shall comply with the downlink frequency plan shown in Table 5.1-22.
Rationale: Frequency allocations are constrained by the transponder design of the TDRS communications payload.

5.2.1.2 Platform Dynamics

SGSS.002087 TDRS Platform Dynamic Constraints
The SNGS shall meet all RF link and user service performance requirements while operating over a TDRS with orbital inclination of 15 degrees or less.
Rationale: The orbital inclination of the TDRS introduces Doppler shift and an apparent spacecraft figure-eight motion when viewed from the ground antenna.

SGSS.002088 User Platform Velocity Constraints
The SNGS shall meet all RF link and user service performance requirements for any user platform having velocity $\leq$ 12 km/sec, as shown in Table 5.2-1.
Rationale: User platform motion places demands on system performance that must be compensated in order to provide dependable acquisition and quality of service. A circular LEO orbit is expected to have orbital speed less than 7.7 km/sec, based on a minimum 300 km orbit. An object in a highly elliptical orbit, with perigee of 500 km and apogee of 40,000 km will have a maximum orbital speed of around 10 km/sec at perigee.

Table 5.2-1 User Platform Dynamics

Parameter	SSA	KSA	MA
Speed: $\dot{R} \leq$	12 km/sec	12 km/sec	12 km/sec
Acceleration: $\ddot{R} \leq$	50 m/sec^2	15 m/sec^2	15 m/sec^2
Jerk (sustained indefinitely): $\dddot{R} \leq$	2 m/sec^3	0.02 m/sec^3	0.02 m/sec^3
Jerk (sustained duration ≤ 1 second): $\dddot{R} \leq$	5 m/sec^3	n/a	n/a
Jerk (sustained duration ≤ 50 milliseconds): $\dddot{R} \leq$	70 m/sec^3	n/a	n/a

SGSS.002089 User Platform Acceleration Constraints for SSA Services
The SNGS shall meet all RF link and user service performance requirements for any user platform having acceleration $\leq$ 50 m/sec2 for SSA services, as shown in Table 5.2-1.
Rationale: Change in velocity, or acceleration, which may occur during orbital maneuvers, presents special challenges for signal acquisition and tracking that must be compensated in order to provide reliable communications. SSA services are often used for launch vehicle communications, which present much higher dynamics than orbital maneuvers.

SGSS.002090 User Platform Acceleration Constraints for KSA Services
The SNGS shall meet all RF link and user service performance requirements for any user platform having acceleration $\leq$ 15 m/sec2 for KSA services, as shown in Table 5.2-1.

Rationale: Change in velocity, or acceleration, which may occur during orbital maneuvers, presents special challenges for signal acquisition and tracking that must be compensated in order to provide reliable communications.

SGSS.002091 User Platform Acceleration Constraints for MA services
The SNGS shall meet all RF link and user service performance requirements for any user platform having acceleration $\leq$ 15 m/sec2 for MA services, as shown in Table 5.2-1.
Rationale: Change in velocity, or acceleration, which may occur during orbital maneuvers, presents special challenges for signal acquisition and tracking that must be compensated in order to provide reliable communications.

SGSS.002092 User Platform Jerk Constraints for SSA services
The SNGS shall meet all RF link and user service performance requirements for any user platform having acceleration $\leq$ 2 m/sec3 for SSA services, as shown in Table 5.2-1.
Rationale: Change in acceleration, or jerk, which may occur during orbital maneuvers, presents special challenges for signal acquisition and tracking that must be compensated in order to provide reliable communications. SSA services are often used for launch vehicle communications, which present much higher dynamics than orbital maneuvers.

SGSS.002093 User Platform Jerk Constraints for KSA services
The SNGS shall meet all RF link and user service performance requirements for any user platform having acceleration $\leq$ 0.02 m/sec3 for KSA services, as shown in Table 5.2-1.
Rationale: Change in acceleration, or jerk, which may occur during orbital maneuvers, presents special challenges for signal acquisition and tracking that must be compensated in order to provide reliable communications.

SGSS.002094 User Platform Jerk Constraints for MA services
The SNGS shall meet all RF link and user service performance requirements for any user platform having acceleration $\leq$ 0.02 m/sec3 for MA services, as shown in Table 5.2-1.
Rationale: Change in acceleration, or jerk, which may occur during orbital maneuvers, presents special challenges for signal acquisition and tracking that must be compensated in order to provide reliable communications.

5.2.1.3 Inter-Service Period Configuration

SGSS.002095 Inter-Service Configuration
Whenever any S-band Single Access Forward (SSAF), Ku-band Single Access Forward (KuSAF), or S-band Multiple Access Forward (SMAF) service channel is not actively being used to support a scheduled Customer service, the SNEGS shall, without operator action, automatically configure the associated SNGS equipment chain and the TDRS payload, as required, to ensure that the RF transmit signal radiated by the service channel's associated TDRS SA or MA antenna continues to not exceed the power flux density limits defined in the Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook), Chapter 8, (applicable to S-band Forward and Ku-band Forward) and International Telecommunication Union (ITU) Radio Regulations, Article 21 (applicable to S-band Forward only).
Rationale: The Inter-Service configuration is required to prevent interference with other authorized users of the same frequency bands. This is commonly accomplished by transmitting a known spread-spectrum signal that complies with the required power flux density limits.

5.2.1.4 Reserved

None.

5.2.1.5 Service Latency and Jitter

SGSS.002069 IF Service Path Delay

The SNGS shall provide a maximum average data latency, measured over a 24 hour period, for each Intermediate Frequency (IF) SN Service as defined in Table 5.2-2 between the ground antenna and the User Local Equipment (ULE) data transfer point.

Rationale: The latency numbers are required as part of user's overall latency budget for time-critical data.

Table 5.2-2 IF Transport Latency and Latency Variation

IF Service	Latency Between a Ground Terminal Antenna and the ULE Demarcation	Latency Variation Over 24 Hour Period
SSAF	28ms	± 48 nanoseconds
SSAR	28ms	± 86 nanoseconds
MAF	N/A	N/A
MAR	N/A	N/A
SMAF	N/A	N/A
SMAR	N/A	N/A
KuSAF	28ms	± 48 nanoseconds
KuSAR	28ms	± 86 nanoseconds
KaSAF	28ms	± 48 nanoseconds
KaSAR	28ms	± 86 nanoseconds
Tracking	28ms	N/A

SGSS.002070 Data Service Path Delay Variation

The SNGS shall provide a maximum SN Service latency variation as defined in Table 5.2-2.

Rationale: The latency numbers are required as part of user's overall latency budget for time-critical data.

SGSS.002096 Forward Service Signal Processing Delay

The SNGS shall provide a maximum Forward path signal processing delay as given in Table 5.2-3.

Rationale: Forward path signal processing delay is defined as the time delay between the time that the leading or trailing edge of any baseband data or clock bit is received at the customer data interface and the time that the leading or trailing edge of the corresponding modulated RF signal data symbol is delivered to the SGL antenna feed. Some customers, including CxP and ELVs have strict signal latency requirements. Signal processing delay is a major source of signal latency in the SNGS. It is important to control this delay whenever possible by efficient signal processing algorithms. Signal processing delay may be bounded by the data rate, especially when processing large blocks at low data rates. Table 5.2-4 provides theoretical limits on the path delay for selected coding schemes.

Table 5.2-3 Signal Processing Path Delay and Path Delay Variation Requirements

Service Description			Path Delay, Peak (milliseconds)	Path Delay Variation, Peak (nanoseconds)		
				Short-Term(2)	Long-Term(3)	Lifetime
SSA	Fwd	Ts < 144 ksps	--	--	--	--
		Ts ≥ 144 ksps	≤ 300	--	--	--
	Rtn	Ts < 144 ksps	--	--	--	--
		Ts ≥ 144 ksps	≤ 150	--	--	--
KSA	Fwd	Ts < 300 ksps	--	--	--	--
		Ts ≥ 300 ksps	≤ 28	≤ 34	≤ 48	--
	Rtn	Ts < 150 Msps	--	--	--	--
		Ts ≥ 150 Msps	≤ 28	≤ 34	≤ 48	--

NOTES:

1. Path delay requirements need not be met when Periodic Convolutional Interleaving (PCI) or block interleaving is scheduled.
2. Peak path variation delay in a one second observation interval over a 24 hour period.
3 Peak path variation delay in 24 hour observation period.

SGSS.002097 Forward Service Signal Processing Delay Variation

The SNGS shall provide a maximum Forward path signal processing delay variation as given in Table 5.2-3. Forward path signal processing delay is defined as the time delay between the time that the leading or trailing edge of any baseband data or clock bit is received at the customer data interface and the time that the leading or trailing edge of the corresponding modulated RF signal data symbol is delivered to the SGL antenna feed.

Rationale: Some customers, including CxP and ELVs have strict signal latency requirements. Signal processing delay is a major source of signal latency in the SNGS. It is important to control this delay whenever possible by efficient signal processing algorithms. Signal processing delay may be bounded by the data rate, especially when processing large blocks at low data rates. Table 5.2-4 provides theoretical limits on the path delay for selected coding schemes.

SGSS.002098 Return Service Signal Processing Delay

The SNGS shall provide a maximum Return path signal processing delay as given in Table 5.2-3. Return path signal processing delay is defined as the time delay between the time that the leading or trailing edge of any modulated RF signal data symbol is received at the SGL antenna feed and the time that the leading or trailing edge of the corresponding baseband data or clock bit is delivered to the customer data interface.

Rationale: Some customers, including CxP and ELVs have strict signal latency requirements. Signal processing delay is a major source of signal latency in the SNGS. It is important to control this delay whenever possible by efficient signal processing algorithms. Signal processing delay may be bounded by the data rate, especially when processing large blocks at low data rates. Table 5.2-4 provides theoretical limits on the path delay for selected coding schemes.

SGSS.002099 Return Service Signal Processing Delay Variation

The SNGS shall provide a maximum Return path signal processing delay variation as given in Table 5.2-3. Return path signal processing delay is defined as the time delay between the time that the leading or trailing edge of any modulated RF signal data symbol is received at the SGL antenna feed and the time that the leading or trailing edge of the corresponding baseband data or clock bit is delivered to the customer data interface.

Rationale: Some customers, including CxP and ELVs have strict signal latency requirements. Signal processing delay is a major source of signal latency in the SNGS. It is important to control this delay whenever possible by efficient signal processing algorithms. Signal processing delay may be bounded by

the data rate, especially when processing large blocks at low data rates. Table 5.2-4 provides theoretical limits on the path delay for selected coding schemes.

Table 5.2-4 Signal Processing Path Delay Limits

Service Description		Path Delay (Max)(1,2), microseconds							
		Uncoded	Rate 1/2 Conv	Rate 1/3 Conv	(255,223) RS	Concatenated (RS+CC)	(2048,1024) LDPC	(8160,7136) LDPC	(128,120)2 TPC
SSA	Forward	--	$\leq \frac{3.9}{R_b}$	--	--	$\leq \frac{1787.9}{R_b}$	$\leq \frac{1026.9}{R_b}$	$\leq \frac{7138.9}{R_b}$	--
	Return	$\leq \frac{4.6}{R_b}+6$	$\leq \frac{111.1}{R_b}+6$	$\leq \frac{110.5}{R_b}+6$	--	$\leq \frac{1895.1}{R_b}+6$	$\leq \frac{1028.6}{R_b}+6$	$\leq \frac{7140.6}{R_b}+6$	--
KSA	Forward	$\leq \frac{2.9}{R_b}$	$\leq \frac{3.9}{R_b}$	--	$\leq \frac{1786.9}{R_b}$	$\leq \frac{1787.9}{R_b}$	$\leq \frac{1026.9}{R_b}$	$\leq \frac{7138.9}{R_b}$	--
	Return	$\leq \frac{4.6}{R_b}+6$	$\leq \frac{111.1}{R_b}+6$	--	$\leq \frac{1788.6}{R_b}+6$	$\leq \frac{1895.1}{R_b}+6$	$\leq \frac{1028.6}{R_b}+6$	$\leq \frac{7140.6}{R_b}+6$	$\leq \frac{14404}{R_b}+6$

NOTES:
1. R_b is defined as the total single steam uncoded bit rate in Mbit/sec.
2. Block interleaving/deinterleaving and Periodic Convolutional Interleaving/Deinterleaving are excluded from the latency calculations.

5.2.1.6 Reserved

None.

5.2.1.7 Waveform Adaptation

SGSS.002079 Waveform Adaptation
The SNGS shall allow the implementation of new waveforms and other signal processing functions by means of software definition, without physical modification or replacement of hardware.
Rationale: A cost-efficient means for upgrading signal processing functions is needed, to permit introduction of new developments in modulation and coding, or to accommodate new customers or new requirements of existing customers, the term "waveform" is used in its broadest sense to encompass a wide range of physical and logical attributes of a communications signal.

5.2.2 Ku-band Space-to-Ground Links

SGSS.005146 Downlink Pulsed RFI Protection
The SNGS shall accept pulsed Radio Frequency Interference (RFI) on the SGL downlink with pulse widths up to 5 microseconds and pulse amplitude up to 10 dB above the average received power without damage or cumulative degradation to SNGS equipment.
Rationale: The system must operate in the existing RFI environment without damage.

SGSS.005147 Operation in Presence of Pulsed RFI
The SNGS shall provide for the operation of all signal processing functions, from RF to baseband, in the presence of pulsed RFI with degraded error performance.
Rationale: The system must tolerate the existing RFI environment with minimal disruption of service.

5.2.2.1 Ku-band RF Performance

SGSS.005001 Ku-band Upconversion
The SNGS shall convert Intermediate Frequencies to the Ku-Band RF uplink frequencies used by SN services.
Rationale: IF-to-RF upconversion is a frequency translation mechanism common to most RF communications systems.

SGSS.005002 Ku-band High-Power Amplification
The SNGS shall amplify Ku-band signals to generate the EIRP required to meet the EIRP specified in Table 5.2-5.
Rationale: Signal processing occurs at low power levels within the terminal. Much higher signal levels are required to overcome transmission path losses and other impairments in order to propagate the signal with adequate fidelity to the satellite.

Table 5.2-5 SGL Uplink EIRP (Effective Isotropic Radiated Power)

Operating Band	Service	Minimum EIRP [1]
Ku-Band: 14,600 MHz to 15,225 MHz		
	KSA	73.5 dBW
	SSA	71.1 dBW
	MA	64.1 dBW
	Command	Adjustable in at least TEN discrete steps from 54 dBW to 83 dBW
	Pilot	Adjustable in at least THIRTY discrete steps from 54 dBW to 83 dBW
S-Band: 2,030.4375 MHz and 2,035.9625 MHz		
	WSC	73.5 dBW
	GRGT	70.5 dBW

NOTES:
[1] Specified EIRP values include radome losses if radomes are provided.

SGSS.005003 Combined Ku Uplink
The SNGS shall transmit a Ku-band frequency division multiplexed (FDM) uplink to any operational TDRS, including any or all of the following signals:
1. SSA-1 forward service signal,
2. SSA-2 forward service signal,
3. KuSA-1 or KaSA-1 forward service signal,
4. KuSA-2 or KaSA-2 forward service signal,
5. Two (2) SMA forward service signals,
6. TDRS command and ranging signals, and
7. Pilot signal (required for TDRS F1-F7).
Rationale: Derived from spacecraft design.

SGSS.005004 Effective Isotropic Radiated Power
The minimum EIRP achievable for each SNGS uplink shall be as specified in Table 5.2-5.
Rationale: EIRP requirements must be met to close the link with the required link margin.

SGSS.005018 Ku-band Receive Performance
The SNGS shall meet the receive Ku-band RF performance requirements in Table 5.2-6.
Rationale: The specified performance requirements are necessary to

1. Establish the SGL links with the required availability

2. Establish the SGL links at frequencies consistent with the spacecraft design

3. Comply with requirements established by national and international regulatory bodies

Table 5.2-6 SGL G/T and Sidelobes

SGL G/T and Sidelobes PARAMETER	REQUIREMENT
Applicable Frequency Bands	
Receive Frequency Band	13,402 MHz to 14,062 MHz
Transmit Frequency Band	14,600 MHz to 15,250 MHz
Gain/Temperature Figure of Merit [1]	
G/T at STGT over Receive Band	40.3 dB/°K, minimum
G/T at WSGT over Receive Band	40.3 dB/°K, minimum
G/T at GRGT over Receive Band	36.3 dB/°K, minimum
Transmit and Receive Sidelobe Pattern [2,3]	*In accordance with FCC Regulation 25.209.*
1° ≤ θ ≤ 7°	G ≤ 29–25 log10(θ) dBi
7°< θ ≤ 9.2°	G ≤ 8 dBi
9.2°< θ ≤ 48°	G ≤ 32-25 log10(θ) dBi
48°< θ ≤ 180°	G ≤ -10 dBi

NOTES:

[1] The specified G/T performance (clear sky) shall include tracking loss (at elevation angles of 5° over the local horizon and whenever the sun is ± 1° or greater off the antenna boresight) and shall include the total contribution from the LNA, associated waveguide switches, couplers and output waveguides. The specified G/T also includes radome loss if radomes are provided.

[2] Where θ is the off-boresight angle in degrees, and G is the gain in dBi at any frequency in the specified frequency band.

[3] At any frequency in the specified band, no sidelobe peak shall exceed this bound by more than 3 dB. No more than 10% of the sidelobe peaks shall exceed the specified bound. Regions within ± 15° from each subreflector support spar plane are exempt from sidelobe limitations

SGSS.005019 Combined Ku-band Downlink

The SNGS shall receive a Composite Ku-band FDM downlink from each operational TDRS, including any or all of the following signals:

1. SSA-1 return service signal,
2. SSA-2 return service signal,
3. KuSA-2 or KaSA-2 return service signal,
4. Up to thirty (30) SMA return service signals, and
5. TDRS telemetry and ranging signal.

Rationale: This requirement is derived from the spacecraft design.

SGSS.005020 Dedicated Ku-band Downlink

The SNGS shall receive a Dedicated Ku-band downlink from each operational TDRS on the polarization orthogonal to the Composite signals, with any one of the following signals

1. KuSA-1 return service signal,
2. KaSA-1 return service signal, or
3. KaSA-3 return service signal

Rationale: This requirement is derived from the spacecraft design. Only one of the named signals may be active at a time because each occupies the same downlink spectrum. The dedicated downlink occupies the Ku-band SGL downlink at a linear polarization orthogonal to that for the composite downlink.

SGSS.005021 Ku-band Receive Low-Noise Amplification
The SNGS shall provide Ku-band low noise amplification of the received downlink.
Rationale: Low-noise amplifiers are required to boost the extremely low signal levels received from the satellite to power levels suitable for further processing of the received signal.

SGSS.005022 Ku-band Down conversion
The SNGS shall down convert received RF signals to Intermediate Frequencies.
Rationale: RF-to-IF downconversion is a frequency translation mechanism common to most RF communications systems

SGSS.005098 Ku-band Forward Services Performance
The SNGS shall provide the composite Ku-band SGL uplink such that the signal power spectral density at the transmit output of the SGL antenna resulting from the simultaneous radiation of all forward service uplink carriers, operating at their maximum specified data rates, shall comply with the emission mask requirements defined in Figure 5.2-1.
Rationale: This is the NTIA out-of-band emissions mask for space services.

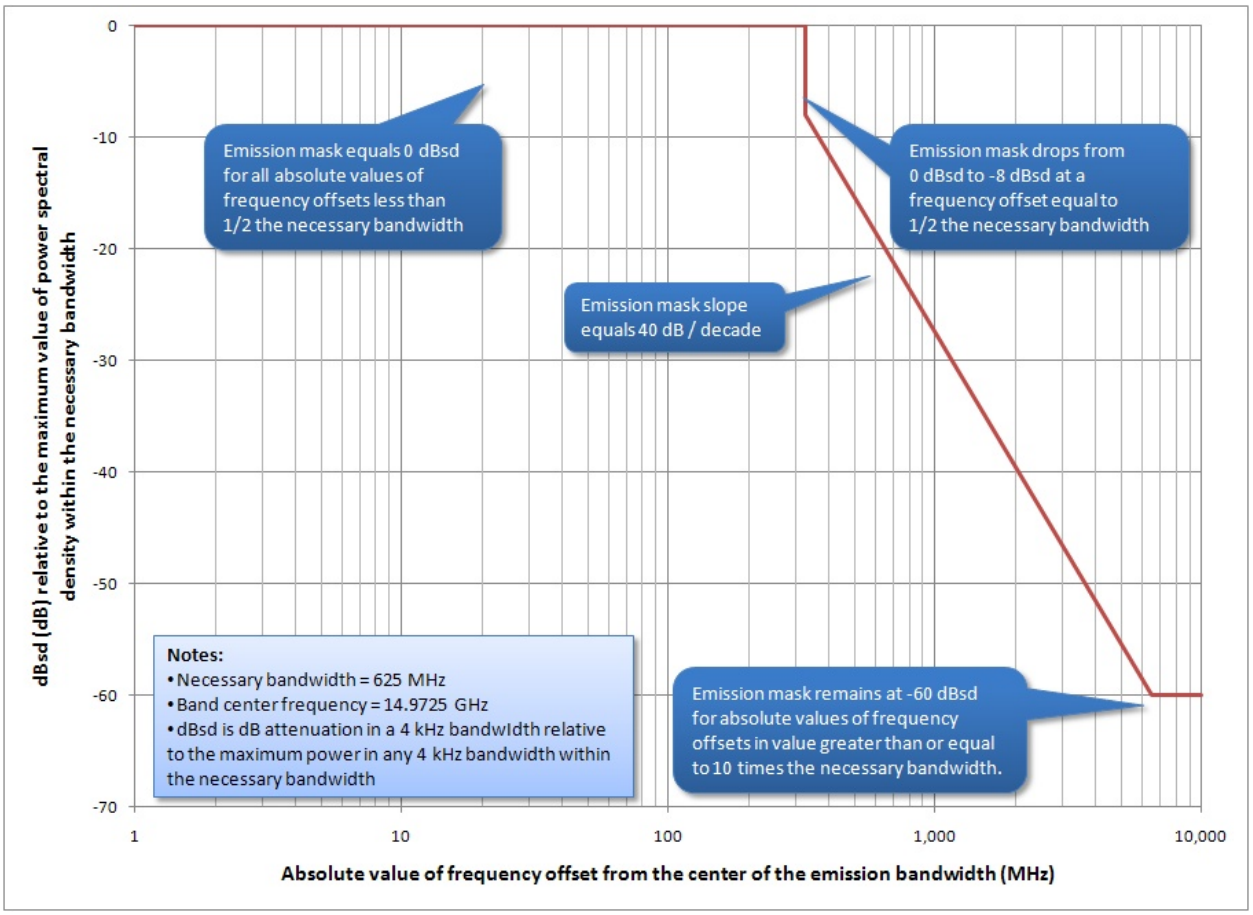


Figure 5.2-1 SGL Ku-Band Uplink Emission Mask

SGSS.005099 SGL Uplink Radiated Interference Limits
The SNGS shall not radiate in the band 14,850 to 15,149 MHz a total EIRP greater than that shown in Figure 5.2-2. Discrete spurs in this band shall each be less than -12 dBWi. The sum of all forward services discrete spurs in this band shall be less than -2 dBWi.

Rationale: This limitation is necessary to prevent interference of the Ku-band SGL uplink into the Ku-band SSL Return service, which operates in the band 14,890.9 MHz to 15,115.9 MHz.

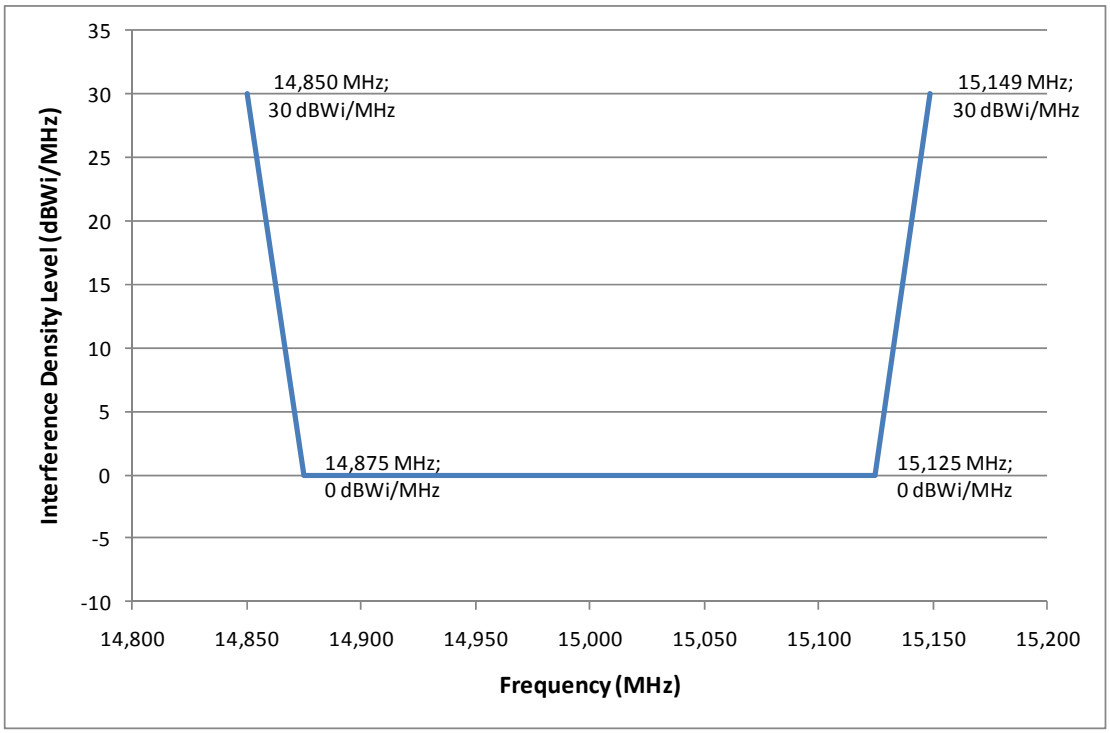


Figure 5.2-2 Radiated Interference Density Level Requirement in the KSAR

<u>SGSS.005119 Ku-Band SGL Uplink Polarization</u>

The SNGS shall transmit the SGL uplink signals in linear vertical polarization with the performance given in Table 5.2-7.

Rationale: The SGL employs linear orthogonal polarization as a means for frequency reuse.

Table 5.2-7 Ku-band SGL Uplink and Downlink Polarization

Parameter	Requirement
Ku-Band SGL Uplink Polarization	
Uplink Polarization Type and Orientation	Linear, Vertical
Uplink Polarization Adjustment	± 90°
Uplink Polarization Alignment Accuracy	± 0.3° with respect to the received vertical polarization.
Ku-Band SGL Downlink Polarization	
Downlink Polarization 1 (Dedicated SGL Downlink) Type and Orientation	Linear, Vertical
Downlink Polarization 2 (Composite SGL Downlink) Type and Orientation	Linear, Horizontal
Polarization Isolation	30 dB minimum
Downlink Polarization Orientation	± 90° from local vertical
Simultaneous Alignment	Orientation of both polarizations shall be aligned simultaneously
Polarization 1 Alignment Accuracy	± 0.3° with respect to the TDRS Polarization 1 transmitted signal

SGSS.005120 Ku-Band SGL Downlink Polarization
The SNGS shall receive the SGL downlink signals in each of two linear polarizations with the performance given in Table 5.2-7.
Rationale: The SGL downlink employs linear orthogonal polarization as a means for frequency reuse.

5.2.2.2 TDRS Pilot Uplink

SGSS.002067 TDRS Frequency Reference
The SNGS shall derive pilot and command carrier frequencies from the ultra-stable frequency reference.
Rationale: The pilot (F1-F7) or the command carrier (F8 and later) is used to provide a stable reference for frequency translation within the TDRS payload. The Timing & Frequency Reference subsystem provides the stable reference for these uplink carriers.

SGSS.005050 Ku-band TDRS Pilot Uplink
The SNGS shall transmit an unmodulated pilot carrier to each first-generation TDRS spacecraft with frequency derived directly from the SNGS ultra-stable frequency reference, having the signal characteristics defined in the Interface Control Document for the TDRSS Spacecraft/Ground Segment, STDN 220.29 for F1-F6 and ICD for the TDRS Spacecraft/Ground Segment, 405-F7-ICD-001 for F7.
Rationale: The pilot provides the frequency reference for the frequency-determining elements onboard the TDRS spacecraft.

5.2.3 S-band Space-to-Ground Links

5.2.3.1 S-band RF Performance

SGSS.005066 First Generation S-band Command Signal Characteristics
The SNGS shall generate S-band Command signals with baseband and subcarrier characteristics that meet the requirements of the TDRS F1-F6 RF ICD, STDN 220.29, Interface Control Document for the TDRSS Spacecraft/Ground Segment.
Rationale: This requirement is based on the existing spacecraft design.

SGSS.005121 TDRS F7 S-band Command Signal Characteristics
The SNGS shall generate S-band Command signals with baseband and subcarrier characteristics that meet the requirements of the ICD for the TDRS Spacecraft/Ground Segment, 405-F7-ICD-001.
Rationale: This requirement is based on the existing spacecraft design.

SGSS.005067 Second Generation S-band Command Signal Characteristics
The SNGS shall generate S-band Command signals with baseband and subcarrier characteristics that meet the requirements of the TDRS H,I,J Space/Ground ICD, DS80409-H00-003 Rev. D.
Rationale: This requirement is based on the existing spacecraft design.

SGSS.005068 Third Generation S-band Command Signal Characteristics
The SNGS shall generate S-band Command signals with baseband and subcarrier characteristics that meet the requirements of the TDRS K Program Space/Ground RF ICD 454-KP-SYS-ICD-001.
Rationale: This requirement is based on the future spacecraft design.

SGSS.005069 S-band Upconversion
The SNGS shall convert Intermediate Frequencies to S-band RF uplink frequencies required for TDRS S-band commanding.
Rationale: IF-to-RF upconversion is a frequency translation mechanism common to most RF communications systems.

SGSS.005070 S-band High-Power Amplification
The SNGS shall amplify S-band signals to generate the EIRP required to meet the S-band EIRP specified in Table 5.2-5.
Rationale: Signal processing occurs at low power levels within the terminal. Much higher signal levels are required to overcome transmission path losses and other impairments in order to propagate the signal with adequate fidelity to the satellite.

SGSS.005072 First Generation S-band Telemetry Signal Parameters
The SNGS shall receive a combined Telemetry and Range S-band signal with the signal characteristics defined in the Interface Control Document for the TDRSS Spacecraft/Ground Segment, STDN 220.29 for F1-F6 and ICD for the TDRS Spacecraft/Ground Segment, 405-F7-ICD-001 for F7.
Rationale: This requirement is based on the existing spacecraft design.

SGSS.005073 Second Generation S-band Telemetry Signal Parameters
The SNGS shall receive a combined Telemetry and Range S-band signal with the signal characteristics defined in the TDRS H,I,J Space/Ground ICD, DS80409-H00-003 Rev. D.
Rationale: This requirement is based on the existing spacecraft design.

SGSS.005074 Third Generation S-band Telemetry Signal Parameters
The SNGS shall receive a combined Telemetry and Range S-band signal with the signal characteristics defined in the Tracking and Data Relay Satellite (TDRS) K Program Space/Ground RF Interface Control Document (ICD), 454-KP-SYS-ICD-001.
Rationale: This requirement is based on the existing spacecraft design.

SGSS.005075 S-band Low-Noise Amplification
The SNGS shall provide S-band low noise amplification of the received downlink.
Rationale: Low-noise amplifiers are required to boost the extremely low signal levels received from the satellite to power levels suitable for further processing of the received signal.

SGSS.005076 S-band Down conversion
The SNGS shall convert S-band RF signals received from the TDRS S-band Telemetry downlink to Intermediate Frequencies.
Rationale: RF-to-IF downconversion is a frequency translation mechanism common to most RF communications systems.

5.2.4 Antenna Control

5.2.4.1 SGL Ground Antenna Control

SGSS.005100 SGL Ground Antenna Control
The SNGS shall control the mechanical pointing of the SGL ground antennas having the properties given in Table 5.2-8.
Rationale: The antennas must be controllable to the extent of their capabilities.

Table 5.2-8 SGL Ground Antenna Properties

Parameter	Performance
Pointing Range	
Azimuth	Rotate ± 100° from 180° true azimuth orientation
Elevation	0° to 90°
Slew Rate	
Azimuth	0.5°/second
Elevation	0.5°/second
Angular Acceleration	0.5°/second^2

SGSS.005101 SGL Ground Antenna Pointing and Tracking Control Modes

The SNGS shall provide the operator-selectable pointing and tracking control modes listed in Table 5.2-9.

Rationale: A range of control methods is required to accommodate the operations, test and maintenance needs of the SNGS.

Table 5.2-9 SGL Ground Antenna Control Modes

Antenna Control Modes
Program Track Mode
Program Spatial Scan Mode
Ku-band Autotrack Mode
S-band Autotrack Mode
Manual Position Control Mode
Manual Velocity Control Mode

SGSS.005102 Program Track Control Mode

The SNGS shall provide a Program Track control mode whereby the SGL ground antenna is controlled with the pointing and tracking performance listed in Table 5.2-10.

Rationale: Program tracking is an open loop control method in which the antenna azimuth and elevation are calculated based on the known location and motion of the satellite.

Table 5.2-10 Program Track Control Mode Requirements

Parameter	Performance
Tracking Rate	
Azimuth	0.0055°/second.
Elevation	0.0015°/second
Angular Acceleration	0.5°/second^2
Pointing Error[1] Under No Wind Conditions (% of Ku-band 3 dB Beamwidth)	≤ 15%, for elevation angles between 4º and 65º

NOTE:
[1] Program track pointing error is the space angle (3-sigma) difference between the antenna pointing command vector (azimuth and elevation) and the position of the antenna RF boresight axis.

SGSS.005103 Program Spatial Scan Mode

The SNGS shall provide a Program Spatial Scan control code whereby the SGL ground antenna first seeks the TDRS spacecraft under program (open loop) control, and then transitions to Autotrack mode after the desired SGL downlink signal has been acquired.

Rationale: This is a transitional mode that bridges between Program tracking and Autotracking.

SGSS.005104 Ku-band Autotrack Mode

The SNGS shall provide a Ku-band Autotrack control mode whereby the SGL ground antenna is controlled with the performance listed in Table 5.2-11.

Rationale: Autotracking optimizes the antenna pointing for best link performance.

Table 5.2-11 Ku-Band Autotrack Control Mode Requirements

Parameter	Requirement
Tracked Signal	TDRS telemetry carrier at both Ku-band carrier center frequencies specified in Table 5.3-4.
Acquisition Threshold	10 dB below the minimum Ku-band telemetry signal level specified in Table 5.3-4.
Autotrack Tracking Range	Once autotrack acquisition has been achieved, the SGL antenna shall maintain Ku-band autotrack operation for received band telemetry signal levels ranging from 10 dB below the specified acquisition threshold level to the maximum level specified in Table 5.3-4.
Pointing Error (1) Under No Wind Conditions	
Error (% 3 dB Ku-band Beamwidth	≤ 10%, for elevation angles between 4° and 65°, and for received telemetry signal levels ranging from the minimum to maximum levels specified in specified in Table 5.3-4.
Loss of Track Action	The antenna control shall revert to the program track control mode upon loss of a usable signal.
Sidelobe Acquisition Prevention (2)	Autotrack control features shall be included to prevent false autotrack acquisition on SNGS SGL antenna sidelobes.

NOTES:
(1) Autotrack pointing error is the space angle (3 sigma) difference between the RF boresight and the TDRS line of sight.
(2) The nominal clear sky TDRS telemetry signal level will be used as the reference for preventing false autotrack acquisition on SNGS SGL antenna sidelobes.

SGSS.005105 S-band Autotrack Mode
The SNGS shall provide an S-band Autotrack control mode whereby the SGL ground antenna is controlled with the performance listed in Table 5.2-12.
Rationale: Autotracking optimizes the antenna pointing for best link performance.

Table 5.2-12 S-Band Autotrack Control Mode Requirements

Parameter	Requirement
Tracked Signal	TDRS telemetry carrier at both S-band carrier center frequencies specified in Table 3-20.
Acquisition Threshold	10 dB below received level with TDRS S-band telemetry signal at minimum specified EIRP (1).
Tracking Fade Margin	The antenna shall maintain antenna tracking under 10 dB telemetry signal fades.
Pointing Error (2)	
Error (% 3 dB S-band Beamwidth) for elevation angles between 4° and 80°	20%
Error (% 3 dB S-band Beamwidth) for elevation angles between 80° and 90°	40%
Loss of Track Action	The antenna control shall revert to the program track control mode upon loss of a usable signal.

Notes:
(1) Minimum EIRP values are specified in: SE-BC-11, TDRS HIJ Space/Ground Segment ICD.
(2) Autotrack pointing error is the space angle (3 sigma) difference between the RF boresight and the TDRS line of sight.

SGSS.005106 Manual Remote Control Mode
The SNGS shall provide a Manual Remote control mode whereby the SGL antenna is controlled remotely by operator initiated commands.
Rationale: Manual remote control is needed for maintenance and test conditions controlled from an operator console.

SGSS.005107 Manual Local Control Mode
The SNGS shall provide a Manual Local control mode whereby the SGL antenna is controlled by a local control panel.
Rationale: Manual local control is needed for maintenance and test conditions controlled directly from the antenna control unit.

5.2.4.2 TDRS SA Antenna Control

Two error signals, one from each channel of a two-axis monopulse system, are generated on the TDRS for the purpose of closed-loop tracking of each KSA antenna. In the TDRS the two error signals, which are time-multiplexed and PN coded, amplitude modulate the KSA return link transmitted to the SGL antenna. An identical process is provided on the second KSA return link for the second SA Antenna.

The autotrack error signal that is amplitude modulated onto the return link has the form shown below:

(1) $$\underbrace{Vr\cos[\omega Rt + \theta R(t)]}_{\text{Return Channel Signal}} \bullet \underbrace{[1 + Me(t)]}_{\text{Error Signal Modulation}} \bullet \underbrace{[1 + N(t)]}_{\text{Incidental AM}}$$

where

ω_R	=	Return signal RF carrier frequency (radians/sec)
θ_R	=	Return signal phase modulation and phase offset
N(t)	=	Incidental AM component

2) Form of Error Signal Modulation

$$M_e(t) = \sum_n \frac{\Delta V_n}{V_R} P_s(t - nT_s) \bullet \sum_m P_c(t - mT_c),$$

where ΔVn = sample of nth error channel voltage (n = 1,2)

V_R = Return Channel Voltage

$-M \leq (\Delta V_n/V_R) \leq +M$, where M = maximum modulation index and M = 0.10.

$P_s(t - nT_s)$	=	1 for $nT_s \leq t \leq (n+1)Ts$
	=	0 elsewhere
	=	time sampling of two error channels with 50% duty factor
$P_c(t - mT_c)$	=	A_M for $mT_c \leq t \leq (m+1)\ T_c$, where $A_M = \pm 1$
	=	Manchester coded pseudo-noise code on error signal

$T_c = 5.0 \times 10^{-4}$ seconds

$T_s = .032$ second

Modulation Index Magnitude, $0 \leq |M_e(t)| \leq 0.10$

The two KSA monopulse channels, corresponding to the two KSA antenna gimbal axes, are time division multiplexed to form a single error signal wave form. The multiplexed signal switches between error channels every 32 milliseconds.

The PN code that is applied to the error signal is a 1024-bit Manchester-coded PN sequence. Since each Manchester-coded PN bit becomes two symbols, the total sequence is 2048 symbols long. This 2048-bit sequence operates at a rate of 2000 symbols per second: the entire sequence repeats every 1024 milliseconds. The PN epoch is coincident with the first millisecond of the KSA inner gimbal axis error signal interval. The error signal is amplitude modulated onto the appropriate KSA return link with a modulation index that may be as low as zero during tracking and as high as 0.10 during autotrack pull-in.

SGSS.005108 TDRS SA Antenna Autotrack Processing

The SNGS shall detect and process the TDRS SA antenna autotrack error signals from the KSA FDM channels of the TDRS SGL downlink.

Rationale: Each TDRS spacecraft provides azimuth and elevation error signals for the purpose of auto-tracking the user platform at Ku-band or Ka-band, where the beamwidths are comparatively narrow. These signals are TDM multiplexed PN spread and AM-modulated on the KSA downlink carrier.

SGSS.005109 TDRS SA Antenna Autotrack Error Data
The SNGS shall provide TDRS SA antenna azimuth and elevation error data for long-loop auto-tracking.
Rationale: After demodulation, de-spreading and demultiplexing, the AZ/EL error signals are published for use in long-loop auto-tracking.

5.3 TDRS Telemetry, Tracking and Command Services

SGSS.005049 Ku-band TDRS Commanding
The SNGS shall transmit TDRS spacecraft commands to operational TDRS spacecraft in Ku-band during normal operations.
Rationale: Ku-Band commanding is the primary means for controlling a TDRS spacecraft, but is only available during normal operations after the TDRS Ku-band SGL antenna has been acquired by the ground terminal.

SGSS.005051 S-band TDRS Commanding
The SNGS shall transmit TDRS spacecraft commands to TDRS spacecraft in S-band during normal, emergency and storage operations.
Rationale: S-band commanding is the primary means for controlling a TDRS spacecraft during emergency and storage operations, and is also available during normal operations.

SGSS.005052 Command/Ranging Combine
The SNGS shall combine the TDRS Command signal with the tone ranging signal when ranging is enabled.
Rationale: The command carrier is amplitude modulated with the ranging tones; whereas the commands themselves are PSK modulated on the sidebands.

SGSS.005053 TDRS Tone Ranging
The SNGS shall perform tone ranging to each TDRS spacecraft as required for radiometric tracking.
Rationale: Tone ranging is a less accurate method than PN ranging, but does not compete with user data for bandwidth resources, and thus can be performed continuously.

SGSS.005054 Simultaneous Ku-band/S-band TT&C
The SNGS shall provide TT&C services simultaneously at both S-band and Ku-band frequencies to any TDRS spacecraft, upon command.
Rationale: Simultaneous operation is required during the transition from S-band to Ku-band nominal operation. S-band may also be used during unfavorable atmospheric propagation conditions.

SGSS.005055 Ku-band TDRS Telemetry
The SNGS shall receive TDRS spacecraft telemetry from operational TDRS at Ku-band in normal operations.
Rationale: Ku-band telemetry is the primary means for monitoring a TDRS spacecraft, but is only available during normal operations after the TDRS Ku-band SGL antenna has been acquired by the ground terminal.

SGSS.005056 S-band TDRS Telemetry
The SNGS shall receive TDRS spacecraft telemetry from TDRS at S-band during normal, emergency and storage operations.
Rationale: S-Band telemetry is the primary means for monitoring a TDRS spacecraft during emergency and storage operations, and is also available during normal operations.

5.3.1 First Generation TDRS TT&C Services

SGSS.005057 First Generation Ku-band Command Signal Characteristics
The SNGS shall receive the Ku-band Telemetry and Range signal having the signal characteristics defined in the Interface Control Document for the TDRSS Spacecraft/Ground Segment, STDN No. 220.29 for F1-F6 and (ICD) for the TDRS Spacecraft/Ground Segment, 405-F7-ICD-001 for F7.
Rationale: Each series of TDRS spacecraft may have unique command signal characteristics.

SGSS.005058 First Generation Ku-band Telemetry Signal Characteristics
The SNGS shall receive the Ku-band Telemetry and Range signal having the signal characteristics defined in the TDRSS Spacecraft/Ground Segment, STDN No. 220.29 for F1-F6 and (ICD) for the TDRS Spacecraft/Ground Segment, 405-F7-ICD-001 for F7.
Rationale: Each series of TDRS spacecraft may have unique telemetry signal characteristics.

SGSS.005059 First Generation Ku-band TT&C Frequency Pairs
The SNGS shall operate in the Ku-band uplink command/downlink telemetry frequency pair modes specified in the TDRSS Spacecraft/Ground Segment, STDN No. 220.29 for F1-F6 and (ICD) for the TDRS Spacecraft/Ground Segment, 405-F7-ICD-001 for F7.
Rationale: This requirement is based on the existing spacecraft design.

5.3.2 Second Generation TDRS TT&C Services

SGSS.005060 Second Generation Ku-band Command Signal Characteristics
The SNGS shall generate Ku-band Command signals with baseband and subcarrier characteristics that meet the requirements set forth in the TDRS H,I,J Space/Ground ICD, DS80409-H00-003 Rev. D.
Rationale: Each series of TDRS spacecraft may have unique command signal characteristics.

SGSS.005061 Second Generation Ku-band Telemetry Signal Characteristics
The SNGS shall receive the Ku-band Telemetry and Range signal having the signal characteristics defined in the TDRS H,I,J Space/Ground ICD, DS80409-H00-003 Rev. D.
Rationale: Each series of TDRS spacecraft may have unique telemetry signal characteristics.

SGSS.005062 Second Generation Ku-band TT&C Frequency Pairs
The SNGS shall operate in the Ku-band uplink command/downlink telemetry frequency pair modes specified in the TDRS H,I,J Space/Ground ICD, DS80409-H00-003 Rev. D.
Rationale: This requirement is based on the existing spacecraft design. A second command link frequency was added to allow collocation with a first-generation TDRS.

5.3.3 Third Generation TDRS TT&C Services

SGSS.005063 Third Generation Ku-band Command Signal Characteristics
The SNGS shall generate Ku-band Command signals with baseband and subcarrier characteristics that meet the requirements set forth in the TDRS K Program Space/Ground RF ICD 454-KP-SYS-ICD-001.
Rationale: Each series of TDRS spacecraft may have unique command signal characteristics.

SGSS.005064 Third Generation Ku-band Telemetry Signal Characteristics
The SNGS shall receive the Ku-band Telemetry and Range signal having the signal characteristics defined in the TDRS K Program Space/Ground RF ICD 454-KP-SYS-ICD-001.
Rationale: Each series of TDRS spacecraft may have unique telemetry signal characteristics

SGSS.005065 Third Generation Ku-band TT&C Frequency Pairs
The SNGS shall operate in the uplink command/downlink telemetry frequency pair modes specified in the TDRS K Program Space/Ground RF ICD 454-KP-SYS-ICD-001.
Rationale: This requirement is based on the future spacecraft design.

5.3.4 TDRS Command Signal Performance Requirements

5.3.4.1 Reserved

None.

5.3.4.2 Command Signal Required RF Characteristics

SGSS.005122 Command Signal Uplink Performance

The SNGS shall meet the Command Signal uplink RF performance requirements in Table 5.3-1.

Rationale: This requirement is based on the existing spacecraft design.

Table 5.3-1 Command Signal Required RF Characteristics

Parameter	Requirement
Command Carrier Center Frequency[1]	
Ku-band F1	14785.9625 MHz
Ku-band F2	14780.4375 MHz
S-band F1	2035.9625 MHz
S-band F2	2030.4375 MHz
Carrier Frequency Accuracy	Carrier derived from TFR
Carrier Modulation	Phase modulation by modulated 16 kHz command subcarrier and range signal
Modulation Index of Command Sub-carrier on Carrier	1.0 ± 10% radians
Ranging Signal Modulation Index	
Major Tone	0.7 radians, ± 10%
Minor Tone	0.7 radians, ± 10%
Carrier Phase Noise	
Ku-band Total Phase Noise:	
1 Hz – 10 Hz	≤ 1.4° rms
10 Hz – 32 Hz	≤ 1.4° rms
32 Hz – 1 kHz	≤ 3.9° rms
1 kHz – 6 MHz	≤ 1.0° rms
Ku-band Phase Noise Component Not Coherent with TFR 10 MHz Reference Signal:	
1 Hz – 10 Hz	≤ 1.0° rms
10 Hz – 32 Hz	≤ 1.0° rms
32 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 6 MHz	≤ 1.0° rms
S-band Total Phase Noise:	
1 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 0.5° rms
Minimum RF Output Power	
Ku-band	As required to meet Ku-band TDRS command link EIRP requirements specified in Table 5.2-5.
S-band	As required to meet S-band TDRS command link EIRP requirements specified in Table 5.2-5.
RF Bandwidth (3 dB)	3 MHz, minimum
Output Carrier Power Level Instability	≤ 0.5 dB per 24 hours.
Signal to Thermal Noise Ratio (within ± 1.5 MHz of the carrier)	
Ku-band	≥ 40 dB at full EIRP.
S-band	≥ 50 dB at full EIRP.
Spurious Outputs From all Sources	
RMS sum of all in-band spurs (within 1.5 MHz of the carrier)	≥ 30 dB below modulated carrier

Parameter	Requirement
Discrete in-band spur (within 1.5 MHz of the carrier)	≥ 40 dB below modulated carrier
Out-of-Band Spurious Signals	≤ -40 dBc (referenced to an unmodulated carrier), up to 30 GHz.
Emission Mask	As defined in Figure 5.3-1.

NOTES:
1. Uplink command frequencies F1 and F2 must be paired with downlink telemetry frequencies F1 and F2, respectively, as defined in Table 5.3-2.

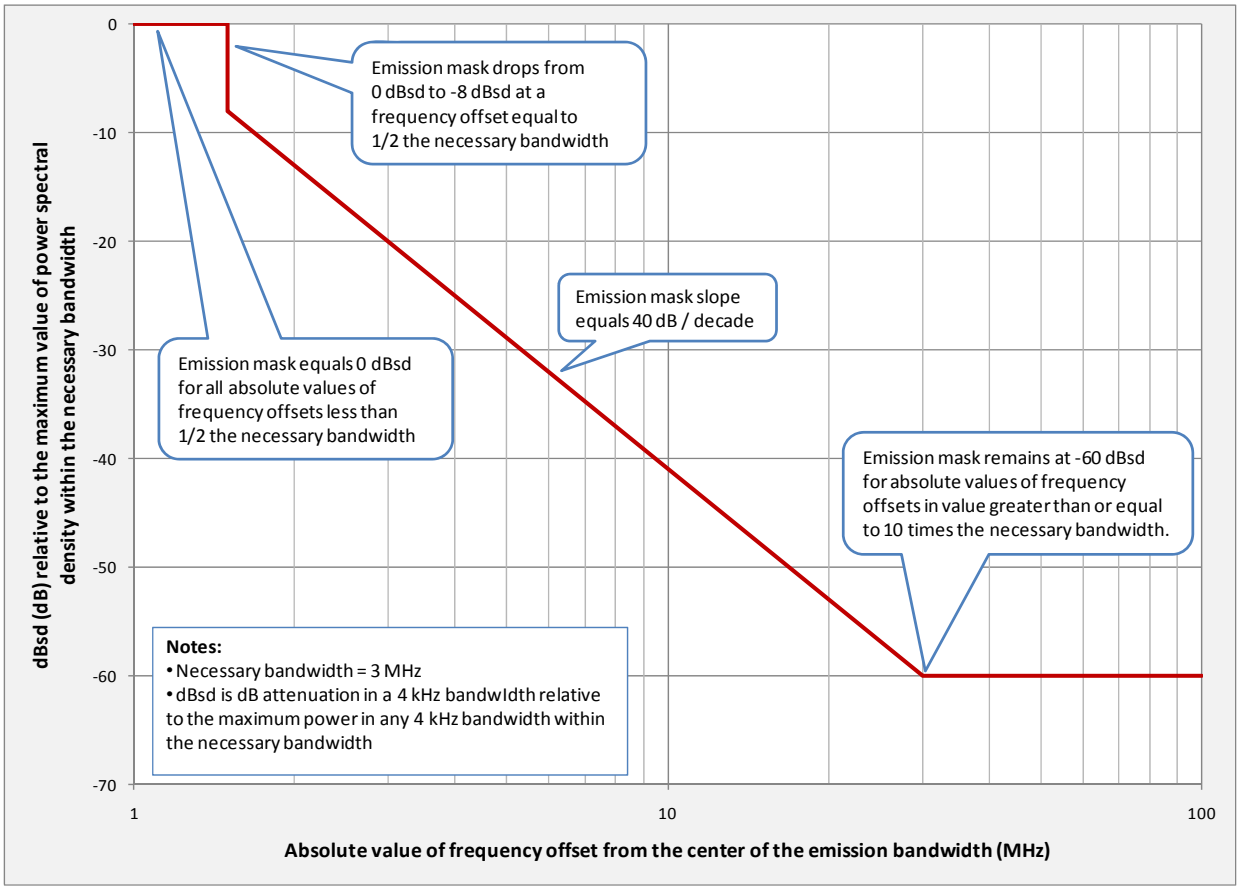


Figure 5.3-1 Required Command Signal Emission Mask

5.3.4.3 Command Carrier Frequency Sweep

SGSS.005123 Command Signal Uplink Frequency Sweep

The SNGS shall be capable of sweeping the Command Signal uplink frequency requirements in Table 5.3-2.

Rationale: This requirement is based on the existing spacecraft design.

Table 5.3-2 Command Carrier Frequency Sweep Requirements

Parameter	Requirement
Sweep Width Range	± 110 kHz, minimum.
Sweep Step Size	16 Hz, maximum.
Sweep Rate Range	Adjustable from 1 kHz/sec to 20 kHz/sec, minimum.
Sweep Rate Adjustment Resolution	1kHz/sec maximum step size.
Modulation	No modulation during carrier sweep.
Sweep Decay	Smooth frequency transition in automatically returning to the nominal carrier frequency after sweep stopped.

5.3.4.4 Command/Telemetry Frequency Pairs

SGSS.005124 TDRS Command/Telemetry Frequency Pair Modes

The SNGS shall operate in the uplink command/downlink telemetry frequency pair modes specified in Table 5.3-3.

Rationale: This requirement is based on the existing spacecraft design.

Table 5.3-3 Command/Telemetry Frequency Pairs

Command/Telemetry Frequency Pair	Uplink (MHz)	Downlink (MHz)
Pair 1	SF_{U1} = 2,035.9625	SF_{D1} = 2,211.0
Pair 2	SF_{U1} = 2,035.9625	KF_{D1} = 13,731.0
Pair 3	KF_{U1} = 14,785.9625	SF_{D1} = 2,211.0
Pair 4	KF_{U1} = 14,785.9625	KF_{D1} = 13,731.0
Pair 5	SF_{U2} = 2,030.4375	SF_{D2} = 2,205.0
Pair 6	SF_{U2} = 2,030.4375	KF_{D2} = 13,725.0
Pair 7	KF_{U2} = 14,780.4375	SF_{D2} = 2,205.0
Pair 8	KF_{U2} = 14,780.4375	KF_{D2} = 13,725.0

5.3.5 TDRS Telemetry Signal Requirements

SGSS.005071 Telemetry and Ranging Signal Requirements

The SNGS shall accept and process telemetry and ranging signals having the characteristics given in Table 5.3-4.

Rationale: This requirement is based on the existing spacecraft design.

Table 5.3-4 Combined Telemetry and Range Signal Characteristics

Parameter	Requirement
Telemetry Carrier Center Frequency	
Ku-band F1	13731.0 MHz
Ku-band F2	13725.0 MHz
S-band F1	2211.0 MHz
S-band F2	2205.0 MHz
Long term (10 yrs) Frequency Stability	
S-band	± 80 kHz, maximum
Ku-band	± 100 kHz, maximum
Received Isotropic Power	
Total Signal (Ku-band)	
Minimum	-213.3 dBW
Maximum	-165 dBW
Total Signal (S-band)	
Minimum	-201.8 dBW (1)
Maximum	-181.8 dBW
Received isotropic telemetry subcarrier level	
S-band Minimum	-207.8 dBW (min)
S-band Maximum	-181.8 dBW (max)
Received isotropic ranging signal level	
S-band Minimum	-221.4 dBW (min)
S-band Maximum	-181.8 dBW (max)
Polarization	Right Hand Circular
Incidental AM	≤ 2%
Incidental Discrete In-band Phase Modulation (within ±1.5 MHz of the carrier)	> 40dB below unmodulated carrier
Spurious Outputs	
Total In-band Spurious Outputs (within ±1.5 MHz of the carrier).	≥ 30 dB below the unmodulated carrier
Discrete In-band Spurious Outputs (within ±1.5 MHz of the carrier)	≥ 40 dB below the unmodulated carrier
Modulation	
Carrier Modulation	Phase Modulation
Sub-carrier Frequency	1.024 MHz
Sub-carrier Frequency Accuracy	± 0.003%
Sub-carrier Modulation Index	1.2 radians
Subcarrier Modulation Index Accuracy	± 10%
Sub-carrier Data Modulation	BPSK, by data.
Subcarrier Data Modulation Index	π radians
Telemetry Data Rate	1000 or 4000 bps selectable
Telemetry Data Rate Variation	

Parameter	Requirement
Ku-band	± 0.03%
S-band	± 0.1%
Telemetry Data Format	
Clear Mode	NRZ-L
Secure Mode	NRZ-M
Data Transition Density	640 transitions minimum every 2560 bit periods with a maximum of 128 transitionless bits.
Range Tones Modulation Index	
Major Tone	0.40 radians
Minor Tone	0.40 radians
Tone Modulation Index Accuracy	± 24% (Major or minor tone).
Spacecraft Turnaround Channel Amplitude Response (in the passband between 3.5 kHz and 530 kHz offset from the carrier)	Within ±1.0 dB of response at 524 kHz offset from the carrier
Spacecraft Turnaround Channel Phase Response (in the passband between 3.5 kHz and 530 kHz offset from the carrier)	Within ±11.65º of linear response
Turn-around Range Signal Phase	Not inverted by TDRS relative to uplink phase
Uncertainty in Total Spacecraft Ranging Phase Delay	≤ 35 ns
Turnaround Command Modulation Index	0.62 radian ±33%
Turnaround Noise Modulation Index	
Ku-band	0.1 radian ±30%
S-band (over 15º conical FOV about +z axis)	0.4 radian ±30%
Double-sided Range Channel Noise Bandwidth	≤ 1.11 MHz

NOTES

(1) At specified minimum G/T, the received signal level shown will result in an Eb/No < 11.6 dB for a 4 kbps telemetry data rate. The minimum signal level shown reflects that which might be expected during a satellite tumble anomaly.

5.4 NEN and DSN Support

SGSS.002052 NEN/DSN Mode TDRS Command

The SNGS shall allow the use of NEN assets to command any TDRS spacecraft in S-band.
Rationale: The SN uses the NEN as a backup/alternate means of communicating with the TDRS constellation.

SGSS.002081 NEN/DSN Mode TDRS Telemetry

The SNGS shall allow the use of NEN assets to receive telemetry from any TDRS spacecraft in S-band.
Rationale: The SN uses the NEN as a backup/alternate means of communicating with the TDRS constellation.

SGSS.002053 NEN/DSN Mode SN Functions

The SNGS shall only provide S-Band TT&C services for any TDRS controlled via the NEN or DSN.
Rationale: The NEN and the DSN do not support Ku-band links, and thus do not have the capability to carry SN user services.

SGSS.002054 NEN/DSN Ground Station Use

The SNGS shall allow use of any NEN or DSN ground station for the control and monitoring of any TDRS spacecraft.

Rationale: For greatest flexibility at launch and early orbit, or in anomaly recovery, the full resources of the NEN and the DSN are available to the SN.

SGSS.002055 NEN/DSN Mode Nominal SN Operations
The SNGS shall allow nominal SN operations via SN ground antennas while using NEN or DSN in a pre-service checkout mode.
Rationale: This provides a means to verify the NEN/DSN capability in a shadow mode, without disrupting SN user services.

SGSS.002056 NEN/DSN Mode Manual SN Radio Frequency (RF) Termination
The SNGS shall allow manual termination of SN RF service use after switching to NEN or DSN RF services.
Rationale: After verification that the NEN/DSN is fully functional, the operator can manually turn off the normal TLM and CMD link.

5.5 Performance Measurement, Monitoring and Calibration

SGSS.005148 Data Presence Monitoring
The SNGS shall continuously monitor the forward data and clock channels for clock signal presence and data signal transition density.
Rationale: Monitoring is required for fault detection and service assurance.

SGSS.005088 Performance Metric Generation
The SNGS shall generate forward and return RF signal performance metrics (spectrum, frequency and power) for all TDRS TT&C and user services provided.
Rationale: Performance metrics are required for local monitoring by Operations, as well as for delivery to customers, when requested.

SGSS.005125 Pre-Service Verification
The SNGS shall provide the means to conduct automated pre-service verification of the operational readiness of a signal processing path prior to the start of a user service support period.
Rationale: This capability provides increased assurance of a successful user service.

SGSS.005126 Post-Maintenance Operational Validation
The SNGS shall provide the means to conduct post-maintenance operational validation testing to ensure operational readiness of a signal processing path after maintenance.
Rationale: This capability provides increased assurance of a successful user service.

SGSS.005089 Ku/S Downlink Test Injection Capability
The SNGS shall provide the means for S and Ku Band downlink test signal injection at the antenna feeds, prior to the LNA(s).
Rationale: Antenna feed signal injection is used for calibration of the receive signal path.

SGSS.005090 MA Forward Test Data Injection
The SNGS shall allow signal injection into the forward MA processing system.
Rationale: Test signals are needed for calibration and troubleshooting

SGSS.005091 BER/EbNo Measurement Capability
The SNGS shall provide the means to perform automated BER vs. Eb/No measurements at any pair of transmit/receive baseband interfaces.
Rationale: BER vs. Eb/No measurements are used to measure the performance of RF signal processing chains. User services are excluded on the tested path for the duration of the test.

SGSS.005092 Spectrum Monitoring and Analysis Capability
The SNGS shall provide real-time spectrum analysis of RF and IF signals at points of interest throughout the signal processing chain.

Rationale: Spectrum analyzer test points are one of the primary means of monitoring and troubleshooting the RF systems.

SGSS.005093 Spectrum Analysis Multiuser Access
The SNGS shall provide simultaneous multiuser access to view real-time spectrum monitoring data by an arbitrary number of authorized operators.
Rationale: The flexibility of multiuser access to real-time performance data is needed especially during anomaly investigation and resolution.

SGSS.005094 Range Zero Set Measurement Capability
The SNGS shall provide the means to automatically measure signal path delays within the SNGS with precision and accuracy equal to or better than the most precise user timing and ranging requirements.
Rationale: Careful calibration of the ground network signal path delays is needed for accurate ranging and time tagging.

SGSS.005127 Return Data Delay Measurement Capability
The SNGS shall provide the means to automatically measure return data processing and forwarding delays within the SNGS, with precision and accuracy equal to or better than the most precise user data latency requirements.
Rationale: Measurement of the ground network data delays is needed to verify Quality of Service commitments.

SGSS.005095 Frequency Test Translation
The SNGS shall provide a ground-based frequency translation capability for loopback testing that is equivalent to the Ku-band frequency translation of the TDRS communications payload.
Rationale: Local loopback testing is used to troubleshoot and verify signal paths and equipment performance. Since the Receive frequencies are different from the Transmit frequencies, a test translator is used to convert the transmit frequency to the receive frequency and close the test loop.

5.6 Time and Frequency Reference (TFR)

5.6.1 General TFR Requirements

SGSS.005079 Time and Frequency Reference
The SNGS shall provide each ground terminal with redundant Cesium frequency and time references synchronized to the US Naval Observatory Universal Time Coordinated (UTC) master clock, meeting the performance characteristics necessary to meet the radiometric, RF, and baseband processing requirements contained elsewhere in this document.
Rationale: The values provided in Table 5.6-1 represent the performance for the existing system and its capabilities. These are provided as guidance in order to meet the radiometric, RF, and baseband processing requirements.

Table 5.6-1 Frequency Reference Performance Requirements

Parameter	Value
Accuracy (Δf/f)	Within ±1.0E-12
Long Term Frequency Stability (Δf/f)	Within ±2.0E-12
Short Term Frequency Stability ($\sigma_y(\tau)$)	
Short Term Stability, 1 sec Averaging Time	< 5.0E-12
Short Term Stability, 10 sec Averaging Time	< 2.7E-12
Short Term Stability, 100 sec Averaging Time	< 8.5E-12
SSB Phase Noise in 1 Hz BW (£(f))	
SSB Phase Noise in 1 Hz BW at 10E0 Hz Offset	< -96 dBc
SSB Phase Noise in 1 Hz BW at 10E1 Hz Offset	< -120 dBc
SSB Phase Noise in 1 Hz BW at 10E2 Hz Offset	< -125 dBc
SSB Phase Noise in 1 Hz BW at 10E3 Hz Offset	< -140 dBc
Harmonic Outputs (any output)	< -40 dBc
Non-Harmonically Related Outputs	< -80 dBc

SGSS.005080 Timing and Frequency Reference Access
The SNGS shall provide access to timing and frequency reference signals for the systems, subsystems and ULE located within a terminal facility.
Rationale: Many systems, subsystems and ULEs depend on the SNGS to provide highly accurate and highly stable timing and frequency references.

5.6.2 Timing References

SGSS.005082 IRIG Timing Reference
The SNGS shall generate and distribute IRIG-Standard timecode(s) with characteristics and accuracy required for timing synchronization within the SNGS and by user local equipment.
Rationale: Timecodes are used for time-tagging system and user data and have different requirements for accuracy and precision depending on the application. Some user local equipment has specific requirements for time codes.

SGSS.005083 Timing Synchronization
The SNGS shall synchronize time references to within 10 nanoseconds of the US Naval Observatory master clock.
Rationale: Highly accurate knowledge of the signal timing is needed in some applications.

SGSS.005084 Stratum-1 NTP Service
The SNGS shall provide Stratum-1 Network Time Protocol service synchronized to the US Naval Observatory master clock
Rationale: NTP is used to provide accurate time to all network-connected hosts that require stable and accurate time.

5.6.3 Frequency References

SGSS.005085 Frequency References

The SNGS shall generate and distribute Frequency Reference(s) with the stability, coherency and accuracy required by SN services and User Local Equipment.

Rationale: Highly stable and accurate frequency references, at standard frequencies such as 5 MHz and 10 MHz, are used to derive all other frequencies, and provide the accuracy and stability required for RF signal coherency, timing generation, Doppler measurement.

SGSS.005087 IF Pilot Frequency Reference

The SNGS shall provide an IF Pilot carrier for distribution to user local equipment.

Rationale: ULE subscribing to IF services uses a station-generated pilot carrier, rather than generating its own IF carrier.

Section 6. Reserved

Section 7. Operational Test Services

7.1 General Operational Test Service (OTS)

SGSS.002501 Test Services
The SNGS shall provide test services that simulate User platforms for any of the SN supported user services.
Rationale: This is an existing capability that the SN uses for compatibility and performance testing.

SGSS.002502 Simultaneous Forward and Return Test Services
The SNGS shall provide simultaneous forward, return, and tracking test services.
Rationale: This is an existing capability that the SN uses for compatibility and performance testing.

SGSS.002503 Simultaneous S and Ku-band Test Services
The SNGS shall provide test services via TDRS consisting of one SSA or one MA simultaneous with one KuSA service for each S/Ku dual band ground test antenna.
Rationale: This is an existing capability that the SN uses for compatibility and performance testing.

SGSS.002504 Simultaneous Ka Test Services
The SNGS shall provide simultaneous data relay and tracking test services via TDRS for all Ka-band ground test antennas.
Rationale: This is an existing capability that the SN uses for compatibility and performance testing.

SGSS.002505 IF Loop Testing With TDRS
The SNGS shall provide IF Loop testing between the user service ground equipment and the test service ground equipment with a TDRS spacecraft in the loop.
Rationale: Existing capability needed for fault isolation and pre-service testing.

SGSS.002507 S-band 2-way Doppler Test Service
The SNGS shall provide 2-way S-band Doppler Test Services for all S-band mode-1 return test services by transmitting the return test service carrier signal exactly as 240/221 of the received simultaneous forward service carrier signal frequency.
Rationale: This is an existing capability for the Test services to emulate the user transponder for unbiased 2-way Doppler tracking.

SGSS.002508 Ku-band 2-way Doppler Test Service
The SNGS shall provide 2-way Ku-band Doppler Test Services for all mode-1 Ku-band return test services by transmitting the return test service carrier signal exactly as 1600/1469 of the received simultaneous forward service carrier signal frequency.
Rationale: This is an existing capability for the Test services to emulate the user transponder for unbiased 2-way Doppler tracking.

SGSS.002509 1-way Doppler Test Service
The SNGS shall provide 1-way Doppler Test Services for all mode-2 return test services by transmitting the return test service carrier signal frequency exactly as scheduled on the return service.
Rationale: This is an existing capability for the Test services to emulate the user transponder for unbiased 1-way Doppler tracking

SGSS.002510 Range Tracking Test Service
The SNGS shall provide range tracking test services for all DG1, mode-1 and mode- 3 return services, by synchronizing the return I channel PN code epoch with the received forward Q-channel epoch.
Rationale: This is an existing capability for the Test services to emulate the user transponder for range tracking.

SGSS.002532 IF Loop Testing Without TDRS
The SNGS shall provide IF Loop testing between the user service ground equipment and the test service ground equipment without a TDRS spacecraft in the loop.
Rationale: Needed for complete end-to-end testing.

SGSS.002533 RF Loop Testing With TDRS
The SNGS shall provide RF Loop testing between the user service ground equipment and the test service ground equipment with a TDRS spacecraft in the loop.
Rationale: Needed for complete end-to-end testing.

SGSS.002534 RF Loop Testing Without TDRS
The SNGS shall provide RF Loop testing between the user service ground equipment and the test service ground equipment without a TDRS spacecraft in the loop.
Rationale: Required for fault isolation and pre-service checkout in the ground segment.

SGSS.002535 Interface Test Results
The SNGS shall store SN interface test results.
Rationale: Storage of interface test results allows Users to access the results and SN to conduct analysis of existing or potential Users.

SGSS.002536 Test Result Availability
The SNGS shall make compatibility, performance, and interface test results available to SN Users.
Rationale: Users conducting tests with the SN required access to the test results for their own analysis.

SGSS.002537 Compatibility/Performance Test Results
The SNGS shall store compatibility and performance test results.
Rationale: Storage of compatibility and performance test results allows Users to access the results and SN to conduct analysis of existing or potential Users.

7.2 OTS Forward Services

SGSS.002511 Forward Test Service (Gain to Temperature Ratio (G/T)
The SNGS shall provide accuracy of forward test service commanded G/T to ±1.0 dB, including test service antenna pointing errors under no-wind conditions.
Rationale: Current capability when properly calibrated to at least 1 dB steps, which is needed to control input noise level for proper link margin and Bit Error Rate (BER) measurements.

SGSS.002512 Forward Test Service Signal Processing
The SNGS shall provide processing of forward test service signals received from TDRS spacecraft or via IF loop.
Rationale: Current Capability that is needed to perform EET testing without a user satellite.

SGSS.002513 Forward Test Service Compatibility
The SNGS shall receive and process forward test service signals which comply with user service RF, IF, and baseband signal specifications.
Rationale: Needed to simulate the full set of Supported User Satellites forward signals.

SGSS.002514 Forward Test Service Configurable Parameters
The SNGS shall allow configuration of user platform G/T, frequency and polarization for the forward test service as defined in Table 7.2-1.

Table 7.2-1 Forward OTS Service Performance Requirements

Parameter	Requirement		
	S-Band	Ku-Band	Ka Band
Center Frequency Range (receive)	2041 MHz to 2118 MHz	13,772.9 MHz to 13777.1 MHz	22.555 GHz to 23.545 GHz in
	Adjustable in 1.0 Hz steps [1]	adjustable in 1.0 Hz steps	5.0 MHz steps
Minimum RF and IF EET Signal Channel 3 dB Bandwidths	20 MHz	50 MHz	50Mz
External IF Output Interface Center Frequency	370 MHz	370 MHz	370 or 1200MHz
Antenna Polarization	RCP or LCP, selectable via command	RCP or LCP, selectable via command	RCP or LCP, selectable via command
Antenna Axial Ratio	<=1.5dB	<=1.5dB	<=3dB
(G/T), over receive frequency range, under clear sky and no-wind conditions. [2]	-50 to +10 dB/°K, minimum range, adjustable in 1.0 dB steps	-27 to +21 dB/°K, minimum range, adjustable in 1.0 dB steps	-35 to +20 dB/K , minimum range, adjustable in 1.0 dB steps
other signal characteristics; values shown are in dB's (maximum) from theoretical Eb/No for the listed BER points) - Under Gaussian White Noise Conditions Only - Uncoded	BER Loss @ 10^{-5} 1.5 @ 10^{-6} 1.6 @ 10^{-7} 1.7	BER Loss @ 10^{-5} 1.5 @ 10^{-6} 1.6 @ 10^{-7} 1.7	BER Loss @ 10^{-5} 1.5 @ 10^{-6} 1.6 @ 10^{-7} 1.7
Signal Acquisition Probability and Time [3]	Pacq ≥ 0.90 within ≤ 10 seconds for C/No equal to that required for uncoded PE = $10^{-2.}$	Pacq ≥ 0.90 within ≤ 10 seconds for C/No equal to that required for uncoded PE = 10-2.	Pacq ≥ 0.90 within ≤ 10 seconds for C/No equal to that required for uncoded PE = 10-2.
Gain Flatness	± 0.4 dB over ± 7.0 MHz	± 0.4 dB over ± 17.5 MHz	≤ 0.6 dB (peak-to-peak) over ± 17.5 MHz about the center frequency
Gain Slope	± 0.1 dB/MHz over ± 7.0 MHz	± 0.1 dB/MHz over ± 17.5 MHz	≤ 0.1 dB/MHz over ± 17.5 MHz about the center frequency
Phase Linearity	± 4.25° over ± 7.0 MHz	± 4.25° over ± 17.5 MHz	≤ 4° (peak-to-peak) over ± 17.5 MHz about the center frequency
Spurious Outputs	≥ 30 dBc over ± 10.0 MHz	≥ 30 dBc over ± 25.0 MHz	≤ - 30 dBc total composite in-band over ±17.5 MHz about the center frequency
Phase Noise	For 1 – 10 Hz, <1.5° rms	For 1 – 10 Hz, <1.5° rms	For 1 – 10 Hz, <2.13° rms
	10 – 32Hz, <1.5° rms	10 - 32Hz, <1.5° rms	10 - 32Hz, <2.13° rms
	32 – 1KHz <3.9° rms	32 – 1KHz <3.9° rms	32 – 1KHz <3.9° rms
	1KHz – 10MHz <1.0° rms	1KHz – 25MHz <2.0° rms	1KHz – 50MHz <1.52° rms
Spurious PM	≤ 1.22 degrees rms	≤ 1.22 degrees rms	≤ 1.22 degrees rms

NOTES:
[1] The required forward service Test Services frequency range excludes valid Customer forward service frequencies from 2030.0 MHz to 2041 MHz in order to preclude interference from TDRS S-band command signals radiated from the same ground terminal.
[2] Specified G/T includes radome losses if a radome is utilized.
[3] Time to acquire includes PN code synchronization (if applicable), carrier synchronization, and bit synchronization, and is measured from the instant the input signal meets the required minimum C/No. Deinterleaving delays are excluded from the acquisition time requirements.

Rationale: These are the minimum performance parameters to meet User service constraints.

SGSS.002515 Forward Test Service Baseband Output
The SNGS shall provide baseband signals as an output from forward test services.
Rationale: This is an existing capability for test source selection.

SGSS.002516 Forward Test Service IF Output
The SNGS shall provide IF as an output from forward test services.
Rationale: This is an existing capability for test source selection.

SGSS.002517 Forward Test Service IP Output
The SNGS shall provide IP as an output from forward test services.
Rationale: Provides access to a remote user for test service

SGSS.002518 Forward Test Service Data Destination
The SNGS shall make forward test service data available to local test equipment, remote SN Users, and User Local Equipment.
Rationale: Current Capability that is needed to deliver demodulated forward simulated or BER data to various elements for processing.

SGSS.002519 Forward Test Service BERT
The SNGS shall measure BER for received forward test service BER test pattern data.
Rationale: Current Capability that is needed to determine performance during SN internal end-to-end testing.

SGSS.002520 Forward Test Service G/T Calibration
The SNGS shall provide self-calibration of forward test service G/T.
Rationale: Current Capability that is needed to control input noise level for proper link margin and BER measurements.

SGSS.002541 Forward Test Service Performance
The SNGS shall meet the performance specifications for the Forward Test services as defined in Table 7.2-1.
Rationale: The SN must maintain at least the performance provided by the legacy system at deployment.

7.3 OTS Return Services

SGSS.002521 Return Test Service Data Source
The SNGS shall process return test service data from local test equipment, remote SN Users, and User Local Equipment.
Rationale: Current Capability that is needed to provide simulated or BER data from various sources for modulation.

SGSS.002522 Return Test Service Baseband Input
The SNGS shall accept baseband signals as an input to return test services.
Rationale: This is an existing capability for test source selection.

SGSS.002523 Return Test Service IF Input
The SNGS shall accept IF signals as an input to return test services

Rationale: This is an existing capability for test source selection.

SGSS.002524 Return Test Service IP Input
The SNGS shall accept IP as an input to return test services
Rationale: Provides access to a remote user for test service

SGSS.002525 Return Test Service Signal Processing
The SNGS shall process and transmit return test service signals to specified test service antennas.
Rationale: Current Capability that is needed for EET testing without the use of the user satellite.

SGSS.002526 Return Test Service Compatibility
The SNGS shall process and transmit return test service signals which comply with user service RF, IF, and baseband signal specifications.
Rationale: Needed to simulate the full set of User Satellites forward signals.

SGSS.002527 Return Test Service Configurable Parameters
The SNGS shall allow configuration of user platform EIRP, frequency and polarization for the return test service as defined in Table 7.3-1.

Table 7.3-1 OTS Return Service OTS Performance Requirements

Parameter	Requirement			
	(a) S-Band	(b) Ku-Band	(c) Ka-Band 225 MHz service	(d) Ka-Band 650 MHz service
Center Frequency Range (transmit)	*2200 MHz to 2300 MHz adjustable in 1.0 Hz steps (1)*	*15,001.3 MHz to 15005.5 MHz adjustable in 1.0 Hz steps*	*TDRS F8-F10+K = 25.2534 GHz to 27.4784 GHz in 5 MHz steps* *SNIP Plan = 25.60 to 27.35 GHz in .2 GHz steps*	*TDRS F8-F10+K = 25.545 GHz to 27.195 GHz in 5 MHz steps.* *SNIP Plan = NA*
Minimum 3 dB Bandwidths	17 MHz	**260 MHz**	**300 MHz**	**800 MHz**
External IF Signal Input Interface Center Frequency	370 MHz	370 MHz	370 MHz	1200 Mhz
Antenna Polarization	RCP or LCP, selectable via command	RCP or LCP, selectable via command	RCP or LCP, selectable via command	RCP or LCP, selectable via command
Antenna Axial Ratio	<=1.5dB	<=1.5dB	<=3dB	<=3dB
EIRP (2)	-11 to 45 dBW, minimum range, adjustable in 1.0 dB steps	-3 to 61 dBW, minimum range, adjustable in 0.5 dB steps	1 to 66 dbW adjustable in 1dB steps	1 to 66 dbW adjustable in 1dB steps
Gain Flatness	**≤ .71 dB over ± 2.1 MHz if <1.024 Msps; ≤ .66 dB over ± 3.5 MHz if >1.024 Msps**	**≤ 2.2 dB over ± 80 MHz**	**≤ 3.1 dB over ± 230 MHz**	**≤ 3.1 dB over ± 230 MHz**
Gain Slope	≤ .17 dB/MHz	**≤ .15 dB/MHz**	**≤ 0.08 dB/MHz over ± 80 MHz**	**≤ 0.08 dB over ± 230 MHz**

Phase Linearity, deg	≤ 7.07 over 2.1 MHz if <1.024 Msps ; ≤ ± 6.56 over ± 3.5 MHz	**≤ 13.6 degrees over ± 80 MHz**	**≤ 111.62 degrees over ± 80 MHz**	**≤ 1.62 degrees over ± 230 MHz**
AM/PM, deg/DB	≤ 21 if <1.024 Msps; ≤ 18 if >1.024 Msps; ≤ 12 if >1.024 Msps and 8PSK	≤ 8.4°/dB	≤ 6°/dB	≤ 6°/dB
Emission Mask (3)	As defined in S-band Emission Mask Figure 7.3-1	As defined in Ku-band Emission Mask Figure 7.3-2	As defined in Ku-band Emission Mask Figure 7.3-3	As defined in Ku-band Emission Mask Figure 7.3-3
Spurious Outputs	≤ -22.2 dBC if <1.024 Msps; ≤ -27.2 dBC if > 1.024 Msps		≤ - 30.4 dBc total composite in-band over ±80 MHz about the center frequency	≤ - 30.4 dBc total composite in-band over ±230 MHz about the center frequency
Phase Noise (° rms) (for S band, 1st limit if < 1.024 Msps)	1 Hz–10 Hz: ≤ 50 ° rms / ≤ 10.3 ° rms	1 Hz – 10 Hz: ≤ 50.2 ° rms	1 Hz – 10 Hz: ≤ 49.94° rms	1 Hz – 10 Hz: ≤ 49.94 ° rms
	10 Hz – 100 Hz: ≤ 6.2 ° rms / ≤ 3.2 ° rms	10 Hz – 100 Hz: ≤ 0.6 ° rms	10 Hz – 100 Hz: ≤ 9.99° rms	10 Hz – 100 Hz: ≤ 9.99 ° rms
	100 Hz – 1 kHz: ≤ 5.2 ° rms / ≤ 4.7 ° rms	100 Hz – 1 kHz: ≤ 2.7 ° rms	100 Hz – 1 kHz: ≤ 3.6 ° rms	100 Hz – 1 kHz: ≤ 3.6 ° rms
	1 kHz – 6MHz: ≤ 3.1 ° rms / ≤ 2.1 ° rms	1 kHz – 150MHz: ≤ 3.2 ° rms	1 kHz – 150 MHz: ≤ 2.00 ° rms	1 kHz – 400 MHz: ≤ 2.00 ° rms
Spurious PM	<= 2.5 ° RMS	≤ 2° (1 KHz to 150 MHz)	≤ 3.00 degrees (1 kHz to 150 MHz)	≤ 3.00 degrees (1 kHz to 400 MHz)

NOTES:

[1] Return Test Services exempt from requirement to support return signal simulation in frequency range of 2200.0 MHz to 2216.0 MHz during periods when it could interfere with reception of TDRS S-band telemetry at 2205.0 MHz or 2211.0 MHz.

[2] Emission mask requirements are defined at the transmit output of the Test Services antenna.

[3] The emission mask requirements are defined at the transmit output of the Test Service antennas.

[4] The KaSAR upconverter shall operate with a 370 MHz or a 1200 MHz IF.

[5.] KaSAR data rates shall be 0.1 to 300 Mbps.

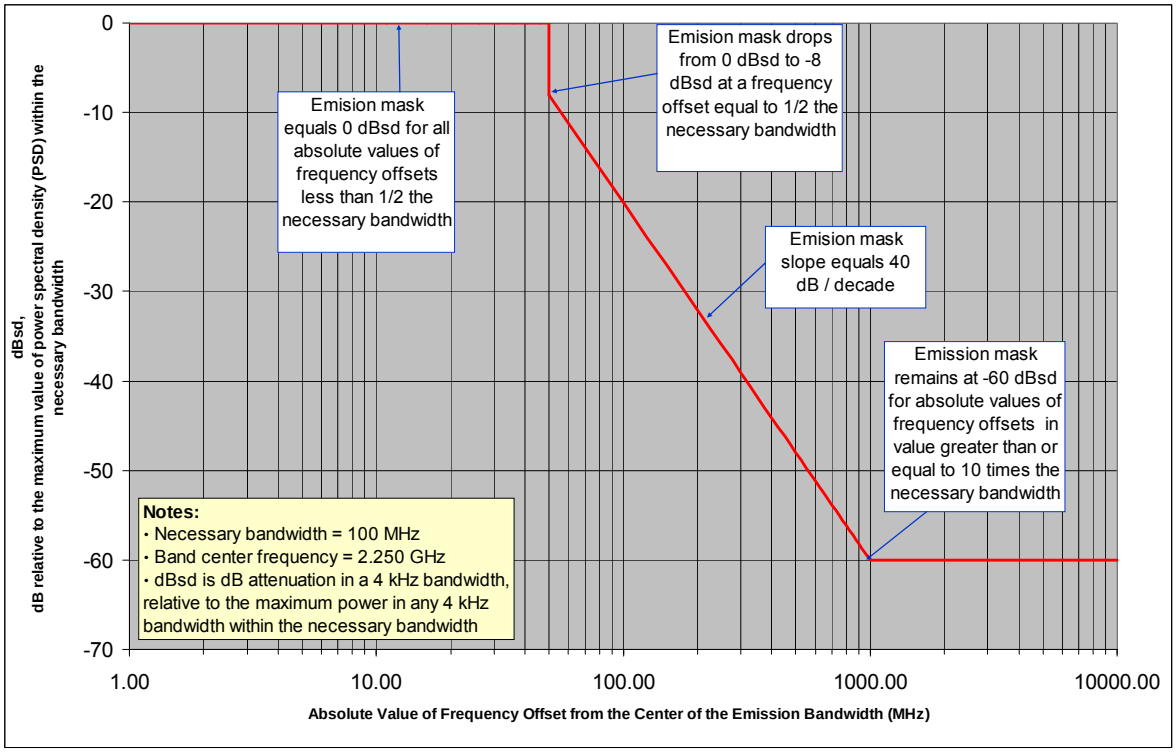


Figure 7.3-1 EET S-Band Emission Mask

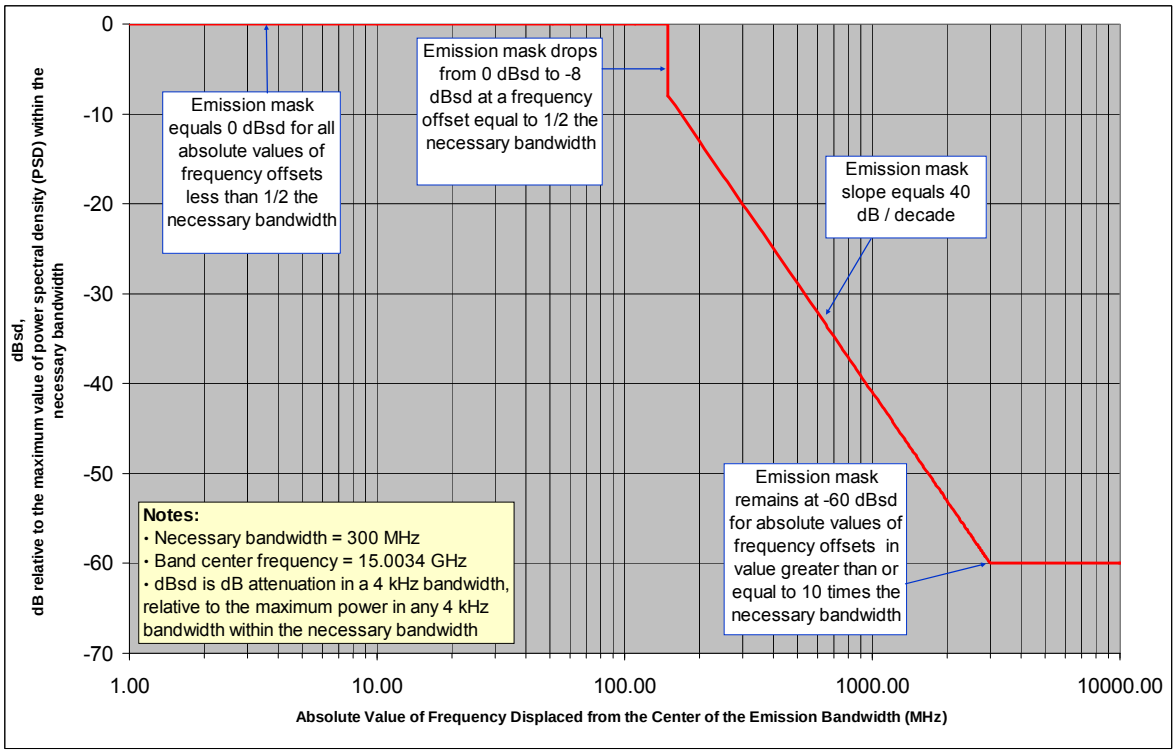


Figure 7.3-2 EET Ku-Band Emission Mask

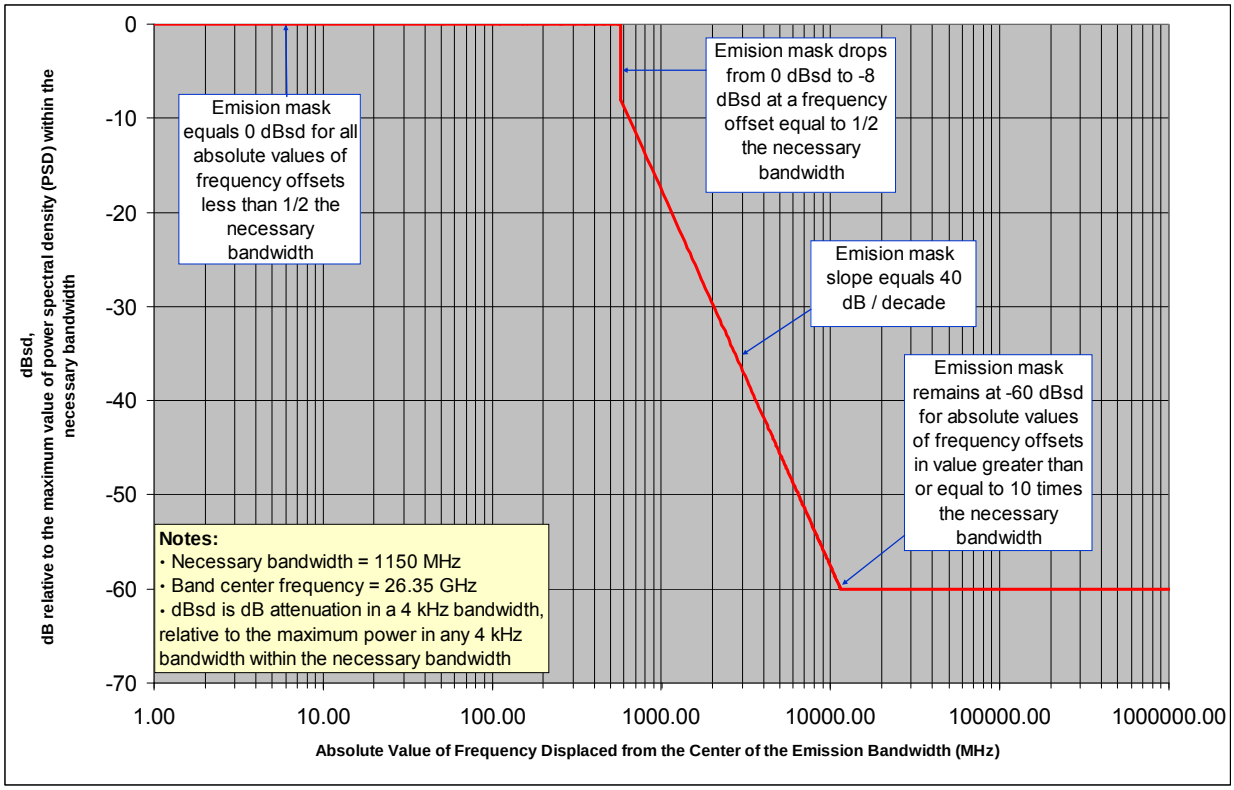


Figure 7.3-3 EET Ka-band Emission Mask

Rationale: These are the minimum performance parameters to meet User service constraints.

SGSS.002528 Return Test Service Self -calibration

The SNGS shall provide self-calibration of all components up to and including the power amplifier, to produce the desired Effective Isotropic Radiated Power (EIRP) from the antenna.

Rationale: Current Capability. Needed to accommodate variations in the system gain/loss to control EIRP level for proper link margin and BER measurements.

SGSS.002529 Return Test Service signal TT&C Interference mitigation

The SNGS shall prevent return test service from radiating at frequencies from 2200 MHz to 2216 MHz.

Rationale: Current Capability that is needed to preclude interference with TDRS S-band command signals radiated in close proximity.

SGSS.002530 Return Test Service BERT

The SNGS shall generate BER test pattern data for modulation on return test services.

Rationale: Current Capability that is needed to determine performance during SN internal end-to-end testing.

SGSS.002531 Return Test Service CW Signal

The SNGS shall provide the capability to transmit a Continuous Wave (CW) signal on all return test services.

Rationale: Current Capability that is needed for link calibration.

SGSS.002540 Return Test Service Performance

The SNGS shall meet the performance specifications for the Return Test Services as defined in Table 7.3-1.

Rationale: The SN must maintain at least the performance provided by the legacy system at deployment.

Section 8. SN Service Management

8.1 Remote User Service Management Interface Support

8.1.1 SN User Profiles

SGSS.003001 Service Agreement Ingest
The SNGS shall ingest User Service Agreements.
Rationale: User service agreements bound SN services and resources that can be requested by a particular SN User.

SGSS.003064 Service Agreement Storage
The SNGS shall store SN User Service Agreements.
Rationale: Storage of SN User service agreements is needed so that they can be accessed later.

SGSS.003089 Service Agreement Modification
The SNGS shall allow operators to modify SN User Service Agreements.
Rationale: Modification of SN User service agreements is needed to accommodate changing SN service needs of the User or the SN.

SGSS.003090 Service Agreement Viewing
The SNGS shall allow SN Users and Operators to view User Service Agreements.
Rationale: The viewing of User service agreements aid the SN Users and Operators in understanding the amount and types of services available to each SN User.

SGSS.003091 Mission Planning Support
The SNGS shall support service planning to support mission design and planning from pre Phase-A through Phase-E.
Rationale: Integration of mission planning into the SNGS will allow NIMO to fully develop User Service Agreements and to explore the range and configuration of SN services for each SN User mission.

SGSS.003003 SN User Profile Modification
The SNGS shall allow operators to create SN User profiles.
Rationale: Operators require the capability to create SN User profiles. The capability to create SN User Profiles is restricted to SN operators for authorization reasons.

SGSS.003004 SN User Profile Deletion
The SNGS shall allow operators to delete SN User profiles.
Rationale: Operators require the capability to delete SN User profiles. The capability to delete SN User Profiles is restricted to SN operators.

SGSS.003005 SN User Profile Modification
The SNGS shall allow operators to modify SN User profiles.
Rationale: Operators require the capability to modify SN User profiles.

SGSS.003006 SN User Profile Storage
The SNGS shall store SN User profiles.
Rationale: Storing User profiles facilitates User service scheduling and allows the SN to provide a default set of service parameters.

SGSS.003007 SN User Profile Management
The SNGS shall allow SN Users to modify their own SN User Profile within the constraints of their User Service Agreement.
Rationale: SN Users require the ability to modify their own default service parameters.

SGSS.003008 SN User Profile Validation
The SNGS shall validate SN User Profiles parameters against the corresponding User Service Agreement.
Rationale: SN User Profile parameters are bound by the performance envelope agreed upon and documented in the User Service Agreement

8.1.2 Service Request Ingest

SGSS.003002 Access Restricted to Authorized SN Users
The SNGS shall allow only authorized users for a mission to plan, request, schedule, and manage the use of network services for that mission.
Rationale: Requests for SN service must originate from authorized SN Users and be constrained to SN User specific authorized resources as specified in the SN User Profile.

SGSS.003009 User Service Request Validation
The SNGS shall validate SN User Service Requests.
Rationale: The SN is a service provider which responds to requests for tracking and data relay services required in the future and in near-real-time. Service requests must be validated upon receipt. Only valid service requests are accepted into the SNGS.

SGSS.003074 Combining Service Requests
The SNGS shall allow SN Users to request a combination of SN services in a single service request.
Rationale: A single request typically includes a request for forward, return and tracking services.

SGSS.003095 Return Service Array Scheduling
The SNGS shall allow Users to schedule multiple simultaneous return services on one (1) or more TDRS spacecraft within view for a given return contact.
Rationale: This is required to support arraying.

SGSS.003013 User Service Request Modification
The SNGS shall allow SN Users to modify their accepted SN service requests.
Rationale: SN Users must be able to modify their already accepted service requests in response to changing mission requirements. This requirement pertains to individual service parameters, as well as the entire request.

SGSS.003014 User Service Request Replacement
The SNGS shall allow SN Users to replace their accepted SN service requests.
Rationale: SN Users must be able to replace an accepted service request in response to changing mission requirements. This requirement pertains to an entire request.

SGSS.003015 User Service Request Deletion
The SNGS shall allow SN Users to delete their accepted SN service requests.
Rationale: SN Users must be able to delete an accepted service request in response to changing mission requirements. This requirement pertains to an entire request.

SGSS.003016 User Service Request Receipt Notification
The SNGS shall generate an acknowledgement for every SN User service request received.
Rationale: SN Users must have acknowledgement that their service request has been received by the SNGS.

SGSS.003017 User Service Request Modification Notification
The SNGS shall notify service requestors upon change of state of their received service request.

Rationale: SN Users, as owners of their request, need insight into the state of their schedule requests.

SGSS.003018 Operator Service Request Modification
The SNGS shall allow operators to modify any aspect of an SN service request.
Rationale: Operators are required to have control of scheduling functions in response to User arbitration, operational events and services, and in response to anomalies.

SGSS.003019 Maintenance Scheduling
The SNGS shall process SN maintenance schedule requests.
Rationale: The SN must add preventative and corrective maintenance activities to the general SN schedule so impacted resources are not allocated for SN services.

SGSS.003020 Cross-Support Service Requests
The SNGS shall allow processing of cross-support service requests.
Rationale: SN offers cross support services to users and must process requests for those services. Cross support means us of MA and SSA service together in one event.

SGSS.003021 Legacy Format Request Processing
The SNGS shall process SN service requests received in legacy formats.
Rationale: The SN must continue to support legacy Users if the User cannot or will not move to a new interface. This function will not be available to new Users.

SGSS.003022 CCSDS SM Request Processing
The SNGS shall process SN service requests received in Consultative Committee for Space Data Systems (CCSDS) Service Management (SM) format as defined in CCSDS 910.11-B-1.
Rationale: The SN is supporting CCSDS SM interfaces and must provide the capability to process messages received in CCSDS-compliant formats.

SGSS.003023 Playback Service Requests
The SNGS shall process CCSDS SLE return service (offline mode) playback requests.
Rationale: SN offers recorded data playback services to users and must process requests for those services.

SGSS.003024 User Test Service Requests
The SNGS shall process User test service requests.
Rationale: SN offers test services to users and must process requests for those services.

SGSS.003072 Operator Service Requests
The SNGS shall allow operators to submit service requests for operational activities that impact the use of SN resources.
Rationale: Operators may need to request SN resources for operational activities, such as TDRS station keeping maneuvers, during which no User services should be scheduled. Operational activities may include the need for multiple events and services.

SGSS.003026 Request Processing Performance
The SNGS shall ingest service requests within 1 second of receipt.
Rationale: In order to provide a robust scheduling system, the SN must provide the capability to validate and accept SN service requests at the rate specified.

SGSS.003065 Service Request Submission Deadline
The SNGS shall allow SN Users to submit valid service requests no later than 10 minutes before the start of the requested service.
Rationale: This constraint on the legacy system in the SNUG is, “no closer than 10 minutes”, which accounts for timing driven by manual activities and current operational procedures. A modern solution to scheduling should not increase this 10 minute buffer and may lower it. The lower limit to this buffer is not established by service request processing. The longest mechanical lead times are imposed by service

request changes that add an SA antenna to the service. This may require greater than 120 seconds for extended SA antenna field of view support.

SGSS.003073 Event Modification Deadline
The SNGS shall allow SN Users to submit valid service event modification requests no later than 5 minutes before the start of the requested service.
Rationale: This constraint on the legacy system in the SNUG is, "no closer than 5 minutes", which accounts for timing driven by frequent manual activities and current operational procedures. If the service event modification adds an SA antenna resource greater than 120 seconds may be required to slew the antenna prior to acquisition start up.

SGSS.003066 Early Service Request Submission
The SNGS shall accept SN Service requests up to 3 months prior to requested service start time if the start time can be predicted to within 1 minute in 3 months.
Rationale: Three months in advance is a reasonable limit for some users with highly controlled or predictable orbits. Inaccurate prediction of the service start times by multiple users or one user should not cause excessive rescheduling activity.

8.1.3 Service Request Processing

SGSS.003010 Service Request Processing
The SNGS shall process SN User service requests.
Rationale: SN offers services to users and must process requests for those services.

SGSS.003025 Operator Service Scheduling
The SNGS shall allow operators to schedule operational activities that impact the use of SN resources.
Rationale: Operators need to schedule operational activities, such as TDRS station keeping maneuvers, during which no User services should be scheduled. Operational activities may include the need for multiple events and services.

SGSS.003027 Scheduled Event Replacement
The SNGS shall allow SN Users to replace their scheduled events.
Rationale: SN Users must be able to replace scheduled events in response to changing mission requirements. This requirement pertains to an entire event.

SGSS.003028 Scheduled Event Deletion
The SNGS shall allow SN Users to delete their scheduled events.
Rationale: SN Users must be able to delete scheduled events in response to changing mission requirements. This requirement pertains to an entire event.

SGSS.003029 Scheduled Event Modification
The SNGS shall allow SN Users to modify their scheduled events.
Rationale: SN Users must be able to modify scheduled events in response to changing mission requirements. This requirement pertains to individual service parameters, as well as the entire event.

SGSS.003030 Schedule Request Storage
The SNGS shall store schedule requests.
Rationale: Storing schedule requests allows for schedule generation, analysis and anomaly resolution.

8.1.4 Service Planning Aids

SGSS.003031 FDF Schedule Planning Aids
The SNGS shall make available Flight Dynamics Facility (FDF) planning aids to SN users.
Rationale: This information allows SN Users to predict periods of contact with each TDRS.

SGSS.003032 User-Defined Scheduling Parameters
The SNGS shall allow Users to define SN service tasks and unique User-defined resource constraints as a method for requesting SN services during the schedule planning period.
Rationale: This gives the SNGS improved flexibility to adjust SN resource allocation times within the User's constraints, TDRS Scheduling Windows (TSWs) provide some of this functionality in the existing system. This will result in fewer request declines, less negotiation between the SN and Users, and improve SN resource loading.

SGSS.003033 MI Schedule Planning Aids
The SNGS shall make Mutual Interference (MI) planning aids available to SN users.
Rationale: This information allows SN Users to schedule around periods of MI that are either restricted or could degrade service performance.

SGSS.003034 RFI Schedule Planning Aids
The SNGS shall make RF Interference (RFI) planning aids available to SN users.
Rationale: This information allows SN Users to schedule around periods of RFI that are either restricted or could degrade service performance.

SGSS.003096 Hypothetical Scheduling Scenarios
The SNGS shall allow the use of historical scheduling input data to run hypothetical scenarios of different scheduling options.
Rationale: SN Users and operators must be able to analyze the impacts of changes to schedule inputs on forecast schedules.

8.2 SN Resource Scheduling

SGSS.003037 Conflict Free Schedule Generation
The SNGS shall generate conflict-free SN service schedules based on SN service requests and available SN resources.
Rationale: The SN must generate a conflict-free schedule to prevent over allocation of resources and to prevent service loss due to overlapping requests.

SGSS.003067 Schedule Optimization
The SNGS shall generate optimized SN service schedules.
Rationale: Optimization is necessary to maximize the use of SN resources.

SGSS.003038 Scheduling Priorities
The SNGS shall use pre-defined priorities as an aid to resolve scheduling conflicts.
Rationale: Prioritizing requests allows the SN to make logical decisions about which requester gets what services in the event of a conflict.

SGSS.003092 Service Agreement Envelope
The SNGS shall manage the provision of standard services in support of all missions based on applicable service agreements.
Rationale: To provide agreed upon services to all SN Users, the SNGS must enforce agreed upon limits for use of SN resources for each User.

SGSS.003039 Service Impact Notification
The SNGS shall notify service requestors upon change of state of their scheduled event within 1 minute of the change.
Rationale: SN Users require this knowledge in order to re-schedule services.

SGSS.003040 User Specific Schedules
The SNGS shall provide schedules to SN Users only for their scheduled events.

Rationale: SN service requestors need to have insight into SN service requests that have been scheduled or rejected in the Active and Operational scheduling phases. An event contains one or more scheduled SN services. An event is continuous between the start and stop time. These schedules also include the general TDRS Unscheduled Time (TUT) time periods available within the schedule timeframe.

SGSS.003041 TDRS Unscheduled Time
The SNGS shall maintain and make available the TDRS Unscheduled Time (TUT) during the Active and Operational scheduling phases.
Rationale: TUT allows SN Users to identify time periods during which specific SN resources are not in use.

SGSS.003075 Exclusion of any TDRS from TUT
The SNGS shall provide the operator with the capability to exclude any TDRS from the general TUT information.
Rationale: The SN should not publish TUT information on SNE dedicated resources. The exclusion of TDRS resources from the general pool of resources may be needed for security reasons or for general availability.

SGSS.003043 Operator Scheduled Service Request Modification
The SNGS shall allow SN operators to modify any aspect of a scheduled event.
Rationale: Operators are required to have control of scheduling functions in response to User arbitration, operational events, and in response to anomalies.

SGSS.003044 Resource and Service Constraint Validation
The SNGS shall validate service requests against SN resource constraints.
Rationale: The SN must be able to prevent the allocation of services to unavailable or restricted resources.

SGSS.003045 Resource Allocation
The SNGS shall assign SN resources to SN services.
Rationale: Resources must be allocated to services to prevent over allocation of resources or over scheduling of services.

SGSS.003068 Pre-Service Configuration Time
The SNGS shall determine and include pre-service configuration time in every scheduled event.
Rationale: SN resources require set up time to support user services.

SGSS.003076 Post-Service Configuration Time
The SNGS shall determine and include post-service processing and delivery time in every scheduled event.
Rationale: SLE services require ground resources to provide post processing and data delivery after the communication link with a TDRS and user platform has ended.

SGSS.003046 Scheduled SN Resource Availability Change
The SNGS shall generate new Active and Operational schedules when changes to SN resources impact scheduled services.
Rationale: SN resources may need to be removed from the operational list of available resources. Regeneration of the schedule allows the SN to notify Users if their service has been impacted by the change in resource status.

SGSS.003048 Schedule Storage
The SNGS shall store SN schedules.
Rationale: The SN must store schedules for planning purposes, execution, analysis and anomaly resolution.

SGSS.003077 Scheduling Phase Boundaries
The SNGS shall allow operators to set boundaries between the Planning, Active, and Operational scheduling phases.
Rationale: SN operators require the ability to define an offset relative to the active timeline for each of the scheduling phases.

SGSS.003078 Automatic Scheduling Lockout
The SNGS shall allow operators to temporarily suspend automatic scheduling of requests for a specified time period on the schedule during the Active and Operational scheduling phases.
Rationale: It is important that only selected schedule requests are included when performing batch scheduling.

SGSS.003079 Batch Schedule Generation Performance
The SNGS shall generate an SN schedule containing 150 service requests within 10 seconds during the Active and Operational phases.
Rationale: Processing this number of requests in 10 seconds is within the bounds of current technology and provides the schedules in a timely manner. 150 service requests is an approximate number of once per orbit acquisitions for tracking and data relay from 30 users occurring in 6 hours.

8.2.1 Planning Phase Scheduling

SGSS.003094 Retransmission Requests
The SNGS shall process service status message retransmission requests.
Rationale: The SN must be able to respond to Users requiring retransmission of status information.

SGSS.003049 Planning Schedule
The SNGS shall generate SN service planning schedules.
Rationale: The SN must generate a planning schedule to maximize the scheduling of service requests. This gives an SN operator lead time to negotiate and reschedule conflicting service request(s) with SN Users as early as possible, reducing the impact on affected SN Users.

SGSS.003080 Advanced SN Resource Schedule
The SNGS shall provide the schedule of SN resources unavailable for use by SN Users during the Planning phase X (configurable) days prior to the event execution timeline.
Rationale: SN Users need to know the availability of SN resources early in the planning phase so that they don't try to schedule already committed resources.

SGSS.003050 Planning Schedule Generation Performance
The SNGS shall generate an SN schedule containing 4000 service requests covering a 1 week period within 3 minutes during the planning phase.
Rationale: 4000 is the typical number of service requests received for a week from 30 Users . Processing this number of requests in 3 minutes is within the bounds of current technology and provides the schedules in a timely operationally responsive manner.

SGSS.003051 Allow Multiple Planning Schedules
The SNGS shall allow the creation of multiple planning schedules with overlapping timeframes.
Rationale: SN scheduling operators need to have the ability to create an ensemble of planning schedules in order to determine the most effective initial forecast schedule.

SGSS.003052 Planning Schedule Selection
The SNGS shall allow selection of a Planning schedule to be added to the Active schedule.
Rationale: SN scheduling operators need to have the ability to select a group of scheduled event and add them to the Active schedule, thus changing the state of all scheduled and rejected service requests covered in the selected timeframe.

SGSS.003081 Routine Service Requests Notification
The SNGS shall generate schedule request confirmation or denial to SN Users for all schedule requests within the Planning schedule timeframe when a Planning schedule has been incorporated into the Active schedule.
Rationale: The promotion of a selected Planning schedule effectively moves schedule events onto the Active schedule. Notification to SN Users is needed to convey whether or not each schedule request has made it into the Active schedule. The SN Users require this to plan their operational activities.

SGSS.003069 Schedule Evaluation
The SNGS shall allow quantitative evaluation of planning schedules.
Rationale: Algorithms may be used to quantify the "goodness" of a given schedule.

SGSS.003070 Manual Schedule Generation
The SNGS shall allow manual control of the schedule generation processes.
Rationale: The level of automation should be controllable, interruptible, and complementary to manual actions.

SGSS.003082 Valid Service Request Confirmation
The SNGS shall provide confirmation of a valid or invalid service request within 10 minutes.
Rationale: Users require timely responses to allow for efficient mission operations.

8.2.2 Active Phase Scheduling

SGSS.003053 Active Schedule
The SNGS shall update the Active schedule as service requests or event modifications are received.
Rationale: The SN must update the Active schedule to allow rescheduling of rejected service requests. This gives the requester some lead time to negotiate and reschedule an SN service request. There may be more than one Active schedule available, but each will not have overlapping timeframes.

SGSS.003083 Active Phase Batch Scheduling
The SNGS shall allow operators to perform batch schedule generation during the Active phase.
Rationale: Due to emergency requests or SN resource failures, the operators will at times require the ability to rework significant portions of the Active schedule.

SGSS.003054 Active Phase Service Event Status
The SNGS shall generate status notifications for changed SN service events in the Active scheduling phase.
Rationale: The SNGS must notify SN Users of the status of scheduled events.

SGSS.003055 Active Schedule Generation Performance
The SNGS shall generate an updated SN schedule during the Active scheduling phase within 10 seconds of initiation.
Rationale: The SN must generate updated Active schedules in a timely manner to keep Users and operators informed of the latest status. 10 seconds is within the bounds of current technology for the amount of data to be processed during Active schedule generation.

SGSS.003084 Service Request Response Performance in the Active Phase
The SNGS shall respond with schedule confirmation or denial to mission service schedule requests within 1 minute of receipt during the Active scheduling period.
Rationale: SN Users must be notified in a timely manner of the scheduling status of their requests during the Active scheduling timeframe. This is especially important for emergency requests.

SGSS.003056 Active Schedule Promotion
The SNGS shall allow promotion of an Active schedule into an Operational schedule.

Rationale: SN scheduling operators need to have the ability to incorporate active schedule events into the operational schedule.

SGSS.003085 Scheduled Event Priority
Except for the receipt of emergency and critical service requests, priority shall be given to events already on the Active schedule.
Rationale: Users' plans should not be disrupted unless absolutely necessary.

8.2.3 Operational Phase Scheduling

SGSS.003057 Operational Schedule
The SNGS shall update Operational schedules as requests or modifications are received.
Rationale: The SN must update the Operational schedule to allow rescheduling of rejected service requests. This allows requesters the opportunity to make last minute service requests.

SGSS.003058 Operational Phase Service Event Status
The SNGS shall generate status notifications for changed SN service events during the Operational scheduling phase.
Rationale: The SNGS must notify SN Users of the status of scheduled services.

SGSS.003059 Operational Schedule Generation Performance
The SNGS shall update an SN schedule during the Operational scheduling phase within 1 second of initiation.
Rationale: The SN must generate Operational schedules in a timely manner to keep Users and operators informed of the latest status and allow for scheduling as close to the active timeline as possible. 1 second is within the bounds of current technology for the amount of data to be processed in Operational schedule updates.

SGSS.003087 Service Request Response Performance in Operational Timeframe
The SNGS shall respond to requests with schedule confirmation or denial to mission service schedule requests within 1 minute during the Operational scheduling period.
Rationale: SN Users must be notified in a timely manner of the scheduling status of their requests during the Operational scheduling timeframe. This is especially important for emergency requests.

SGSS.003088 Scheduled Event Priority
The SNGS shall give priority to scheduled events on the Operational schedule with the exception of critical and emergency service requests.
Rationale: Users' plans should not be disrupted unless absolutely necessary.

8.3 Service Accountability and Reporting

SGSS.003060 Service Accounting Data Availability
The SNGS shall make service accounting data available to individual SN Users for provided services.
Rationale: This provides SN Users with service accounting information for services provided including service duration, QOS, etc.

SGSS.003061 Service Configuration Report
The SNGS shall provide an accounting of SN components and resources that supported each SN event.
Rationale: SN Users and the SNGS must know exactly which pieces of equipment provided the service for latency purposes as well as for maintenance and fault detection and isolation.

SGSS.003062 Service Accountability Information
The SNGS shall make service accountability information available for each service instance within 10 minutes of event termination.

Rationale: 10 minutes is a reasonable amount of time to accumulate, process, and make this information available.

SGSS.003063 User Service Performance Data Availability

The SNGS shall make post-service performance data available for each service provided.

Rationale: This is required to allow service requesters to have insight into the performance of a given service. These parameters include User Performance Data (data lock, signal/noise ratio, data quality monitoring (frame sync), etc.), Return Channel Time Delay, Time Transfer Messages, and Acquisition Failure Notification.

SGSS.003071 Scheduling Performance Metrics

The SNGS shall provide scheduling performance metrics.

Rationale: Performance by user and for all the users is necessary for evaluating the Service Management function. Metrics such as scheduled services versus requested services and scheduled versus required are useful to this end.

SGSS.003093 SN Utilization Statistics

The SNGS shall generate utilization statistics including: time committed to services, time committed to maintenance activity, time committed to required testing, time committed to idle time and time committed to service configuration.

Rationale: These statistics are required for loading assessments and provide input to the system optimization process.

Section 9. User Services Gateway

9.1 General Requirements

SGSS.003501 SN Status Message Broadcast
The SNGS shall make network status available to SN Users.
Rationale: These messages are a means of letting users know of any performance constraints associated with the TDRS spacecraft in a timely fashion, which improves User service and is within the bounds of current technology.

SGSS.003502 User Performance Data Messages
The SNGS shall generate UPD messages at a configurable rate of no more than once per second for each ongoing User service during an event.
Rationale: Users need to have access to the information which gives insight into the system's real-time performance in providing services during an event. These messages contain information such as loss-of-lock indications and provide data to verify the level of service received. Planned enhancements to the UPD messages include the addition of the following parameters: Channel Error Rate, Bit Error Rate, Signal to Noise Ratio, C/No, and measured frequency.

9.2 Remote User Service Interface Support

9.2.1 Space Link Extension (SLE) Service Interfaces

SGSS.003503 SLE Forward Command Link Transmission Unit (F_CLTU)
The SNGS shall provide SLE Forward Command Link Transmission Unit (F_CLTU) forward data services as defined in CCSDS Recommendation 912.1-B-2, SLE Forward CLTU Service Specification.
Rationale: The SLE services extend the return Telemetry (TM), forward Telecommand (TC) and forward Advanced Orbiting Systems (AOS) Space Link services defined by CCSDS that are used by many spacecraft operators between ground stations and spacecraft. CCSDS 912.1-B-2 governs the implementation of SLE F_CLTU services for CCSDS-based flight systems.

SGSS.003504 SLE F_CLTU Forward Service Status Reporting
The SNGS shall provide forward service status and statistics to SN Users as defined in CCSDS Recommendation 912.1-B-2 for all SLE F_CLTU Forward Service configurations.
Rationale: CCSDS 912.1-B-2 defines the minimum set of status and statistical information that must be reported to the remote user during a Forward Service provisioning.

SGSS.003505 SLE Return All Frames (RAF) Service
The SNGS shall provide SLE Return All Frames (RAF) return data services as defined in CCSDS Recommendation 911.1-B-2, SLE Return All Frames Service Specification.
Rationale: CCSDS 911.1-B-2 governs the implementation of SLE RAF services for CCSDS-based flight systems and Constellation (Cx) Emergency Communications and Post-Landing Communications requirements specified in CxP 70022-01.

SGSS.003506 SLE RAF Service Status Reporting
The SNGS shall provide status and statistics to SN Users as defined in CCSDS Recommendation 911.1-B-2, SLE Return All Frames Service Specification for all SLE RAF Return Service configurations.

Rationale: 911.1-B-2 defines the minimum set of status and statistical information that must be reported to the remote user during a RAF Return Service provisioning.

SGSS.003507 SLE Return Channel Frames (RCF) Service
The SNGS shall provide SLE Return Channel Frames (RCF) return data services as defined in CCSDS Recommendation 911.2-B-1, SLE Return Channel Frames Service Specification.
Rationale: CCSDS 911.2-B-1 governs the implementation of SLE RCF services for CCSDS based flight systems and Cx Emergency Communications and Post-Landing Communications requirements specified in CxP 70022-01.

SGSS.003508 SLE RCF Service Status Reporting
The SNGS shall provide status and statistics to SN Users as defined in CCSDS Recommendation 911.2-B-1, SLE Return Channel Frames Service Specification for all SLE RCF Return Service configurations.
Rationale: CCSDS 911.2-B-1 defines the minimum set of status and statistical information that must be reported to the remote user during a RCF Return Service provisioning.

SGSS.003509 SLE Return Operational Control Fields (ROCF) Service
The SNGS shall provide CCSDS Return Operational Control Fields (ROCF) services as defined in CCSDS Recommendation 911.5-B-1, SLE Return Operations Control Fields Service Specification.
Rationale: CCSDS 911.5-B-1 defines a CCSDS service to provide users the operational header fields for Master Channel and Virtual Channel frames.

SGSS.003510 SLE Return Service Timely Online Mode
The SNGS shall provide all "Timely Online" mode SLE Return Services as specified in CCSDS Recommendation 910.4-B-2, Cross Support Reference Model, Section 3.4.2.1.2.
Rationale: The "Timely On-Line" mode of SLE return services provides the user the option to receive only the most recent data received, within a specified time window, regardless of any networking delays encountered between the SLE User (remote) and Provider (SNGS) functions. "Timely On-Line" is a standard SLE Return Service optional mode of operation.

SGSS.003511 SLE Return Service Complete Online Mode
The SNGS shall provide all "Complete Online" mode SLE Return Services as defined in CCSDS Recommendation 910.4-B-2, Cross Support Reference Model, Section 3.4.2.1.2.
Rationale: The "Complete On-Line" mode of SLE return services provides the user the option to receive all the data received regardless of any networking delays encountered between the SLE User (remote) and Provider (SNGS) functions. "Complete On-Line" is a standard SLE Return Service optional mode of operation.

SGSS.003512 SLE Return Service Offline Mode
The SNGS shall provide all "Offline" mode SLE Return Services as defined in CCSDS Recommendation 910.4-B-2, Cross Support Reference Model, Section 3.4.2.2.
Rationale: The "Offline" mode of SLE return services provides the option to retrieve return service data at some time after the data has been collected and recorded by the SLE Provider (SNGS) function. This option provides support for retrieving return service Line Outage Recording data in a playback mode to meet Cx Program and other SN user requirements.

SGSS.003513 SLE Provider
The SNGS shall provide SLE Provider functions as defined in CCSDS Recommendation 914.0-M-1, SLE Application Program Interface (API) for Transfer Services - Core Specification.
Rationale: In order to support user MOCs capable of utilizing SLE services, the SNGS must properly implement the SLE Provider function.

9.2.2 IP Gateway

SGSS.003514 IP-based Forward Service
The SNGS shall provide an IP-based forward service.
Rationale: The South Pole TDRSS Relay (SPTR) communications link to the South Pole provides the primary communications path to Antarctica through the SN. The traffic on that link is IP-based and must be supported by the SNGS for the foreseeable future. CxP also requires IP-based services for its operational links to Orion and Ares.

SGSS.003515 IP-based Return Service
The SNGS shall provide an IP-based return service.
Rationale: The SPTR communications link to the South Pole provides the primary communications path to Antarctica through the SN. The traffic on that link is IP-based and must be supported by the SNGS for the foreseeable future. CxP also requires IP-based services for its operational links to Orion and Ares.

SGSS.003516 HDLC Frames Transmission
The SNGS shall allow transmission of HDLC frames via forward link services.
Rationale: Some form of framing is required to transit the SN RF Links, and HDLC provides a commercially supported, standardized and proven frame structure for satellite links, minimizing cost and complexity for SN and the SPTR.

SGSS.003517 HDLC Frames Receipt
The SNGS shall allow receipt of HDLC frames from the SN Return Service link.
Rationale: Some form of framing is required to transit the SN RF Links, and HDLC provides a commercially supported, standardized and proven frame structure for satellite links, minimizing cost and complexity for SN and the SPTR.

9.2.3 Legacy NASCOM 4800 BB Gateway

SGSS.003518 User Datagram Protocol/Multicast (UDP/MC) Service
The SNGS shall provide User Datagram Protocol/Multicast (UDP/MC) services as defined in the WDISC System Requirements document (CSOC-GSFC-RD-002090).
Rationale: Many existing SN Users forward their data via NISN supported UDP/MC IP services. Those users unable to migrate to the SLE service offerings will need to be supported for the duration of their missions.

SGSS.003519 Legacy Messages
The SNGS shall process legacy messages in accordance with 452-ICD-SN/CSM, Interface Control Document between the Space Network and Customers for Service Management and 452-ICD-SN/FDF (TDMs only).
Rationale: SNGS must provide legacy services to those missions which cannot upgrade to the any new message formats. These legacy formats may be phased out for new SN users.

SGSS.003520 Legacy Ground Control Messages (GCMs)
The SNGS shall process Ground Control Messages (GCMs) in legacy formats.
Rationale: The SNGS must provide legacy services to those missions which cannot upgrade to the new message formats. GCMs will probably not be executed in the same manner as with the current SN, and new message types may be defined to support the new services and architecture, but legacy message formats must be accommodated. These legacy formats may be phased out for new SN users.

SGSS.003554 Legacy Tracking Data Messages
The SNGS shall process legacy tracking data messages in accordance with 452-ICD-SN/FDF, Interface Control Document between the Space Network and the Flight Dynamics Facility.
Rationale: SNGS must provide legacy TDM services to those missions which cannot upgrade to the new message formats. These legacy formats may be phased out for new SN users.

9.2.4 Real-Time Reconfiguration Request Interface

SGSS.003521 Reconfiguration of Service Parameters
The SNGS shall allow SN Users to request reconfiguration of Forward or Return Service configurations within operational envelopes defined in User Profiles.
Rationale: SN Users will be allowed to reconfigure certain service configurations (e.g., data rate) within a predefined service envelope as long as the configuration changes do not impact SNGS resources allocations for the service or TDRS flight system configuration changes, which will require monitor and control functions to command the TDRS flight system.

SGSS.003522 Reconfiguration of Tracking Modes
The SNGS shall allow SN Users to request reconfiguration of tracking modes and sample rates.
Rationale: SN Users need to be able to select one of the three tracking modes in Data Group 1, or choose "coherent" or "noncoherent" mode in Data Group 2. Additionally, SN Users need to be able to select the rate at which they receive data samples of range measurements. Once these selections are made, they need the flexibility to make alternate selections while service is being provided by the SNGS.

9.2.5 General CCSDS Service Monitoring

SGSS.003525 Selectable Service Monitoring Rate
The SNGS shall generate cyclic service monitor and performance data at a maximum selectable rate of once per second.
Rationale: CCSDS is in the process of developing a Space Communications Cross Support (SCCS) Service Monitoring service which could provide the over arching architecture for a new, general service monitor capability. Each SN service would have defined status, configuration and performance data available for SN users during service provisioning. Cyclic reporting is a feature of the SCCS Monitor Service concept.

SGSS.003526 On Demand Service Monitoring Messages
The SNGS shall generate in-progress service monitor and performance data upon request.
Rationale: CCSDS is in the process of developing a SCCS service monitoring service which could provide the over arching architecture for a new, general service monitor capability. Each SN service would have defined status, configuration and performance data available for SN users during service provisioning. On Demand reporting is a feature of the SCCS Monitor Service concept in order to provide customers a current snapshot of service status and performance.

9.2.6 Tracking and Clock Correlation Messages

SGSS.003527 Tracking Data Message (TDM) Generation
The SNGS shall generate Tracking Data Messages as defined by CCSDS Recommendation 503.0-B-1, Tracking Data Message.
Rationale: Tracking Services provided by the SN will comply with CCSDS standards for Tracking Data Message contents and formats as defined in CCSDS 503.0-B-1 to promote international interoperability and cross support. Tracking Data Messages are provided to Users, FDF, and others per IRDs.

SGSS.003528 Universal Tracking Data Format (UTDF) Tracking Data Message
The SNGS shall generate Tracking Data Messages as defined by the TDRSS Universal Tracking Data Format (UTDF) as defined by JSC-11534.
Rationale: Adheres to CxP 70118-6 requirements on TDM delivery. This is specifically for CxP and ISS support.

SGSS.003529 User-Configurable TDM Transmission Rate
The frequency of TDM delivery shall be user-selectable rate of between 1 per second and 1 per 5 seconds in 1 second increments.

Rationale: Provides the ability for customers to select the TDM rate best suited to their operational requirements, with a minimal rate which is consistent with Cx Program requirements.

SGSS.003530 Clock Correlation Data Message Generation
The SNGS shall generate Clock Correlation Data messages as defined in User Spacecraft Clock Calibration System Users' Guide (531-TR-001).
Rationale: Clock correlation is necessary for mission operations and required by SN Users. These messages are generated to transfer clock correlation information to SN Users.

9.3 User Data Services

9.3.1 AOS/ENCAP Processing

SGSS.003531 Forward Service ENCAP Processing
The SNGS shall encapsulate IP packets into ENCAP packets as defined in CCSDS ENCAP Recommendation 133.1-B-1.
Rationale: For the Forward Service Cx Operational Links, Cx and SCaN have agreed to use the CCSDS ENCAP protocol to flow IP packets across the RF space links in accordance with CCSDS Recommendation 702.1-R-2(3), IP Over CCSDS. ENCAP is required to meet Cx operational link requirements and provide for international interoperability and cross support.

SGSS.003532 Return Service ENCAP Processing
The SNGS shall extract IP packets from ENCAP packets as defined in CCSDS ENCAP Recommendation 133.1-B-1.
Rationale: For the Return Service Cx Operational Links, Cx and SCaN have agreed to use the CCSDS ENCAP protocol to flow IP packets across the RF space links in accordance with CCSDS Recommendation 702.1-R-2(3), IP Over CCSDS. ENCAP is required to meet Cx operational link requirements and provide for international interoperability and cross support.

9.3.2 Reserved

9.3.3 Real-Time Reconfiguration Request Processing

9.3.4 User Command Echo Service

SGSS.003536 CxP Command Echo
The SNGS shall capture all Forward Service IP packets from the Constellation Program and transmit them back to a unique Constellation IP address within 5 seconds.
Rationale: Constellation has a requirement to 'echo' back command data to the Mission Control Systems. Since SN cannot distinguish between command packets and other forward link packets at the IP layer, all packets will be captured and transmitted back to a mission control application.

9.3.5 Rate Buffering

SGSS.003553 Rate Buffering Service
The SNGS shall provide a rate buffering option on return User services.
Rationale: This service will be provided to allow SN Users to receive data at lower than real-time rates. This is a service currently provided by the Ground Network, and a mission-unique Gamma-ray Large Angle Space Telescope (GLAST) Front End Processor (GFEP) at WSC. It may attract new users that do not have full return service bandwidth to a MOC from WSC or deploy their own equipment at WSC. This will be particularly important to high-rate K-band users, as well as to facilitate moving data between operations facilities.

9.4 User Data Recording

9.4.1 General Requirements

SGSS.003537 Return Data Recording
The SNGS shall record user return service baseband data.
Rationale: The SNGS will record customer return service flows and retain these for later retrieval by the customer MOC to provide a back up capability in case communications between the MOC and SNGS are temporarily down. This capability has historically been referred to as "Line Outage Recording (LOR)".

SGSS.003538 LOR Data Processing
The SNGS shall provide recorded baseband data in the format specified in the User Profile.
Rationale: The recorded baseband data will need to be put into the SN Users' expected format in order for them to use the data.

SGSS.003539 Tracking Data Message Recording
The SNGS shall store user Tracking Data Messages.
Rationale: Meets Cx requirements for providing LOR of TDMs.

SGSS.003540 Clock Correlation Data Message Recording
The SNGS shall store customer Clock Correlation Data Messages.
Rationale: Provides equivalent LOR capability to CCDMs.

SGSS.003542 Status Message Recording
The SNGS shall store Status Messages.
Rationale: Allows SN Users to retrieve Status Messages should they be unable to be delivered in real-time.

SGSS.003543 Retaining Recorded Data
The SNGS shall retain all line outage recorded data for seven days from the time it is made available to the customer MOC.
Rationale: Requirement consistent with the minimum data retention period for the current LOR.

SGSS.003544 Extended Return Data Storage
The SNGS shall enable storage of recorded data for longer than seven (7) days upon request up to maximum of 20% of recorder capacity.
Rationale: This would cover special situations where SN Users need SN Operations to retain their stored data beyond the nominal storage period.

SGSS.003549 Recorded Return Data Availability
The SNGS shall make recorded Return Service data available to SN Users within 10 minutes of service termination.
Rationale: The SNGS will be collecting the Return Service data and can store it as a complete record of the Return Service data flow once the service has terminated.

SGSS.003551 User-configurable Data Request by Date/Time
The SNGS shall allow Users to request recorded baseband data by date and time.
Rationale: Users will be able to request their data based on the SNGS-generated date and time stamp .

SGSS.003552 User-configurable Data Request by Service ID
The SNGS shall allow users to request recorded baseband data by service ID.
Rationale: Users will be able to request their data based on the service ID associated with that data.

9.4.2 Recorded Data Access

SGSS.003545 Recorded Data Retrieval
The SNGS shall allow Users to retrieve recorded return service data.
Rationale: User must be able to retrieve recorded data from the SN.

SGSS.003547 SLE Offline Mode Access
The SNGS shall allow SN Users to retrieve data recorded through the SLE "Off-Line" mode for RCF and RAF services, as defined in CCSDS Recommendation 910.4-B-2, Cross Support Reference Model.
Rationale: Allows for playback of the recorded data through standard SLE service modes.

SGSS.003550 Zero-Impact Data Access
The SNGS shall make recorded return service data available to SN Users without impact to on-going real-time SN Services.
Rationale: Users should be able to access their recorded data as long as their doing so would not hinder nominal system operations.

Section 10. Fleet and Ground Management

10.1 Command and Control

SGSS.004001 Ground System Flexibility
The SNGS shall allow the addition and deletion of monitored SN components without requiring application software changes.
Rationale: Changes to SN resources should not require changes to code in order to expand or reduce the scope of operational functions.
SGSS.004002 Space Segment Diversity and Evolution
The SNGS shall be capable of supporting the full suite of operation activities required to operate all TDRS spacecraft currently on-orbit and under development.
Rationale: The TDRS fleet is not constrained to one spacecraft provider. For example, the SNGS must support the first two generations of spacecraft currently flying and TDRS K/L which are currently being developed.
SGSS.004003 Automation Control
The SNGS shall allow automated control of SN resources.
Rationale: The response time for the expected scheduled service traffic cannot be reliably supported by manual operations. Currently service configuration control is automatic while non-service control includes many high risk manual processes that are candidates for risk reduction by automation. (Ref. TDRS 3 and TDRS 9 IRT Reports.)
SGSS.004131 Manual Control
The SNGS shall allow manual control of SN resources.
Rationale: Although automated processes can improve efficiency and reliability of execution, when automated systems fail due to software deficiencies, misconfiguration, poor timing, etc., the operators must have the ability to reconfigure components to establish service even if those methods are not preferred for normal operations. This includes automation for both space and ground components.
SGSS.004132 Automation Level Control
The SNGS shall allow operators to set the level of automated operation of SN resources.
Rationale: Automated logic relies upon data and control logic to successfully execute. The system should allow the operator to control the rate at which logic steps through its procedures, examine the current state and to the extent that it is feasible and safe, allow the operator to alter the command directives pre-programmed by the automation. The specifics of what is possible will likely vary depending upon the SN resource. However, the user should be able to select a level of automation from minimal to maximum as appropriate.
SGSS.004004 Operator Confirmation For Automated Actions
The SNGS shall allow operators to define and set decision points in automated processes.
Rationale: Hazardous and critical activities require operator authorization to proceed. Failsafe checkpoints must be able to be defined for these authorizations to be provided. Authorizations can be one or two step confirmations depending on the criticality or hazard level of the automated actions.
SGSS.004005 Operator Override of User Actions
The SNGS shall allow operators to reproduce any User-initiated action.
Rationale: Operator override of automated actions and resumption of the procedure in a controlled manner is required to ensure the safety of the SN assets.
SGSS.004006 Designation of Hazardous/Critical Commands
The SNGS shall allow definition of special handling for hazardous and critical commands and logic.

Rationale: Certain commands or automated procedures can be potentially hazardous to the health and safety of SN resources and human beings. These commands need to be identified so that special handling (e.g., audible alerts, visual cues, two stage operator confirmation, restricted authorization to execute, etc) may be associated with their execution.

SGSS.004133 TDRS Telemetry Tracking & Command (TT&C) Processing

The SNGS shall process TDRS telemetry and commands as defined in TDRS RF ICDs (TDRS F1-F6 RF ICD STDN 220.29; TDRS F-7 ICD for the TDRS Spacecraft/Ground Segment (10/1993) 405-F7-ICD-001; TDRS F8-F10 RF ICD DS80409-H00-003 Rev D; and TDRS K Program Spacecraft/Ground Segment RF ICD 454-KP-SYS-ICD-001).

Rationale: Processing TDRS telemetry and commands is essential to SNGS operation.

SGSS.004007 Designation of Hazardous/Critical Automated Logic

The SNGS shall allow definition of automated logic functions upon execution of designated commands.

Rationale: As certain commands may be deemed hazardous or critical to health and safety, the system needs to provide a means to associate actions with the execution of commands.

10.1.1 SN Fleet

SGSS.004008 Single TDRS Command Coordination

The SNGS shall coordinate all TDRS commanding.

Rationale: The ground system must coordinate commanding from multiple sources including ground sources and autonomous spacecraft sources.

SGSS.004009 TDRS Command Generation

The SNGS shall generate TDRS spacecraft commands in unencrypted format.

Rationale: TDRS spacecraft commands are required for all spacecraft operations and the encryption is not a requirement of the control function

SGSS.004010 TDRS Command Constraints

The SNGS shall allow definition of command constraints associated with each TDRS spacecraft command and with a block of TDRS spacecraft commands.

Rationale: Some spacecraft commands may require specific initial conditions or may need to be executed without interference from other commands in the system. The system must be capable of defining execution constraints so that command operations may be safely coordinated.

SGSS.004011 Command Load Production

The SNGS shall allow the construction of TDRS command loads.

Rationale: Current and future spacecraft implement commands from tables of commands loaded periodically by the ground segment into the flight computer memory.

SGSS.004012 Command Load Transmission

The SNGS shall allow the transmission and verification of a command load for all applicable flight processors on any TDRS spacecraft.

Rationale: Maintenance of TDRS spacecraft includes occasionally uploading command loads. Command loads are transmitted to the spacecraft, dumped, and then compared to what was sent to verify that it was successfully received.

SGSS.004013 Flight Processor Memory Load Production

The SNGS shall allow for the production of memory loads for all applicable flight processors on any TDRS spacecraft.

Rationale: Volatile RAM is used to store dynamic and static data, control logic, procedures, and patches that are essential to spacecraft operations. The SNGS needs the capability to transmit new tables, FSW patches, etc. to TDRS.

SGSS.004014 Flight Processor Memory Load Transmission

The SNGS shall allow the transmission and verification of a flight processor memory load for all applicable flight processors on any TDRS spacecraft.

Rationale: Maintenance of TDRS spacecraft includes occasionally uploading flight processor memory loads.

SGSS.004016 TDRS Command Verification

The SNGS shall provide the capabilities to verify that TDRS commands have been successfully executed.

Rationale: Safe operation of TDRS spacecraft requires the SNGS to provide capabilities to verify a command (or uplink packet for loads) has been successfully transmitted, received, and executed by the target spacecraft.

SGSS.004017 TDRS Command Logging

The SNGS shall record all commands, command loads and table loads transmitted to TDRS spacecraft.

Rationale: A record of all commands, command loads and table loads must be maintained for each TDRS spacecraft, along with any responses or assessments on the success of the action from the flight system or ground control systems

SGSS.004018 TDRS User Service Antenna Control

The SNGS shall command TDRS F1 through F7 SA and MA antennas in real-time from the ground.

Rationale: SA and MA antenna control for the F1 through F7 spacecraft is a space/ground closed loop process since these spacecraft do not support this activity.

SGSS.004019 S-band TT&C

The SNGS shall allow control of TDRS spacecraft over an S-band RF link.

Rationale: The TDRSs can transmit and receive telemetry and commands respectively on an S-band RF Link.

SGSS.004020 Clear Mode Commanding

The SNGS shall allow switching to unencrypted uplink while using the S-band RF link.

Rationale: The SNGS allows control of the TDRS command receiver and decoder to detect and execute commands that are not encrypted.

SGSS.004021 Ku-band TT&C

The SNGS shall allow control of TDRS spacecraft over a Ku-band RF link.

Rationale: The TDRSs can transmit and receive telemetry and commands respectively on an Ku-band RF Link.

SGSS.004022 Flight Processor Memory Dump

The SNGS shall process TDRS spacecraft memory dumps.

Rationale: The onboard image is transmitted to the ground to verify uploads, diagnose anomalies, examine spacecraft state not normally telemetered, etc.

SGSS.004025 Command Constraint Satisfaction

The SNGS shall validate the construction of commands prior to transmission.

Rationale: Some ground and flight system logic may require specific initial conditions or may need to be executed without interference from other functions in the system. The system must be capable of defining execution constraints so that command operations may be safely coordinated.

SGSS.004120 Single Command Source

The SNGS shall limit commands to any single TDRS spacecraft from a single ground source at any given time.

Rationale: TDRS spacecraft control must come from a single source. Two sources implementing either different automated logic configurations, or being run with different levels of operator control, or running under different configurations, can cause erroneous and hazardous action be taken. Therefore the SNGS must institute a fail safe method to limit command actions for a specific TDRS spacecraft to one source.

SGSS.004121 TDRS Command Constraint Checking

The SNGS shall check that command constraints are satisfied prior to releasing a command or block of commands for transmission to a TDRS spacecraft.

Rationale: When commands or command groups are issued either by operators or automated logic, the system must compare any defined command constraints against the current state of the system to ensure proper and successful execution of the command.

SGSS.004123 Command Transmission Validation Suspension
The SNGS shall allow suspension of command execution validation prior to transmission.
Rationale: There may be times where telemetry validation is not possible and pre-command checks cannot be performed. The system must allow an operator to override these checks and allow commanding "in the blind" in such anomalous conditions.
SGSS.004128 Command Constraint Violation Reporting
The SNGS shall alarm, warn, and notify on command constraint violations.
Rationale: Alarming, warning, and notifying constraint violations prior to transmission of commands is necessary for operator awareness and response.

10.1.2 SN Ground Systems

SGSS.004023 Coordinated Ground Commanding
The SNGS shall coordinate all ground resource commanding.
Rationale: The ground system must coordinate commanding from multiple sources for ground resources.
SGSS.004024 SN Ground System Command Generation
The SNGS shall generate SN Ground System commands in unencrypted format.
Rationale: Encryption is applied when control is extended beyond the local SGSS secure network and is optional within the network.
SGSS.004026 SN Ground System Command Execution Verification
The SNGS shall verify that a command has been successfully executed by an SN Ground Resource.
Rationale: Safe operation of SN Ground Resources requires the SNGS to verify that a command has been successfully executed. This includes both real time commands and stored or delayed commands. If the command execution checks fail the SNGS should treat it as it would any other serious limit violation (e.g., audible alarms, visual cues, alarm messages, etc.).
SGSS.004027 Ground Antenna Control
The SNGS shall control SN ground segment antennas in real-time.
Rationale: All of the ground antennas must be aligned to follow the orbital motion of the TDRSs as viewed from the Earth fixed frame. This motion is applied by the antenna control mechanisms under the direction of the ground system.
SGSS.004028 Ground System Control Logging
The SNGS shall record all configuration information transmitted to SN ground resources.
Rationale: A record of all control messages and configuration loads/data must be maintained for all SN operational ground systems. This excludes non-operational systems such as training systems, office computers, etc.
SGSS.004029 Ground System Data Loading
The SNGS shall allow the loading of data into ground system components.
Rationale: Some ground system components may require the loading of software, firmware, tables, etc.
SGSS.004122 Single Command Source (Ground Resources)
The SNGS shall limit commands to any single ground resource from a single ground source at any given time.
Rationale: Ground resource control must come from a single source. Two sources implementing either different automated logic configurations, or being run with different levels of operator control, or running under different configurations, can cause erroneous and hazardous action be taken. Therefore the SNGS must institute a fail safe method to limit command actions for a specific ground resource to one source.
SGSS.004124 Configuration Transmission Recording
The SNGS shall record status of configurations transmitted to SN ground resources.
Rationale: The results of all control messages and configuration loads/data must be maintained for all SN operational ground systems.

10.1.3 User Services

SGSS.004030 User Service Schedule Processing
The SNGS shall configure SN resources to provide SN services based on the active schedule.
Rationale: The space and ground segment elements and functions are configured to provide user specific tracking and data relay service between a designated start and stop time for multiple users of the SN.
SGSS.004031 Parallel User Service Support
The SNGS shall ensure pre-service configuration activities do not interfere with other services in progress.
Rationale: SN supports multiple user services in parallel and must ensure services do not conflict with each other. For example, the re-pointing of an SA antenna must be executed without perturbing the attitude of the spacecraft to degrade other services. The SNGS control system must provide the capability to check and verify service execution is not performed in a manner that can disrupt other services.
SGSS.004033 Automated Service Control
The SNGS shall allow autonomous control of SN service configurations.
Rationale: SN Service control and monitoring may be executed as specified by the operational schedule without operator intervention, including scheduled "in-service" configuration changes.
SGSS.004034 User Control Of SN Services
The SNGS shall process in-progress service change requests by SN Users in an automated manner.
Rationale: Many aspects of the SN Service may be controlled by the SN User (e.g., link rate, status reporting rate) within a predefined and validated service resource envelope. The SNGS must allow users to control these parameters and service functions without requiring operator intervention. SN Users may make multiple service change requests during an in-progress service.
SGSS.004035 User Service Constraint Validation
The SNGS shall validate all service configurations and changes against system constraints and user service profiles prior to execution.
Rationale: Validation prior to and after each action to implement user services will assure reliability, safety, and awareness.
SGSS.004036 SN Service Abort
SNGS shall allow services in progress to be terminated by operator control or an exceptional condition.
Rationale: There are a number of scenarios where in progress services need to be safely aborted by SN operators. An example of an exceptional condition is when a TDRS enters ETO. The ETO command sequence (64 commands to remove user service equipment and configure to the S-Band TT&C mode) is not interruptible. The SNGS must respond with a similar reconfiguration of the ground resources to maintain control safely. Another example is when operators need to accommodate emergency requests.

10.2 Monitoring

SGSS.004038 Telemetry Logging
The SNGS shall log all telemetry from SN assets.
Rationale: Trending and analysis of system performance relies on a comprehensive archive of data and events. System model development to support system evolution can be validated against this archive. All status data reported by components in the SN, both fleet and ground, are monitored and logged with time tags to be accessible for analysis subsequent to the time it was logged. Synchronous status data transmitted from ground components/software also qualifies as a form of telemetry.
SGSS.004039 Alarm, Warning & Event (AWE) Alerts
The SNGS shall provide an integrated Alarm, Warning & Event function that manages all SNGS alarm, warning and event alerts.
Rationale: Situational awareness related to a large, autonomously executing and complex system as with the SN and SNGS requires an integrated system for managing all forms Alarm, Warning & Event alerts in a single manner. Alarms, Warning & events are triggered by the monitoring functions which detect

conditions that require notification or response. The AWE function includes messages, displays, audible alarms, visual cues, email/paging notifications, etc.

SGSS.004040 Linking Information Sources To Alarms, Warnings, and Events

The SNGS shall provide links to technical information for command constraint violations, alarms, warnings, and events.

Rationale: Following notification of failures or limit violations there is a need for detailed technical material and/or contingency materials. The ability to retrieve critical information will enhance the operators' ability to safely and efficiently deal with anomalous events.

SGSS.004041 SN Operational Constraint Checking

The SNGS shall check SN telemetry against pre-defined constraints.

Rationale: Limits define the range of allowable operational performance and can be used to define the expected range in normal operations. Limit check processing includes (but is not limited to) red-yellow-green ranges, rate of change boundaries, state change flags, persistence checks, etc. SNGS telemetry includes TDRS spacecraft and ground system data.

SGSS.004042 SN Limit Violation Actions

The SNGS shall allow association of system response actions with any operational constraint check or class of operational constraint check.

Rationale: Examples of actions that can be triggered by limit violations can include any combination of the following: alarm/warning message generation, visual representations on operator consoles, audible alarms, paging of key personnel, execution of automatic control sequences.

SGSS.004043 SN Pseudo Telemetry

The SNGS shall provide the capability to define pseudo telemetry parameters by mathematically combining one or more other telemetry parameters.

Rationale: Pseudo telemetry is often used to further enhance operational or situational awareness of the system or sub-system being monitored by combining and/or consolidating data types, applying filters, and executing higher level functions.

SGSS.004044 Remote Access To Engineering Data

The SNGS shall allow authorized remote access to SN engineering data.

Rationale: By allowing authorized operators and analyst not on site remote access to engineering data delays in responding to anomalies can be minimized.

SGSS.004045 SN Monitoring Displays

The SNGS shall provide SN operators with an integrated set of displays that provide global situational awareness for all SN assets.

Rationale: Integrated operational global situational awareness for space and ground SN resources is imperative. The separation of space and ground asset status has been a cause of problems in the current system.

10.2.1 SN Fleet

SGSS.004046 Fleet Monitoring Displays

The SNGS shall provide SN operators with an integrated set of Fleet-wide displays of SN flight assets, service loading and general condition.

Rationale: Operational global situational awareness of the SN Flight Segment as a whole is imperative to insuring SN operational availability and service quality. Fleet wide displays of the TDRS fleet should include (but not be limited to) their current mode (e.g., providing services, in 'spare' mode), their current over health status, their current service loading, their current orbital position inside their orbit slot, the location of customer platforms they are supporting, a forward view of customer platforms will be servicing, etc. Note, these do not need to be on one display, but range of fleet wide displays showing various aspects of the fleet as a whole are required.

SGSS.004047 Navigation Between Fleet And Spacecraft Level Displays
The SNGS shall provide SN operators with the ability to transition between fleet level and spacecraft specific displays.
Rationale: Operators need the ability to 'bore down' into spacecraft specific details to assess limit violation alerts, or explore the service loading details at the spacecraft level. The spacecraft level and fleet wide displays need to be integrated so operators can navigate between both domains quickly and easily.
The SNGS shall convert digital telemetry data into calibrated engineering data and status.
SGSS.004048 Telemetry Data Conversion
Rationale: Telemetry must be converted into engineering units and meaningful status to be useful to operators, analysts and engineers.
SGSS.004049 Multiple TDRS Telemetry Streams
The SNGS shall allow receipt of telemetry from one TDRS via multiple RF downlink sources.
Rationale: TDRS operations require TDRS be handed over between S-band TT&C and Ku-band TT&C modes, and during these transitions the SNGS will, for a brief time, be receiving TDRS telemetry over both RF links. In addition, there may be other operational situations, e.g. launch and early orbit or contingencies, where more than two simultaneous telemetry streams will be active via multiple ground antennas. The system should be able to handle at least five identical, simultaneous telemetry streams.
SGSS.004050 TDRS Attitude Determination
The SNGS shall compute TDRS attitude.
Rationale: TDRS Attitude is needed for health and safety monitoring and to support accurate and reliable user SA and MA open loop antenna pointing control functions running in the ground system.
SGSS.004051 SN Flight Segment Message Logging
The SNGS shall capture and record all flight segment messages.
Rationale: Flight System messages include status message, control messages, event message, etc. The logging of these messages is required for anomaly resolution and system performance analysis.

10.2.2 SN Ground Systems

SGSS.004053 MABE Performance Monitor
The SNGS shall monitor MA Beam Forming Equipment (MABE) performance.
Rationale: The MA system is calibrated continuously and monitored to assure service performance.
SGSS.004054 Doppler Control Monitor
The SNGS shall monitor Doppler control performance.
Rationale: Doppler Compensation and Doppler Shift Monitor is required to monitor Doppler shifts when off and sustain RF receiver lock. Doppler compensation is applied to forward and return RF carriers, and monitored by comparing the SGL Doppler shift to calculated values based upon ephemerides.
SGSS.004055 Facility Monitoring
The SNGS shall monitor the environmental status of SN facilities housing SN operational ground equipment.
Rationale: The condition of facility power and air handling must be maintained to assure the performance of all SN operational systems. The term 'facility' includes any structure that houses operational equipment (e.g., tunnels, equipment shacks).
SGSS.004056 Ground Segment Timing Performance
The SNGS shall monitor ground segment time delays.
Rationale: Performance of the SNGS is tightly coupled to time delays and accuracies in the system. For example, User tracking accuracy and precision are dependent upon knowledge of time delays and phase errors introduced by components in the space and ground segment which are used to determine range and to transfer time.
SGSS.004057 SN Ground Segment Message Logging
The SNGS shall capture and record all ground segment messages.

Rationale: Ground System messages include status message, control messages, event message, etc. The logging of these messages is required for anomaly resolution and system performance analysis.

10.2.3 User Services

SGSS.004058 User Acquisition Sequence Monitoring
The SNGS shall monitor the performance and success of User Acquisition Sequences as specified in the service profile for acquiring the user downlink.
Rationale: The SNGS needs to monitor the success or failure of user defined acquisition sequence directives to assess whether the user downlink has been properly acquired, this aids in situational awareness in support of the SN user. One example of this monitoring is the Doppler compensation performance.

SGSS.004059 User Return Service Monitoring
The SNGS shall monitor key return service configuration parameters to ensure the quality and performance of the return services provided to SN Users.
Rationale: The SNGS must monitor key performance parameters and events to ensure the service being provided is in line with the service profile. Examples of such parameters include RF lock, frame synchronization, error detection and correction, signal strength, etc.

SGSS.004060 User Forward Service Monitoring
The SNGS shall monitor key forward service configuration parameters.
Rationale: The SNGS must monitor key performance parameters and events to ensure the service being provided is in line with the service profile. Examples of such parameters include those detailed in Spacecraft Telecommunications Services section of this document. Also, in some cases the return link is dependent upon proper forward configuration.

SGSS.004061 Tracking Service Monitoring
The SNGS shall monitor key tracking service configuration parameters to ensure the quality and performance of the tracking services provided to SN Users.
Rationale: The SNGS must monitor key configuration parameters and events to ensure the service being provided is in line with the service profile. An example of one such parameter is the transit delays for range-zero settings.

SGSS.004062 SN Service Performance Reporting
The SNGS shall generate and process SN Service performance data.
Rationale: The SNGS must maintain agreed to service performance. This requires adapting to degradation when it is sensed and providing performance data.

SGSS.004063 SN Service Performance Monitoring and Recording
The SNGS shall monitor and record all SN Service performance data.
Rationale: The SNGS measures service execution performance to ensure that services are being provided at the agreed upon levels. Performance monitoring is also useful for maintenance planning.

SGSS.004064 Service Availability
The SNGS shall collect and maintain parameters used to determine actual SN service availability.
Rationale: SN Service availability must be monitored to assure the system is operating at peak efficiency and capacity.

SGSS.004065 User Service Latency Monitoring
The SNGS shall measure and record user data transport delays within the SN system.
Rationale: Latency performance is a key requirement in SN service quality.

SGSS.004066 Recording Executed Service Schedules
The SNGS shall record and log the executed service schedules clearly identifying SN resources allocated and related performance data.
Rationale: The SN requires a record of the actual services provided and the associated performance measures be recorded and maintained.

SGSS.004126 Ground Segment Reconfiguration Performance
The SNGS shall implement validated ground and TDRS reconfiguration requests within 35 seconds of receipt.
Rationale: Consistent with current performance.
SGSS.004127 Command Rate Processing Performance
The SNGS shall process commands at a rate of at least 50 commands/sec.
Rationale: This supports maintaining users services with first generation TDRS spacecraft for a 2kbps command bit rate and 50 cmds per second command rate. The HIJ spacecraft are 2kbps with 80-bit commands for a maximum rate of 25 commands per second.

10.3 Operations Analysis

SGSS.004067 Analysis Data Retrieval and Processing
The SNGS shall allow retrieval and analysis of archive data without impact to operational performance.
Rationale: Engineering Analysis activities should not impact the operational system's performance.
SGSS.004068 Data Retrieval Time Periods
The SNGS shall provide the capability to retrieve process and display data from a specified time interval.
Rationale: Separate from the real time plot display, this extends the view of real time display data during anomalies and events. This function is necessary in the operations room.
SGSS.004069 Data Export
The SNGS shall allow export of trending and analysis data.
Rationale: Some analyses may not be possible in the online system or at a facility that is supporting the operations. It should be possible to export large volumes of data to external applications. This is occasionally necessary when logistics and cost dictates or when analysis expertise and computational resources only exist offsite in a component vendors laboratory or at another NASA facility.
SGSS.004070 Storing Analysis Products
The SNGS shall record and store Mission Planning, Mission Engineering, and Flight Dynamics analysis products.
Rationale: Historical records of analysis products are necessary for anomaly analysis and long-term trending.

10.3.1 Mission Planning

SGSS.004071 TDRS Maneuver Planning and Analysis
The SNGS shall provide TDRS spacecraft orbit management planning and analysis.
Rationale: SNGS operations must have the capability to produce detail schedules, command sequences, constraints, key parameters, etc for all events leading up to and through a spacecraft maneuver sequence and subsequent return to operations.
SGSS.004130 Post TDRS Maneuver Orbital State Vector
The SNGS shall provide the post-burn orbital state vector within 30 minutes of an orbital maneuver.
Rationale: To optimize the use of SN resources by ensuring efficient link acquisition.
SGSS.004072 TDRS Fleet Orbit Management
The SNGS shall provide TDRS fleet orbit management planning and analysis.
Rationale: The TDRS spacecraft orbits are controlled to constrain the equator crossing longitude to within 0.1 degrees. The measurement of the TDRS orbital status and drift rate is necessary to maintain and coordinate a longitude management plan. Maneuver performance analysis is necessary for trending data on thruster performance and calibration to maintain the quality of maneuver plans.
SGSS.004073 TDRS Angular Momentum
The SNGS shall allow the management of TDRS Angular Momentum.
Rationale: Angular momentum accumulates from solar light pressure and IR emission torque which is minimized by a trim tab adjustment. The prediction and control of angular momentum is necessary to maintain reaction wheel speeds in a safe range.

SGSS.004074 East/West Station Keeping
The SNGS shall maintain Longitude of equator crossing for all TDRS spacecraft.
Rationale: Although typical geosynchronous orbit management concepts include inclination and longitude control, because TDRS inclination is not controlled, the only time the longitude must be constrained is at the northward and southward equator crossings.
SGSS.004075 Change of TDRS Location
The SNGS shall execute Longitude station changes.
Rationale: Station changes are necessary to replace failed assets following launch and in orbit checkout of new spacecraft, to balance resources, and to store spacecraft in non-interfering locations.
SGSS.004076 End of Life Decommissioning
The SNGS shall allow creation of plans for TDRS decommissioning.
Rationale: To honor international agreements for RF interference and space debris mitigation, at the end of spacecraft life, a geosynchronous orbiting spacecraft is raised 300 km circular above the geo orbit.
SGSS.004077 On-Board Propellant Management
The SNGS shall provide the capabilities to manage and plan TDRS propellant usage.
Rationale: Operation of the TDRS satellites includes management of TDRS propellant and tracking of the propellant utilization, both in mission planning and post maneuver assessment.

10.3.2 Mission Engineering

SGSS.004078 TDRS On-Board Fault Detection Management
The SNGS shall calibrate TDRS F8 and newer fault detection test models and thresholds.
Rationale: For TDRS F8 and up, limit checks are performed onboard the spacecraft. The thresholds used for these checks must be calibrated to minimize false alarms, which degrade service availability unnecessarily.
SGSS.004079 Statistical Analysis of Performance
The SNGS shall provide statistical analysis of SN service performance.
Rationale: Statistical analyses reveal small changes in system calibration and performance that are not seen in real-time plots.
SGSS.004080 Ku-band Ground Antenna Pointing Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for the Ku-band operational antenna pointing systems.
Rationale: To assure maximum service quality and reliability it is necessary to know the Ku-band RF pattern in terms of antenna position angles measured by the azimuth and elevation sensor and corrected by calibration for non-linear effects in the output of those sensors.
SGSS.004081 S-band Ground Antenna Pointing Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for the S-band operational antenna pointing systems.
Rationale: The S-band RF beam pattern is different than the K-band RF pattern requiring separate analysis.
SGSS.004082 OTS Antenna Pointing Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for operational test antenna pointing systems.
Rationale: The OTS antennas are controlled the same way as the SGL ground antennas except that there is also a Ka-band RF uplink and return beam pattern to analyze.
SGSS.004083 MA Ground Antenna Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for RF phase delays and biases in the ground segment forward and return MA beam forming system.
Rationale: For F1-F7 and F11-F13 the MA beam forming equipment on the ground must be calibrated continuously using the MA source calibration signal from an antenna at the WSC.

SGSS.004084 Range Bias Calibration
The SNGS shall calibrate range biases from all space and ground components in the tracking data generation systems.
Rationale: Range measurement accuracy performance is dependent upon knowledge of the delay introduced by the components in the ground and flight segments.
SGSS.004085 SNGS Monitor System Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for all analog and digital ground segment sensors.
Rationale: Service performance and reliability is dependent upon accurate measurement of trends in monitored parameters in the ground equipment and the calibration of spectrum analyzers and frequency generation equipment. Examples of these are sensors are for frequency, temperature, voltage, pressure, power, and current.
SGSS.004086 TDRS Actuator Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS control actuators.
Rationale: To optimize onboard and remote control performance and to establish baselines for trending, actuators such as wheels, thrusters, solar array and antenna drives, active and passive magnetic dipoles, and active and passive solar light pressure control surfaces are analyzed and calibrated.
SGSS.004087 Sun Sensor Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS Sun sensors.
Rationale: Sun sensors are semiconductor devices, which are susceptible to degradation and changes in calibration from space radiation, contamination, and electronic aging. These sensors are the input to solar array and yaw attitude control of the spacecraft. Knowledge of spacecraft yaw attitude is necessary for optimum pointing of SA and MA antennas to users.
SGSS.004088 Earth Sensor Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS Earth sensors.
Rationale: Earth sensors must be calibrated initially and periodically to assure SA and MA antenna pointing and reliable prediction of solar and lunar IR impingement on the Earth sensor.
SGSS.004089 Inertial Measurement Unit Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS attitude rate sensors
Rationale: Gyros, Inertial Reference Units (IRUs) are essential to attitude rate measurements which are components of attitude control during normal and contingency operations. Initial and periodic calibration of attitude rate measurements for rate bias, linearity, alignment, and rate noise effects are components of this calibration.
SGSS.004090 Mass Properties Analysis
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS mass properties.
Rationale: Knowledge of spacecraft mass properties is necessary for angular momentum management, propellant budgeting to assure proper decommissioning at end of life, and for reliable attitude control during orbit adjust maneuvers.
SGSS.004091 TDRS Appendage Actuators Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS appendage actuators.
Rationale: Appendage actuators control antennas, solar arrays, and articulated surfaces to control solar light pressure torques and forces. To optimize onboard and remote control performance and to establish baselines for trending, actuators such as wheels, thrusters, solar array and antenna drives, active and passive magnetic dipoles, and active and passive solar light pressure control surfaces.

SGSS.004092 TDRS Battery Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS battery charge capacities and pressures.
Rationale: Knowledge of battery performance, capacity, and state of health is essential to eclipse operations and contingency support which ultimately influences the useful life of the spacecraft. The complement of battery types in the flight segment requires diverse calibration and trending analyses.
SGSS.004093 Torque Models
The SNGS shall calibrate TDRS angular momentum loading models.
Rationale: Optimum service scheduling depends in part upon reliable prediction and control of angular momentum build up which is done by comparing trends to models.
SGSS.004094 Solar Array Power Measurement
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS solar array efficiency.
Rationale: Solar arrays are solid state devices with different designs for each generation of TDRSs. The efficiency must be tracked to adjust the operational approach to power management as space radiation effects lower the solar array efficiency to produce electrical power.
SGSS.004095 Thruster Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS thruster alignment and specific impulse.
Rationale: Thruster actuators are used to manage and control the orbit and spacecraft angular momentum. The accuracy of the calibration of thrusters determines the efficiency of full usage and thus mission lifetime. Baselines on thruster calibration with periodic updates make it possible to detect performance degradation if it should occur.
SGSS.004096 MA Element Phase Bias
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS MA element biases.
Rationale: The MA antenna elements must be calibrated initially for reliable beam forming performance and the calibrations will change due to use and space environment aging effects.
SGSS.004097 TDRS SA and MA RF Beam Analysis
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS coordinates azimuth and elevation to SA and MA RF beam alignment.
Rationale: TDRS SA antennas are controlled in azimuth and elevation with encoders to measure these angles. The RF beams for S-band, Ku-band, and Ka-band do not coincide with the null of these encoders and must centered and characterized throughout the range of these encoders. Also the encoders will change.
SGSS.004098 TDRS Ku band RF alignment
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS Ku antenna pointing and RF beam alignment.
Rationale: The Ku-band beam pattern on the TDRS SGL antenna is different than the S-Band antenna pattern.
SGSS.004099 TDRS S-band RF Alignment
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS S-band antenna pointing and RF beam alignment.
Rationale: This applies to all antennas including the SGL and Omni antennas which may have RF nulls which need to be understood.
SGSS.004100 TDRS RF Transmitter Calibration
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS RF power amplification.
Rationale: Initial baseline calibrations on-orbit is compared with ground calibrations and specifications and compared with subsequent mission calibrations to monitor health and trend the systems.

SGSS.004101 TDRS RF Time Delay Measurement
The SNGS shall provide the capabilities to support planning, execution and validation of calibration activities for TDRS RF time delays.
Rationale: RF time delays are an essential component to the assurance of accuracy and stability of the tracking services and of services where quality is dependent upon well known values for data latency.
SGSS.004129 Time Bias Alignment
The SNGS shall allow the application of time biases to plotted tabulated data.
Rationale: Management of the time base is highly useful in both simulation environments (where time is usually in the future) and fleet situations where data from multiple spacecraft can be presented together if time can be realigned to compensate for environmental geometry (e.g. sun position).

10.3.3 Flight Dynamics

SGSS.004102 TDRS Ephemeris Propagation
The SNGS shall provide predicted TDRS ephemerides.
Rationale: The TDRS ephemeris is propagated in the SNGS using a starting vector in IIRV format from GSFC FDF or internally generated from the Orbit Determination process at the SNGS.
SGSS.004103 TDRS Orbit Determination
The SNGS shall provide TDRS orbit determination.
Rationale: The TDRS -3 Independent Review Team noted that the tools to perform TDRS orbit determination were available in the current ground station and that they should be used to maintain technical skills needed to backup Flight Dynamics Functions and to recover from anomalies.
SGSS.004104 Vector Translations
The SNGS shall provide Earth-based vector generation.
Rationale: The SN must support TDRS tracking for Earth fixed platforms such as launch sites, WSC Test antennas, and other globally distributed ground antennas and transmitters.
SGSS.004105 Solar, Lunar, and Stellar Vectors
The SNGS shall provide solar, lunar, and stellar vectors.
Rationale: To assess RFI and IR intrusion into sensors and RF receivers on the TDRS spacecraft the Solar and Lunar positions must be known. Also for gravitational force models in propagators and orbit determination systems the location of the Sun and Moon must be known. Similarly celestial objects known as Quasi Stellar Radio Sources (QUASARs) are used as calibration targets on flight segment equipment.
SGSS.004106 TDRS Ground-to-Space Vector Generation
The SNGS shall provide vectors between the SN ground stations and TDRS spacecraft.
Rationale: Vectors in IIRV format must be converted to pointing angles and Doppler shifts for RF acquisition and communication between the Ground Stations and TDRS spacecraft.
SGSS.004107 TDRS-to-User Platform Vector Generation
The SNGS shall provide vectors between the TDRS spacecraft and the User Platform.
Rationale: The SNGS combines propagated and interpolated vectors from the User Platform and TDRS to generate pointing vectors from TDRS to users with the predicted Doppler frequency shifts.
SGSS.004108 SN Flight Dynamics Products
The SNGS shall provide TDRS related flight dynamic products to support SN operations.
Rationale: Flight Dynamics products (e.g., viewing periods from the GTs to the TDRSs, RF interference times, sensor intrusion periods and Doppler and ranging information) are necessary to support SNGS operations.
SGSS.004109 User Platform Orbit Prediction
The SNGS shall provide predicted SN User platform ephemerides.
Rationale: User Improved Inter-Range Vectors (IIRVs) must be propagated forward and backward from their epoch in order to support SN Services. The SN must also support TDRS pointing on Earth fixed

platforms such as launch sites, WSC Test antennas, BRTS stations and other globally distributed ground antennas and transmitters.

SGSS.004110 User Platform Flight Dynamics Products

The SNGS shall provide SN User flight dynamic products to support SN operations.

Rationale: Flight Dynamics products (e.g., viewing periods from the user platform to the TDRSs, RF interference times, sensor intrusion periods and Doppler and ranging information) are necessary to support SNGS operations.

10.3.4 Off-line Engineering Analysis Tools

SGSS.004111 Automated Data Retrieval and Analysis

The SNGS shall allow automated data retrieval and analytical processing based on events or schedule.

Rationale: Automated scheduling of engineering data retrieval and processing eliminates tedious, repetitive tasks (i.e. plotting, trending, and de-trending) and increases operations efficiency. Event driven retrieval and processing allows for analysis data to automatically be collected and processed in response to anomalies or defined events.

SGSS.004113 Analytical Models and Algorithm Development

The SNGS shall allow interactive, graphical development of models and algorithms necessary for all forms of operations data analysis.

Rationale: The ability to implement advanced trending and analysis techniques is required to support anomaly investigation analysis, as well as general SN system calibration and test activities.

SGSS.004114 Testing Prototype Processes

The SNGS shall allow prototyping, validation, and testing of real-time models and algorithms.

Rationale: Prior to use in the operational environment analytical models and algorithms need to prototyped, tested and validated against actual SN system data.

SGSS.004115 Engineering Analysis Mathematical Functions

The SNGS shall provide a suite of standard mathematical functions to support operational analysis functions.

Rationale: Standard filters such as least squares fit. Digital filter libraries, and fast Fourier transforms (FFT) should be in the engineering toolbox without requiring that the engineers develop them from scratch.

Section 11. Space Network Operations

11.1 Primary SN Operations

SGSS.004501 Centralized SN Control
The SNGS shall allow the direction of all SN operational activities from the primary SN operations control center.
Rationale: The current operational concept calls for there to be a centralized control center for the SN.

SGSS.004502 Decentralized SN Control
The SNGS shall allow the direction of SN operational activities from distributed SN operations control centers.
Rationale: Even though the current operational concept calls for a centralized SN control center, operations may want to decentralize operations temporarily to deal with an anomaly or permanently for other reasons.

SGSS.004503 SNOC Relocation
The SNGS shall allow the relocation of the primary SN operations control center among pre-defined SN facilities.
Rationale: This facilitates various continuity of operations scenarios. SNOC portability allows the primary SNOC to move among facilities as conditions dictate (uninhabitable, equipment down, etc.).

SGSS.004504 Continuous SN Operations
The SNGS shall allow continuous monitoring and control of SN activities and resources at the primary SN operations control center.
Rationale: The primary function of the control center is to monitor and control SN resources and activities.

SGSS.004530 PSNOC Location
The Primary SNOC shall be located at the STGT.
Rationale: STGT is the newest SN facility and contains the best physical accommodations to support primary SN operations.

11.2 Operator Environment

SGSS.004505 Operator Work Space
The SNGS shall provide operator work areas to accommodate normal operations staff for any given shift plus additional work areas for special activities.
Rationale: Each person on a standard SN operations shift requires a place to work. In addition, there need to be spare work areas for activities such as launch support, special TDRS events, and anomaly resolution/recovery.

SGSS.004506 Operator Work Area Human Factors
The SNGS shall provide operations work areas in accordance with OSHA Ergonomic Solutions; Working Safely With Video Display Terminals (OSHA 3092 - Revised 1997); Human Factors / Ergonomics - Health And Safety In The Workplace.
Rationale: These standards must be adhered to in order to minimize the risk of preventable work place injury. They are required by NASA and the US Government. This is needed to maintain human health and safety.

SGSS.004507 Time Displays
The SNGS shall provide displays of UTC and local time for each SN operations facility.
Rationale: This allows operators to predict what staff are available in each SN operations center.

SGSS.004508 Room-Size Displays
The SNGS shall provide large displays visible from any operational position in the SNOC.
Rationale: Large room-sized displays are necessary to facilitate situational awareness. These can be used to display fleet information, special displays, or normal display pages.

SGSS.004509 NASA/NISN Voice Communications
The SNGS shall provide NASA/NISN internal voice capability at each operator work area.
Rationale: The function allows communication with other NASA entities for coordination of operations between TDRS facilities and between SN and Users.

SGSS.004510 Event Timers
The SNGS shall provide an event timer at each operator work area capable of counting up or down.
Rationale: Event timers are used by operators to track User Mission Elapsed Time (MET) and to count up or down TDRS events such as maneuvers and anomalies.

11.3 Operator Interface

SGSS.004511 Operator Interface
The SNGS shall provide an operator interface from which all SN resources and services can be monitored and controlled.
Rationale: Operators require a way to view monitoring data and enter system commands. The expectation is that this will be high-resolution color graphical interface.

SGSS.004512 Interface Functional Equivalence
The SNGS shall provide equivalent functional capabilities at all operator interfaces.
Rationale: This allows operators to log in at any interface at any SN operations facility and configure the interface for their specific tasks.

SGSS.004513 Remote Control via Operator Interface
The SNGS shall allow operators to exercise remote control of SN resources via monitoring and data entry devices.
Rationale: This function allows operators to log in at any work area and perform their duties without being located physically next to resources being controlled.

SGSS.004514 Management of Operational Displays
The SNGS shall provide the capability for SN operators to develop, maintain and manage operational displays.
Rationale: The SNGS control system needs to allow operators to develop and maintain all operations displays without requiring SW engineering skills or tools. Displays must be capable of being added, updated or deleted without recompiling, linking or loading software applications. Displays include graphs, charts, alpha –numeric tables, representative graphical widgets, etc.

SGSS.004516 Single Interface SN Control
The SNGS shall allow control of the entire SN or any portion of the SN from a single operator interface.
Rationale: As staffing and operational procedures are unknown, the capability for a single operator to control the SN from a single interface is required in the event that only one is available. Additionally, the ability to split operations functions among various interfaces is also required to facilitate multiple operators simultaneously.

SGSS.004517 Multiple Simultaneous Displays
The SNGS shall allow multiple simultaneous displays on a single operator interface.

Rationale: Operators will be required to monitor and control various aspect of the SN using different display pages simultaneously. The ability to view them on the same interface increases operational efficiency and saves money.

SGSS.004518 Common Display Time Source
The SNGS shall use the common SN time source to display UTC on operator interfaces.
Rationale: A common time source for all information and displays in the SN is required to correlate data with events across the network.

SGSS.004519 Dynamic Information Update Performance
The SNGS shall refresh output to be displayed in an operator interface at a selectable rate with a maximum refresh rate of once per second.
Rationale: Operators should have the capability to increase or decrease the update rate on dynamic information as appropriate so as to not overload the capabilities of the operator interface.

SGSS.004520 Operator Interface Log In Performance
The SNGS shall complete the log-in sequence for an operator interface within 1 minute and the log-off sequence within 30 seconds.
Rationale: Operators should be able to log into the interface as quickly as possible, particularly in the event of an anomaly or move to another control center. 30 seconds is consistent with current technology.

SGSS.004521 Display Activation Performance
The SNGS shall activate any requested display in an operator interface within 5 seconds.
Rationale: Operators require timely response to display requests. 5 seconds is consistent with current technology.

SGSS.004522 Interface State Capture
The SNGS shall provide a mechanism to save the state of each SN operations interface in the event of an anomaly.
Rationale: This information is useful in anomaly resolution and prevents data from being lost or corrupted.

SGSS.004523 Interface Scalability
The SNGS shall allow the addition of new operations interface and removal of existing operations interfaces without impacting SN operations.
Rationale: This facilitates scaling the number of interfaces up or down without impacting operations.

SGSS.004524 Operator Analysis Tool Access
The SNGS shall allow SN operators to access engineering analysis tools, data, and products.
Rationale: Operators are required to perform certain trending functions in the operational environment. This should be done using the common set of analysis and engineering tools and will inhibit the need to develop custom tools for operators.

SGSS.004525 Minimum Simultaneous Interfaces
The SNGS shall accommodate a minimum of 50 simultaneous active operations interfaces without performance degradation.
Rationale: This is the minimum number of interfaces likely to be required by operations to perform their duties. This includes interfaces in the all SN operations control centers, SNEF, and NIC.

SGSS.004526 Operator E-Mail Service
The SNGS shall provide an internal messaging system via the operator interface.
Rationale: Internal communications are required among operators.

SGSS.004527 Display Printout
The SNGS shall provide the capability for SN operators to capture displays or screen snapshot and print these out in color hard copy.

Rationale: The SNGS control system needs to provide the capability to snapshot displays and their current contents, and have the snapshots stored and printed out to hard copy format to support various reporting requirements.

SGSS.004528 Local Hardware Interface

The SNGS shall provide a local operator interface to operational hardware.

Rationale: Operations need a local interface to hardware in the equipment room for local monitoring and controlling of devices, test ports, and maintenance activities.

SGSS.004529 Configuration Management of System Displays

The SNGS shall provide the capability to manage the configuration of operational system displays.

Rationale: Access to safeguards which restrict who can activate or change the operational display suite must be limited to authorized personnel only. The ability to modify, add and delete displays is independent from the process of making the displays "operational". The migration of a display from the concept phase to operational utilization needs to be tightly controlled.

Section 12. Reserved

Section 13. Enterprise Infrastructure

13.1 Communications Infrastructure

13.1.1 General Requirements

SGSS.005501 Standards Based Message Service
The SNGS shall use standards based message communications between SNGS functions.
Rationale: Standards based services ensure interoperability and portability.

SGSS.005503 Message Routing
The SNGS shall route messages between SNGS functions based on the message contents and a predefined set of criteria (policy).
Rationale: Message Routing is required to send messages to registered services.

SGSS.005505 IPv4 and IPv6 Compliance
The SNGS shall interoperate with both IPv4 and IPv6 components.
Rationale: The SNGS will need to retain IPv4 compatibility while IPv4 systems are present in the system.

SGSS.005507 SNMP Compliance
The SNGS communication equipment shall comply with SNMP standard v.3.
Rationale: Centralized monitoring of equipment status and alarms for trend tracking and quick repair response. Compliance with latest industry standard permits use of up-to-date network management features.

SGSS.005508 User Data Isolation
The SNGS shall isolate all user service data from other SN data within the SN communications infrastructure.
Rationale: Ensuring user's access to services (e.g., bandwidth) and data confidentiality require the SNGS communications and data management infrastructure to isolate data flows from other SN activities

SGSS.005509 TDRS TT&C Data Isolation
The SNGS shall isolate all TDRS TT&C data flows from all other SN data within the SN communications infrastructure.
Rationale: Ensuring security and access to the TDRS spacecraft require the SNGS communications infrastructure to isolate TDRS telemetry and command data flows from other SN activities.

SGSS.005510 Test and Maintenance Data Isolation
The SNGS shall isolate all SN test and maintenance data flows from operational data flows supporting SN services and operations.
Rationale: Ensuring SN services and operations can execute without accidental interruption requires the SNGS communications infrastructure to isolate test data from other SN activities.

SGSS.005511 Data Flow Isolation
The SNGS shall allow for any class of internal data flows to be isolated from other internal SN data communications as deemed necessary to provide data security and optimal performance.
Rationale: The SNGS communications architecture needs to be flexible in order to allow for isolation of internal communications flow as needed over the life of the SNGS architecture.

SGSS.005540 Distributed Message Service

The SNGS shall use distributed message communications between SNGS functions.
Rationale: Distributed message services eliminate the risk of signal point of failure.

13.1.2 SN Intrafacility Communications

SGSS.005506 Communications Routing
The SNGS shall allow routable communication within the SN facilities.
Rationale: The SN must provide communications within facilities between and among SNGS elements. Without the use of internal communications, implementation of a complex ground system is impossible.

SGSS.005512 Intrafacility Baseband Switching
The SNGS shall allow switching of the baseband traffic within an SN facility.
Rationale: To allow switching between the back-end electronics components and the test service components.

SGSS.005513 ULE Baseband Switching
The SNGS shall allow switching of baseband traffic to ULE.
Rationale: Multiple SN Users require baseband interface to the SN. The SNGS must allow switching of baseband signals to ULE to provide services to these Users.

SGSS.005514 Configurable Baseband Switching
The SNGS shall allow dynamic switching of baseband signal paths.
Rationale: To allow the configuration of the signal path automatically or based on predefined criteria.

SGSS.005515 Baseband Data Rate
The SNGS shall be capable of transporting baseband data at rates of at least 1.5 Gbps per service.
Rationale: The SN provides user data return services with data rates up to 1.5Gbps. The communications infrastructure must transport and direct baseband data at these rates to meet user requirements and service agreements.

SGSS.005517 Baseband Configuration Polling
The SNGS shall provide the ability to be polled for current configuration/path settings.
Rationale: To ensure the switch can provide the current service configuration.

SGSS.005518 Baseband Switch Configuration
The SNGS shall allow dynamic configuration of the baseband switch path in less than 1 second.
Rationale: Configuring the baseband switch path within 1 second facilitates minimum interruption in services and maximizes operational efficiency within the bounds of current technology.

SGSS.005519 Configurable Intra-facility IF Signal Path
The SNGS shall allow dynamic configuration of the IF signal path between SN facilities at the WSC.
Rationale: To allow configurations of the IF signal path across the IFL.

SGSS.005520 ULE IF Switching
The SNGS shall allow switching of IF signals to ULE.
Rationale: Multiple SN Users require an IF interface to the SN. The SNGS must allow switching of IF signals to ULE to provide services to these Users.

SGSS.005521 Configurable IF Switching
The SNGS shall allow dynamic switching of IF signal paths.
Rationale: To allow connections across the switch to be made without manual intervention.

SGSS.005522 IF Bandwidth
The SNGS shall support a maximum bandwidth of 650 MHz per service.

Rationale: The SN provides user services with bandwidth up to 650 MHz. The communications infrastructure must transport and configure IF data at these bandwidths to meet user requirements and service agreements.

SGSS.005524 IF Configuration Polling
The SNGS shall provide the ability to be polled for current IF configuration/path settings.
Rationale: To ensure the switch can provide the current configuration when queried.

SGSS.005525 IF Switch Configuration
The SNGS shall allow dynamic configuration of the IF switch path in less than 1 second.
Rationale: Configuring the IF switch path within 1 second facilitates minimum interruption in services and maximizes operational efficiency within the bounds of current technology.

SGSS.005542 Serial Clock and Data to ULE Jitter
The SNGS shall provide return service serial clock and data to ULE with a latency variance of no more than:
a. KuSAR: 3800 bps per second
b. KaSAR: 3800 bps per second
Rationale: Existing SN requirement levied by certain Users that must be maintained per service agreements.

13.1.3 SN External Communications

SGSS.005533 Mission Voice Service
The SNGS shall utilize Mission Voice services from NISN.
Rationale: NISN is the provider for all SN external communications services.

SGSS.005534 NISN Closed IONet Services
The SNGS shall utilize the NISN-provided Closed IONet.
Rationale: The SN is required to communicate with Users and other entities in at security levels provided by NISN Closed IONet services. Use of NISN-provided services to facilitate these communications is mandated by NASA.

SGSS.005535 NISN Restricted IONet Services
The SNGS shall utilize the NISN-provided Restricted IONet.
Rationale: The SN is required to communicate with Users and other entities in at security levels provided by NISN Restricted IONet services. Use of NISN-provided services to facilitate these communications is mandated by NASA.

SGSS.005536 NISN Corporate Network Services
The SNGS shall utilize the NISN-provided Corporate Network services.
Rationale: The SN is required to communicate with Users and other entities in at security levels provided by NISN Corporate Network services. Use of NISN-provided services to facilitate these communications is mandated by NASA.

SGSS.005541 NISN Open IONet Services
The SNGS shall utilize the NISN provided Open IONet service.
Rationale: The SN is required to communicate with Users and other entities in a non-secure manner. Use of NISN-provided Open IONet services to facilitate these communications is mandated by NASA.

13.2 IT Security

SGSS.005701 Defense in Depth - Technical
The SNGS shall incorporate multiple security layers.

Rationale: Defense-In-Depth (DID) is an approach to design, implementation, and operation where several different security-related technical methods are employed to protect the SNGS information system. The use of multiple information technology security methods like intrusion detection systems, firewalls and antivirus software, just to name a few, helps mitigate the risk of one component of the system being compromised or circumvented.

SGSS.005702 Technical Controls
The SNGS shall adhere to the technical security control requirements specified in NASA Procedural Requirements (NPR) 2810.1A, Security of Information Technology, Section V.
Rationale: The SNGS must comply with NASA requirements for the development, design, construction, and activation of all technical security controls that the SNGS information system implements.

13.2.1 Access Control

SGSS.005703 Automatic Account Management
The SNGS shall implement automated management of the system access accounts for SN personnel and SN Users.
Rationale: SNGS information system operators must manage information system accounts, including establishing, activating, modifying, reviewing, disabling, and removing user accounts in accordance with NPR 2810.1A, Section 19.

SGSS.005704 SN Operator Account Management
The SNGS shall allow SN operators to manage the system access accounts of SN personnel and SN Users.
Rationale: SNGS information system operators must manage information system accounts, including establishing, activating, modifying, reviewing, disabling, and removing user accounts in accordance with NPR 2810.1A, Section 19.

SGSS.005705 Access Authentication
The SNGS shall validate the unique identity and then authenticate SN operators and SN Users attempting to access the system.
Rationale: Authentication is required for access to SNGS IT systems as a means to validate the claimed identity of the person attempting the access. This applies to both internal and external users of the SNGS and will be a means to prevent group and shared accounts. User IDs and passwords, both of which should be unique for each account assigned to an individual, are proven methods to validate the identity and authenticate personnel who access the SNGS. The SNGS will also ensure it does not provide information that would allow an unauthorized user to compromise the authentication process or mechanism.

SGSS.005706 Password Enforcement
The SNGS shall implement automated enforcement of password requirements.
Rationale: SNGS IT system security is diminished when passwords are easy to guess or easily cracked by adversary software tools. The automatic enforcement of robust passwords strengthens the authentication process which in turns strengthens the SNGS IT system security posture. This control is specified in NPR 2810.1A, Section 11.3.7.

SGSS.005707 Access Enforcement - External Access
The SNGS shall prevent external access into SNGS's internal networks except as appropriately mediated.
Rationale: Preventing unauthorized external access into SNGS's internal networks is paramount to protecting the SNGS IT system from unauthorized access, use, disclosure, disruption, modification, or destruction of the information or information systems that lie within.

SGSS.005708 Access Enforcement - Privileged Functions
The SNGS shall restrict access to privileged functions based on user authorization levels.

Rationale: SNGS information system must enforce assigned authorization levels in order to control access between users and objects.

SGSS.005709 Access Enforcement - Security-Relevant Information
The SNGS shall restrict access to security-related information and functions to explicitly authorized users.
Rationale: SNGS information system must enforce assigned authorization levels in order to control access to security-related information and functions. This will help avoid compromise of information and functions that could in turn be used to aid in the attack of the system.

SGSS.005710 Separation of Duties
The SNGS shall enforce separation of duties through assigned access authorizations.
Rationale: The SNGS must establish appropriate divisions of responsibility and separate duties as needed to eliminate conflicts of interest in the responsibilities and duties of individuals.

SGSS.005711 Unsuccessful Login Attempts
The SNGS shall limit the number of failed user account access attempts prior to locking out the account.
Rationale: Limiting the number of failed logon attempts help prevent unauthorized access to the SNGS IT system. The account lockout threshold should be set in accordance with NASA's Federal Desktop Core Configurations (FDCC) Baseline controls for configuring NASA systems (ref: CCE-2986-8).

SGSS.005712 System Warning Banner
The SNGS shall display a System Warning notification message before granting system access.
Rationale: The System Warning Banner message informs potential users: (a) that the user is accessing a U.S. Government information system; (b) that system usage may be monitored; and (c) that unauthorized access or use of the system is prohibited and subject to criminal and civil penalties. This control is specified in NPR 2810.1A, Section 11.3.6.

SGSS.005713 Concurrent Session Control
The SNGS shall have the capability to limit the number of concurrent sessions any one user can establish at any one given time.
Rationale: Helps control user access and prevent SNGS IT system compromise by limiting the number of sessions users can establish at any one given time. For example, the SNGS should prevent a single user from logging on to a particular system say from one computer, then go across the room and log on from another computer, then go to an adjoining room and log on from yet another computer, and so forth. This control will also make auditing user events and the safeguarding of SNGS data and information more manageable.

SGSS.005714 Automatic Marking
The SNGS shall automatically label screen displays and hardcopy printouts using standard security naming conventions.
Rationale: This will help identify FOUO, SBU, and classified data and/or information being visually displayed on computer screens or being printed out on hardcopy products that are output from the information system, which in turn should prompt special dissemination, handling, or distribution instructions for the display(s) or hardcopy products.

SGSS.005715 Remote Access Monitoring and Control
The SNGS shall monitor and control all methods of remote access to the SNGS.
Rationale: The SNGS needs an automated means to monitor and control all users, IT systems and components that remotely access the SNGS IT system through external, non-organization-controlled networks (NISN, VPN, IONet). This remote access monitoring and control also supports COOP implementation.

13.2.2 System & Communications Protection

SGSS.005716 External Boundary Protection
The SNGS shall implement boundary protection at the external boundary of the SNGS.
Rationale: Protecting the external boundaries of the SNGS operational network from external entities with malicious intent, intentional or inadvertent denial of service attacks and unauthorized access or disclosure of sensitive information are essential activities of network security.

SGSS.005717 Internal Boundary Protection
The SNGS shall implement boundary protection at key internal boundaries of the SNGS.
Rationale: Protecting the key internal boundaries of the SNGS operational network from malicious insiders and unauthorized access or disclosure of sensitive information are essential activities of network security.

SGSS.005718 External Boundary Protection Monitoring
The SNGS shall monitor and control external SN system boundary protection measures.
Rationale: External boundary protection measures provide protection and monitoring capabilities for the network perimeter. The SNGS information systems operators must be able to remotely monitor the health and status of these external boundary security measures to ensure they maintain their appropriate security postures.

SGSS.005719 Internal Boundary Protection Monitoring
The SNGS shall monitor and control internal SN system boundary protection measures.
Rationale: Key internal boundary protection measures provide protection and monitoring capabilities for the internal operational network. The SNGS information systems operators must be able to remotely monitor the health and status of these internal boundary security measures to ensure they maintain their appropriate security postures.

SGSS.005720 Penetration Testing
The SNGS shall allow performance of penetration testing by a NASA-approved independent entity who can do so without impact to SN operations.
Rationale: In accordance with NPR 2810.1A, Section 11.3.4, annual penetration testing is required on all NASA IT systems. Therefore, the system must include the tools and mechanisms required to execute this security control.

SGSS.005721 Network Traffic Security Monitoring
The SNGS shall continuously monitor SN telecommunications traffic for security incidents and anomalies.
Rationale: In accordance with NPR 2810.1A, Section 16.3, SNGS operators be able to monitor the SNGS network traffic for security incidents like data leakage of sensitive data (e.g. can track the flow of data packets throughout the network) or security anomalies like significant increases in message traffic (which could indicate a possible Denial of Service (DoS) attack).

SGSS.005722 Network Component Security Monitoring
The SNGS shall continuously monitor SNGS communication and computer components for security incidents or anomalies.
Rationale: In accordance with NPR 2810.1A, Section 16.3, SNGS operators must be able to monitor the SNGS telecommunications components for security incidents like unauthorized access to the component or security anomalies like a secured port on the component being open (which could indicate unauthorized access).

SGSS.005723 Vulnerability Scanning
The SNGS shall scan for vulnerabilities in the SNGS.

Rationale: Vulnerability scanning is a key component of network security and is required by NPR 2810.1A, Section 16.4. Therefore, The SNGS must be scanned for vulnerabilities, which may potentially put the SNGS system at risk, using appropriate scanning tools and techniques.

SGSS.005724 New Network Device Scanning
The SNGS shall scan SN networks to detect new devices without disrupting normal SN operations.
Rationale: This helps to ensure the SNGS network stays secure and maintains top performance by ensuring unauthorized devices are not being installed on the network.

SGSS.005725 Antivirus Protection
The SNGS shall provide antivirus protection measures.
Rationale: Antivirus protection measures are used to find, remove or fix files that are infected with computer viruses. It is important that the SNGS operational network have the capability to automatically detect and eradicate viruses before they can cause harm to the system.

SGSS.005726 Security Alerts
The SNGS shall alert operations personnel of security incidents or anomalies.
Rationale: Security alerts provide timely notification that there is a current security issue, vulnerability, or exploit affecting the SNGS.

SGSS.005727 Auto-Discovery and Asset Status
The SNGS shall provide an automated reporting system that identifies all assets being protected and their status.
Rationale: The ability to auto-discover and provide the security posture status of those SNGS communications assets being protected is an important security reporting tool when performing audits, responding to security incidents or dealing with unauthorized intrusions into the SNGS network.

SGSS.005728 Automatic Security Configuration Updates
The SNGS shall allow automatic updates of security configuration information.
Rationale: In accordance with NPR 2810.1A, Section 16.5, designated SNGS operators must manage and control security configurations so that the system is the intended version (configuration) and that any changes to be made are reviewed for security implications. This requirement provides an automated way to update security controls.

SGSS.005729 SN Operator-Initiated Security Configuration Updates
The SNGS shall allow SN operators to update security configuration information.
Rationale: In accordance with NPR 2810.1A, Section 16.5, designated SNGS information systems operators must manage and control security configurations so that the system is the intended version (configuration) and that any changes to be made are reviewed for security implications. This requirement provides the ability to update security controls manually.

SGSS.005730 Application Partitioning
The SNGS shall allow separate security domains on a per application basis.
Rationale: Separating differing information system functions allows for better security practices as you can make one application (e.g. scheduling) more secure than other processing more mundane information (e.g. web browsers).

SGSS.005731 Security Function Isolation
The SNGS shall isolate security functions from non-security functions.
Rationale: Keeps your security mechanisms logically separated from those non-security-related functions which, in turn, reduces the risk of compromise of those security mechanisms in place.

SGSS.005732 Residual Information Transfer
The SNGS shall prevent unauthorized and unintended residual information transfer.

Rationale: This requirement prevents information, including encrypted representations of information, produced by the actions of a prior user/role from being available in the form of remnance (i.e. residual, leftover, etc) to any current user/role or process that obtains access to a shared system resource.

SGSS.005733 Denial of Service Protection
The SNGS shall protect against or limit the effects of denial of service (DoS) and distributed denial of service (DDoS) attacks.
Rationale: This requirement prevents the SNGS information system from being maliciously saturated with illegitimate external communications requests such that it cannot respond to legitimate traffic, or it responds so slowly as to be rendered effectively unavailable.

13.2.3 Data Flow Security

SGSS.005734 Information Flow Control
The SNGS shall control the flow of information within the system and between interconnected systems.
Rationale: This regulates where information is allowed to travel within the SNGS information system and between SNGS information systems and without explicit regard to subsequent accesses to that information.

SGSS.005735 Transmission Integrity
The SNGS shall protect the integrity of transmitted information.
Rationale: This ensures transmitted information is not altered or changed during transmission and is received in its intended state.

SGSS.005736 Transmission Confidentiality
The SNGS shall protect the confidentiality of transmitted information.
Rationale: This ensures transmitted information is not compromised (i.e. unauthorized disclosure) during transmission.

13.2.4 Data Confidentiality, Integrity, and Availability

SGSS.005737 Multifactor Authentication
The SNGS shall allow multifactor authentication.
Rationale: This adds another layer of protection for the SNGS by forcing users to provide more than one form of authentication or identification in order to verify their identity or legitimacy for access.

SGSS.005738 Session Authenticity
The SNGS shall provide mechanisms to protect the authenticity of communications sessions.
Rationale: This control focuses on communications protection at the session, versus packet, level. The intent of this control is to implement session-level protection where needed.

SGSS.005739 Use of Cryptography
The SNGS shall implement cryptographic mechanisms that comply with Federal Information Processing Standards Publication (FIPS PUB) 140-2 guidance.
Rationale: All cryptographic mechanisms implemented by Federal organizations must comply with FIPS PUB 140-2 as it provides a standard that will be used when these organizations specify that cryptographic-based security systems are to be used to provide protection for sensitive or valuable data.

SGSS.005740 Cryptographic Module Authentication
The SNGS shall employ authentication methods that comply with Federal Information Processing Standards Publication (FIPS PUB) 140-2 guidance for authentication to a cryptographic module.
Rationale: All cryptographic module authentication methods employed by Federal organizations must comply with FIPS PUB 140-2 as it provides a standard that will be used when these organizations specify that cryptographic-based security systems are to be used to provide protection for sensitive or valuable data.

SGSS.005741 PKI Certificates
The SNGS shall issue public key certificates following the NASA standard for Public Key Infrastructure (PKI).
Rationale: For user PKI certificates, it is mandated by Office of Management and Budget (OMB) Memorandum 05-24 that the SNGS use certificates from an agency certification authority cross-certified with the Federal Bridge Certification Authority at medium assurance. For NASA, this agency is the NASA Headquarters Office of Security and Program Protection.

SGSS.005742 Internal Encryption
The SNGS shall encrypt communications between SN facilities when required by security policy.
Rationale: Due to the sensitive nature of the telemetry and telecommunications data that will flow between SN facilities, it is necessary to ensure this data can be protected via encryption methods when necessary.

SGSS.005743 Audit Records
The SNGS shall generate audit records for SGSS-defined auditable security events.
Rationale: Events that are significant and relevant to the security of the information system must be captured in an audit log and serve as a means to provide a historical review, force accountability, reconstruct data or information, monitor intrusion detection and identify problems. SGSS-auditable events include, at minimum: accounting of user access, use of identification and authentication mechanisms, failed login attempts, devices used, process startup, attempted file access, introduction of objects into a customer's address space (e.g., file open, program initiation), deletion of objects, changes to user accounts, system changes, system backups, network performance, and actions taken by computer operators, system administrators and/or system security officers. The contents of these records must include at a minimum: the date and time of the security event(s), information to establish what security event(s) occurred, the sources of the event(s), and information to establish the outcomes of the security event(s).

SGSS.005744 Audit Processing Failures
The SNGS shall alert SN operations in the event of an audit processing failure or anomaly.
Rationale: Audit processing failure alerts will notify SNGS operators that significant security-relevant event(s) are no longer being captured due to an audit processing failure.

SGSS.005745 Non-Repudiation
The SNGS shall provide mechanisms that ensure SN operators and SN Users cannot repudiate their actions.
Rationale: Non-repudiation helps enforce user and data integrity. In addition, it protects against later false claims by an individual of not having taken a specific action, by an author of not having authored a particular document, a sender of not having transmitted a message, a receiver of not having received a message, or a signatory of not having signed a document.

13.3 Data Management and Storage

13.3.1 General Requirements

SGSS.005901 Common Storage
The SNGS shall maintain a common repository for stored SN data and products.
Rationale: A common repository will enhance the data integrity, eliminate the maintenance efforts associated with multiple repositories within the system, and ensure that all customers are seeing the same set of data.

SGSS.005902 Data Retention
The SNGS shall allow retention of SN internal data and products for the life of the SN.

Rationale: SN internal data flowing through the system will need to be retained as long as the SNGS is in operation, as this data is critical when there is a need to analyze system anomalies. SN internal data includes TDRS telemetry, commands, messages and service management data. It does NOT include user service data. Retention of user service data is addressed in other requirements.

SGSS.005903 Storage Access
The SNGS shall allow access to the SN mission dataset from any SN operations facility.
Rationale: Accessing data from any SN facility enhances availability and ensures that all operational functions are seeing the same set of data in the same format.

SGSS.005904 Storage Mirroring
The SNGS shall maintain duplicate synchronized datasets at all SN Operations Centers.
Rationale: The SNGS includes both a local and a remote backup operational capability. Storage data must be current in order to achieve seamless failover. Backup systems must mirror back to the primary system to allow the primary system to come back online.

SGSS.005905 Project Reference Dataset
The SNGS shall retain a project reference dataset containing detailed descriptions of the flight and ground segment configurations, operational parameters, and constraints.
Rationale: Provides a centralized repository for database information and facilitate easier and more reliable database maintenance. The set would include TDRS descriptors, commands, parameters, algorithms, characteristics, information required to operate each TDRS spacecraft, and information required to configure and maintain the ground segment. This requirement s is implied by GSFC-STD-1000, 3.14.

13.3.2 Primary Data Storage

SGSS.005906 Storage Retrieval Performance
The SNGS shall provide 5 years of archived engineering data for a single datum measured at a rate of 1Hz within 5 minutes from the time the request is received.
Rationale: Robust retrieval response time minimizes resource allocation for data retrieval tasks.

SGSS.005907 Most Recent Accessible Storage Data
The SNGS shall provide access to all processed data and products up to the requested time.
Rationale: Only the data processed at the time of the request can be retrieved.

SGSS.005908 System Documentation
The SNGS shall retain system documentation for the life of the SN Mission.
Rationale: Retaining Technical Specifications, design documents, training materials/certifications will give valuable insight on how the system works and who is trained in what areas for the next generation of support personnel.

SGSS.005922 Log Retrieval
The SNGS shall allow retrieval of log files based on user-defined search parameters.
Rationale: Operators are required to retrieve data based on various parameter searches for real-time and long-term analysis.

13.3.3 Reporting

SGSS.005909 Event-based Reports
The SNGS shall provide the capability for reports to be generated based on an event.
Rationale: Automated report generation reduces the work of the operations staff for reports that are needed when certain predefined events take place.

SGSS.005910 Predefined Reports
The SNGS shall provide predefined reports.
Rationale: Having pre-defined reports available, increases quality of report results and efficiency in the operations.

SGSS.005911 Operator-defined Reports
The SNGS shall allow SN operators to define and maintain reports.
Rationale: Having the ability to define and save new reports makes the operations function more efficient and able to provide better support.

SGSS.005913 On-Demand Report Generation
The SNGS shall allow generation of reports on demand.
Rationale: Operators must be able to produce reports on demand outside of scheduled report runs.

13.3.4 Offsite Backup

SGSS.005915 Offline Data Restoration
The SNGS shall allow restoration of the offline backup data.
Rationale: In order to be functional, the backup data must be able to be restored. Using media compatible with the system ensures that data can be restored to active storage, read, and processed.

SGSS.005916 Scheduled Backups
The SNGS shall perform backups of the primary data store based on a schedule.
Rationale: Backups performed automatically at designated times, reduce the operator intervention and improves efficiency.

13.3.5 Data Access

SGSS.005917 Legacy Data Access
The SNGS shall allow on-line access to all historical SN data and products.
Rationale: Access to historical data is necessary for trending, analysis, and anomaly resolution. This would include data produced prior to SGSS deployment which must be ingested and made available in the same manner as data and products ingested post-SGSS deployment.

SGSS.005918 Project Reference Dataset Management
The SNGS shall allow SN operators to manage stored project reference datasets.
Rationale: Operators need to be able to modify the project reference dataset as operational needs change over time.

SGSS.005919 Dataset Logging and Reporting
The SNGS shall log and report any changes to project reference datasets.
Rationale: Because of the criticality of the project reference dataset, it is important that any modifications are documented and reported.

SGSS.005920 Online Access
The SNGS shall provide online access to all SN documentation.
Rationale: Online access allows the operators quick and accurate access to the system data.

SGSS.005921 Fully Accessible Storage Data
The SNGS shall allow online access to the entire extent of stored data and products from the start of the archive until the most recent transaction.
Rationale: No speed penalty to access older data. All is equally accessible.

13.4 TDRS Encryption/Decryption

SGSS.005950 TDRS Command Encryption

The SNGS shall encrypt TDRS command data using only NSA-approved Type 1 encryption and authentication methods.

Rationale: The Space Network (SN) and TDRS assets are considered a Class A, Category 1 mission; therefore TDRS commands must be accurate, timely and in the correct format at all times. Encrypting these commands using only NSA-approved Type 1 encryption and authentication methods safeguards these commands from compromise, disclosure, or manipulation. This requirement also complies with NASA Procedural Requirements (NPR) 2810.1A, Security of Information Technology, Section 11.3.5.5.

SGSS.005951 TDRS Telemetry Decryption

The SNGS shall decrypt TDRS telemetry data using only NSA-approved Type 1 encryption and authentication methods.

Rationale: Decrypting TDRS downlink telemetry data using only NSA-approved Type 1 encryption and authentication methods safeguards this telemetry from compromise, disclosure, or manipulation.

SGSS.005952 Manual TDRS Encryption Bypass

The SNGS shall allow manual bypass of secure mode on the TDRS encryption equipment.

Rationale: This will allow SN operators to manually bypass the encryption equipment and send unencrypted commands to the TDRS (i.e. turn the secure mode off) in those situations when it is necessary to maintain the health and welfare of the TDRS.

Section 14. Continuity of Operations

14.1 General

SGSS.006002 30-Day Continuity
The SNGS shall be able to continue mission-essential SN operations during an emergency situation for a minimum of 30 days.
Rationale: Presidential Decision Directive (PDD) 67, Enduring Constitutional Government and Continuity of Government Operations, dated October 21, 1998, requires that Federal agencies implement the capability to continue mission-essential operations during a time of emergency. In addition, NPR 1040.1, NASA Continuity of Operations (COOP) Planning Procedural Requirements w/Change 1 (03/29/04), Section 3.3.2, specifies that the COOP is intended to implement a viable and effective essential function in an alternate location for a minimum of at least 30 days. The term "Mission essential" is defined to be The capability to provide monitoring and control of TDRS spacecraft sufficient to ensure TDRS spacecraft health and safety, plus the capability to provide SN User Services for all mission priority levels greater than "Normal Operations" (i.e., Emergency and Critical services).

SGSS.006003 Coordinated Primary Operations
The SNGS shall allow coordinated transfer of primary operations among SN operations centers.
Rationale: NPR 1040.1, Section 4.10.9, NPR 1040.1, Section 4.6.9.

SGSS.006020 Data Communications Reroute
The SNGS shall allow data communications traffic to be rerouted among SN operations centers.
Rationale: This requirement will provide a means to recover from a catastrophic natural or human-induced failure that occurs at both the primary and local backup SN operations facility. Comply with NPR 1040.1 (Section 3.3.2).

SGSS.006022 Software and System Data Backup
The SN shall maintain an up to date off-site backup of software and system data required to rebuild the SN ground segment in a location geographically separate from the primary SNOC.
Rationale: This requirement will provide a means to recover from a catastrophic natural or human-induced failure at any SN operations facility. Comply with NPR 1040.1 (Section 3.3.6.3, 3.3.6.6, 4.5.10, 4.5.12, and B.2.3) and NPR 8715.2a (Section 6.1.1).

SGSS.006033 Continuation of Commanding
The SNGS shall continue SN service support via schedule-based autonomous TDRS commands if communications with the Primary SNOC is lost.
Rationale: Maximize use of operational resources. There is no reason to terminate the schedule.

14.2 Local Backup SNOC

SGSS.006004 Local Backup SNOC (LBSNOC) Functional Equivalency
The SNGS shall maintain a local backup SNOC that is functionally equivalent to the primary SNOC.
Rationale: A redundant local operations facility containing all of the TDRS operations and user service functions of the primary operations facility will ensure continuity of operations and allow the SN to meet availability requirements in the event of an anomaly at the primary operations facility.

SGSS.006008 Remote Control from LBSNOC
The SNGS shall allow remote control of SN assets in any SN operations facility from the LBSNOC.

Rationale: If operations are transferred to the LBSNOC, operators will still require remote access to operational equipment at SN operations facilities (see table 3.5-1). Comply with NPR 1040.1 (Section 4.6.9) and NPR 8715.2a (Section 6.1.1.4).

SGSS.006009 Transfer of External Interface POPs

The SNGS shall maintain the integrity of external interfaces independent of the location of SN operations.
Rationale: TDRS Operations and User Services can still be offered when operating from the LBSNOC. To facilitate continuity of operations, the SN must be able to transfer external interface POPs to another location if circumstances dictate.

SGSS.006029 Redundant Operator Workspace

The SNGS shall provide operator workspace in the LBSNOC functionally equivalent to the primary SNOC.
Rationale: Operators will require a place to work if operations are transferred to the LBSNOC.

SGSS.006030 LBSNOC Transfer Of Operations Performance

The SN shall allow transfer of operations from the primary SN operations facility to the LBSNOC within 5 minutes of transfer initiation.
Rationale: A redundant local operations facility containing all of the TDRS operations and user service functions (including the operations control center) of the primary operations facility will ensure continuity of operations and allow the SN to meet availability requirements in the event of an anomaly at the primary operations facility. This is of primary importance with Human Spaceflight missions and users responsible for National Security. This will prevent the first generation of TDRS from beginning the ETO process.

SGSS.006034 GRGT Local Control

The SNGS shall provide local control at GRGT for IOR TDRS spacecraft TT&C and user services.
Rationale: In the event that land-line contact is lost with WSC, GRGT should provide the capability to continue TDRS health and safety functions and user services from a local control function.

SGSS.006035 LBSNOC Location

The Local Backup SNOC shall be located at the WSGT.
Rationale: The LBSNOC must be located in a physically separate facility from the primary SNOC and still local enough for fast transfer of operations to meet availability and continuity of operations requirements. WSGT provides these benefits, as well as being located within the same physical and IT security boundaries.

Section 15. RMA

15.1 Reliability

SGSS.006512 MTBF Definition
The SNGS shall determine mean time between failures (MTBF) in accordance with the SGSS MAR 458-MAR-0001.
Rationale: Standard calculation of MTBF is required to commonly determine availability.

15.2 Maintainability

SGSS.006501 Fault isolation
All SNGS equipment shall facilitate fault detection and fault isolation to the LRU level.
Rationale: Fault detection and isolation at the LRU level will decrease MTTR and enable short loop testing.

SGSS.006502 Maximum Time To Restore Service (General)
The Maximum Time To Restore Service for all User and TT&C services shall not exceed 10 seconds for 99.9 percent of failures, except in the case of failures of the secure equipment or failures of an antenna requiring switching to a backup antenna.
Rationale: Existing Users and operators expect this level of service from the SNGS. This level must be maintained as a minimum.

SGSS.006504 Maximum Time To Restore Service (Secure Equipment)
The Maximum Time To Restore Service in case of failure of the secure equipment shall not exceed 1 minute.
Rationale: Existing Users and operators expect this level of service from the SNGS. This level must be maintained as a minimum.

SGSS.006505 Maximum Time To Restore Operational Readiness (Antenna)
The Maximum Time To Restore Operational Readiness in case of failure of an antenna requiring switching to a backup antenna shall not exceed 10 minutes.
Rationale: Existing Users and operators expect this level of service from the SNGS. This level must be maintained as a minimum. Operational Readiness is defined as pointing an SGL antenna at a TDRS and radiating.

SGSS.006506 Mean Time To Repair
The mean time to repair (MTTR) for all equipment, except for repairs on antennas, shall not exceed 30 minutes.
Rationale: The MTTR has to be kept short to reduce the need for redundancy, which will reduce cost. The Mean Time To Repair to will include Level-1 maintenance only (see also [MAR 176]).

SGSS.006507 Maximum Time To Repair
The maximum time to repair, except for repairs on antennas, shall not exceed 1 hour for 90 percent of failures.
Rationale: The Maximum Time to Repair has to be kept short to reduce the need for redundancy. The Maximum Time To Repair to will include Level-1 maintenance only (see also [MAR 176]).

15.3 Availability

SGSS.006508 User Service Operational Availability

The SNGS shall provide an operational availability for User Services as defined in Table 15.3-1 for any period of 10,000 hours throughout the expected life of the system.

Table 15.3-1 Operational Availability

Service	WSC	GRGT
Each Single Access User Service, including tracking services	0.99990	0.99990*
Each Multiple Access User Service, including tracking services	0.99990	0.99990*
Each Cross Support User Service, including tracking services	0.99990	0.99990*
Each TDRS TT&C	0.99990	0.99990*
Non-critical support functions	0.9900	0.9900*

*The operational availability for GRGT are calculated including all elements needed to provide the service except the primary SNOC-GRGT communication links. Interface equipment to the primary SNOC-GRGT link is to be included. These numbers assume 1 spare antenna at WSC and 1 at GRGT.

Rationale: Consistent with current specifications. The operational availability for GRGT is to be calculated including all elements needed to provide the service except the communication link between WSC and GRGT. Interface equipment to the WSC-GRGT link is to be included.

SGSS.006511 TDRS TT&C Operational Availability

The SNGS shall provide an operational availability for TDRS TT&C as defined in Table 15.3-1 for any period of 10,000 hours throughout the expected life of the system.

Rationale: Consistent with current specifications. The operational availability for GRGT is to be calculated including all elements needed to provide the service except the communication link between WSC and GRGT. Interface equipment to the WSC-GRGT link is to be included.

SGSS.006513 Non-Critical Support Functions Operational Availability

The SNGS shall provide an operational availability for non-critical support functions as defined in Table 15.3-1 for any period of 10,000 hours throughout the expected life of the system.

Rationale: Consistent with current specifications. Non-critical support functions include all functions which do not provide real-time SN service support.

SGSS.006514 BPGT Support Operational Availability

The SNGS shall provide an operational availability of 0.999950 for TDRS TT&C services to the BPGT interface, excluding the primary SNOC-BPGT communications link.

Rationale: Overall availability of the BPGT is expected to be 0.99990. Availability of the equipment and services to the interface must be higher. SGSS will only provide equipment and services up to the interface.

Section 16. Maintenance and Training Facility

16.1 Hardware Maintenance & Test

SGSS.007001 LRU Diagnostic Tools
The SNGS shall provide LRU-level diagnostic tools.
Rationale: Isolating an SNGS hardware fault to a Line Replaceable Unit is necessary to accomplish the maintenance philosophy of SGSS.

SGSS.007002 Hardware Calibration Tools
The SNGS shall provide SN hardware calibration tools.
Rationale: Calibration equipment is required to keep the SNGS hardware operating at optimal levels to support user missions and TDRS Health and Safety.

SGSS.007003 Front Panel Test Points
The SNGS shall provide front panel test points on each LRU.
Rationale: Front panel test points can be used by maintenance technicians to isolate problems/failures to the LRU level.

SGSS.007004 Preventive Maintenance Scheduling
The SNGS shall generate preventive maintenance schedules based on subsystem and component maintenance schedules and SNGS performance trending data.
Rationale: A preventive maintenance schedule facilitates PM to be performed on a scheduled basis. SNGS performance trends can also drive preventive maintenance. This information should be forwarded to SM in the form of SN Schedule requests.

SGSS.007005 Automatic Maintenance Scheduling
The SNGS shall process automated preventive maintenance schedule requests based on SN resource status trending.
Rationale: This function allows automated scheduling of SN resource maintenance based on persistent or worsening resource status information. This may prevent service interruption from resource failure by taking it out of the schedule prior to failure.

SGSS.007048 SNGS Hardware Modification Testing
The SNGS shall be capable of integrating and testing future Ground Segment hardware changes and modifications.
Rationale: The SNGS s required to be extensible and expandable. Integration and Test of hardware to support these qualities is necessary to meet those fundamental requirements.

16.2 Software Maintenance & Development

SGSS.007006 Simulation with FSW Loads
The SNGS shall provide the capability to simulate operations with new or modified TDRS flight software loads prior to uplink to the spacecraft.
Rationale: Simulation of operations with new or modified FSW Loads for TDRS F8+ allows the SNGS to test the new code or updates in a flight-like environment which increases the validity of the test.

SGSS.007007 Simulation with TDRS Table Loads
The SNGS shall provide the capability to simulate operations with new or modified TDRS table loads prior to uplink to the spacecraft.

Rationale: Simulation of operations with new or modified TDRS table loads (for TDRS F1-F7) allows the SNGS to test the new or updated tables in a flight-like environment which increases the validity of the test.

SGSS.007008 Simulation with Command and Telemetry Databases
The SNGS shall enable simulation of operations with new or modified command and telemetry databases prior to use in operations.
Rationale: Simulation of operations with new or modified command and telemetry databases allows the SNGS to test the new or modified commands and/or telemetry in a flight-like environment which increases the validity of the test.

SGSS.007009 Flight Software and Table Loads from Vendor
The SNGS shall accept TDRS flight software loads and table loads from the spacecraft vendor.
Rationale: New or updated FSW and table loads will be delivered from the spacecraft Vendors, and the SNGS requires the ability to accept the delivery.

SGSS.007010 Flight Software and Table Loads to Operations
The SNGS shall allow transfer of verified TDRS flight software and tables loads from the test environment to the operational environment.
Rationale: Verified TDRS FSW Loads and TDRS Table loads need to be uplinked to the spacecraft after verification, so delivery to operations is necessary.

SGSS.007011 Software Engineering and Development Tools
The SNGS shall provide software engineering and development tools.
Rationale: Accommodations such as reverse engineering tools, code conversion tools, compilers, etc. are required to facilitate on-going software maintenance, upgrades and new feature development.

SGSS.007012 System Development Environment
The SNGS shall provide a off-line system development environment functionally equivalent to and separate from the operations environment.
Rationale: This environment is required to support on-going software and hardware maintenance and development efforts. It must remain separate from the operations environment (and all other environments) to prevent corruption of operations from these efforts. The intent is for this environment to exist separately and distinctly from any other environment required, and to enable activities in this environment in parallel with any and all other environments.

SGSS.007013 Data Set Conversion
The SNGS shall convert and translate vendor-supplied data sets into data sets compatible with the operational SN.
Rationale: This is required to ingest data such as new telemetry and command database. There may be other data types associated with transitioning a new TDRS spacecraft to operations.

16.3 Simulation/Model Development and Maintenance

SGSS.007014 SN Data Flow Model
The SNGS shall provide a data flow model of the entire SN including computing and network performance and external interface points.
Rationale: This functionality provides an efficient way to monitor ground segment performance without any potential impact to operations, to support processing resource allocation and to predict system performance under varying workloads and to change ground segment parameters in a virtual sense to optimize performance. The modeling should include external interfaces.

SGSS.007015 SN Performance Model
The SNGS shall provide a performance model of the entire SN to the LRU level, including external interface points.

Rationale: The SNGS should provide such a capability in support of more efficient and timely scheduled and unscheduled maintenance activities. These models may be used by the scheduler to determine the impacts of equipment failure or maintenance activities on system services availability, and by engineering to model new hardware before deployment to the operational environment.

SGSS.007016 Simulator Development and Maintenance Environment
The SNGS shall provide a simulator development and maintenance environment.
Rationale: The simulator development and maintenance environment is used to develop and update simulations and models used in testing, analysis and training within the SNGS. It is used to create new models and simulations and to maintain existing models and simulations. The intent is for this environment to exist separately and distinctly from any other environment required, and to enable activities in this environment in parallel with any and all other environments.

SGSS.007017 Simulation of Flight and Ground Segment Anomalies
The SNGS shall enable simulation of flight segment and ground segment anomalies in the simulation environment.
Rationale: The capability to simulate Ground and Flight-based anomalies in the Operations Simulation environment allows testing and training to be more realistic and thus more valuable.

SGSS.007018 Simulation of Security Events
The SNGS shall allow simulation of security anomalies and events.
Rationale: The heightened importance of IT and Physical Security requires this capability to provide realistic testing and training.

SGSS.007019 Simulation of Normal Operations
The SNGS shall enable simulation of normal operations.
Rationale: This includes single TDRS and TDRS fleet operations.

SGSS.007020 Simulation of MOC
The SNGS shall simulate a generic MOC.
Rationale: The generic MOC can be a signal source and sink during simulations and testing. All SM/MOC messaging should be simulated.

SGSS.007021 High Fidelity Simulator (F1-F7)
The SNGS shall provide a high-fidelity simulator for TDRS F1-F7.
Rationale: This is required to accurately simulate spacecraft operations and facilitate anomaly resolution. The models must include accurate flight dynamics models, respond to commands and send telemetry as the actual TDRS spacecraft would. The models should include the capability to induce spacecraft anomalies of various classes for each subsystem and the telecommunication payload.

SGSS.007022 High Fidelity Simulator (F8-F10)
The SNGS shall allow integration of the High Fidelity TDRS HIJ Emulators as provided by the Space Network.
Rationale: This is required to accurately simulate spacecraft operations and facilitate anomaly resolution. The simulator must be integrated into the SNGS after delivery.

SGSS.007023 High Fidelity Simulator (TDRS-K, L and future)
The SNGS shall allow integration of the high fidelity emulators for TDRS K and L and future generation TDRSs when delivered by the Space Network.
Rationale: This is required to accurately simulate spacecraft operations and facilitate anomaly resolution. The simulator must be integrated into the SNGS after delivery.

SGSS.007043 TDRS Fleet Simulation
The SNGS shall simulate the entire TDRS fleet.

Rationale: The ability to simulate the entire TDRS Fleet provides the ability to test the Fleet Management Software and run full fleet simulations for test and development.

SGSS.007044 High Fidelity Simulator (Ground Segment)
The SNGS shall provide a high fidelity ground segment simulator.
Rationale: The ground segment simulator will replace the current HSIM and will be based on the final design of the ground segment.

SGSS.007046 Stand Alone End-to-End Training Simulator
The SNGS shall provide a software training simulator.
Rationale: The training simulator would be a simulator based on a single computer that will be used to start training of new satellite operators.

SGSS.007047 SNGS Simulators
The SNGS shall simulate all types of SN message traffic.
Rationale: The SNGS will require some method of simulating the scheduling capability of the SN Scheduler as well as a method to create state vectors, ODMs, OPMs and SHOs in order to provide fidelity for testing, training, and development.

16.4 Software Testing

SGSS.007025 Test Environment
The SNGS shall provide an off-line integration and test environment identical in hardware and software to the operations environment.
Rationale: This environment is required to support the formal integration and test processes for new or modified SN software and hardware in a "test as you fly" mode and using Hardware in the Loop testing. This will minimize the risk of introducing anomalies migrating from one environment to another. This also provides a capability to support acceptance test of any element or collection of elements of the SNGS. The intent is for this environment to exist separately and distinctly from any other environment required, and to enable activities in this environment in parallel with any and all other environments.

SGSS.007026 Automated Software Test Tools
The SNGS shall provide automated software test tools.
Rationale: These tools facilitate efficient baseline and regression testing of SN software prior to migration to operations. Automated tools can determine that the software is developed and maintained according to the specified standards must be provided. Tools must include auditors to determine that software is structured, units are of appropriate length, units are structured, and program, file and data variables are named according to the established standard. Reports must tabulate the results of audit.

SGSS.007028 Simulation Data to Ops Environment
The SNGS shall enable the transfer of simulation data to the operational environment in support of end-to-end ground segment operational testing ONLY.
Rationale: This is so test services can receive sim data internally and remotely, and the Operational FWD/RTN services can process it as if it were a real user.

16.5 System Configuration Management

SGSS.007029 Hardware and Software Configuration Management
The SNGS shall provide integrated configuration management of all system hardware and Software elements, interfaces, interconnections, and documentation, including effective change control of processes and procedures.
Rationale: Hardware and Software configuration must be tracked in a system as large as the SN Ground Segment, to allow operators and maintainers to identify, control, account and audit the configuration

items of the SN Hardware and Software to support maintenance and operation and manage version control of software releases.

SGSS.007030 Configuration Management (CM) of Flight Data and Code
The SNGS shall maintain configuration controlled digital images of all operational flight code.
Rationale: Anomalies that cause corruption of onboard flight code require a reload of the image and analysis of suspected events from the flight code will include a downlink dump and comparison of the onboard code with the configured image on the ground.

SGSS.007031 CM of Flight Code Patches
The SNGS shall maintain configuration controlled digital images of all TDRS flight code patches.
Rationale: All date in the form of tables and executable code uplinked to the TDRSs is retained and protected for anomaly recovery, reuse, reporting, or analysis.

SGSS.007032 Flight Code Management External Interface
The SNGS shall allow ingest of flight code images from external sources.
Rationale: New and revised flight code is necessary to accommodate the discovery of new requirements from aging, early mission failures, and enhancements can originate from the spacecraft vendor and subcontractors to the vendor.

SGSS.007033 Maintenance/Asset Management
The SNGS shall manage SN hardware, software, and facility resource maintenance.
Rationale: NASA is replacing its legacy systems for equipment and property management with a new Integrated Asset Management/Property Plant and Equipment (IAM_PP&E) System. [NASA IRM Strategy Plan September 2007]. The new system provides an integrated capability that enables greater tracking and visibility of assets for logistics and bridges the gap between finance and logistics. Levying Asset Management and similar requirements on the SGSS Project will help ensure the sustained Ground Segment makes maximum and efficient use of the new IAM_PP&E system. Other capabilities include discrepancy reporting, maintenance planning and scheduling, work orders and workflow management, all maintenance records and statistics on maintenance tasks, and third party maintenance data and report generation (canned and custom).

SGSS.007034 Integrated Maintenance Management System
The SNGS shall integrate maintenance management with configuration management.
Rationale: Integrated CM and Maintenance Management systems enables sharing of information between the two functions. A single source of information and documentation such as ECRs, DRs, Work orders and maintenance procedures integrated with workflow function enables efficient maintenance and configuration management, accounting and auditing. The intent is for the new SNGS Maintenance Management System to absorb all Legacy maintenance data in all of its formats, so as not to lose continuity of SN maintenance history.

16.6 Training

SGSS.007035 Training Environment
The SNGS shall provide an off-line training environment identical in hardware and software to the operations environment.
Rationale: This type of environment is necessary to support training activities which replicate as closely as possible the operational and maintenance activities, without impacting operations. One intent is to replicate the Operations Control Center which provides the most realistic training environment and adds value to the operations training. This environment should include all User data processing, planning and scheduling and monitor and control hardware and software but may exclude the end to end test systems, antenna systems for signals to and from TDRS beyond the antenna drive electronics, and any enterprise infrastructure for the Ground Segment. This environment is intended to exist separately and distinctly

from any other environment required, and to enable activities in this environment in parallel with any and all other environments.

SGSS.007036 Anomalies in the Training Environment
The SNGS shall enable instructors to induce anomalies in the training environment.
Rationale: The capability to induce anomalies onto a normal operations simulation/training environment is required to train and test all operations and maintenance activities.

SGSS.007037 Operations Control Center Replication
The SNGS shall replicate the operations control center environment and interfaces in the training environment.
Rationale: The replication of the Operations Control Center provides the most realistic training environment and adds value to the training

SGSS.007038 Hardware and Software Maintenance Training
The SNGS shall enable hardware and software maintenance training in the training environment.
Rationale: Training in hardware and software maintenance activities is necessary to keep the SNGS running at its most efficient level.

SGSS.007039 Operations Training
The SNGS shall enable TDRS operations training in the training environment.
Rationale: TDRS operations training should include normal operations and anomaly operations. A certification process should exist to ensure operators are well qualified; and a proficiency training program to maintain that assurance.

SGSS.007040 Remote Access to Training Resources
The SNGS shall enable access to training resources from any SN operations facility.
Rationale: Required to maintain a high-level of System-wide personnel proficiency while minimizing travel expenses. This functionality is especially important in the face of a large number of anticipated personnel retirements over the next decade.

SGSS.007041 On-Line Training
The SNGS shall provide on-line training instruction.
Rationale: Self-paced, computer-based online instruction for some academic training subjects can be an effective and efficient method of such training under certain circumstances.

SGSS.007042 Ingest of Operational Data
The SNGS shall enable ingest of operational data in real-time or recorded modes into the training, test, simulation, and development environments.
Rationale: This is required to train operations personnel without impact to normal operations. This is a "push" mode ONLY with no data flowing from the training environment to the operational environment, except as stated in Software Testing above.

Section 17. Interfaces

17.0 SNGS Interfaces Overview

17.1 External SN Interfaces

SGSS.007501 SN Inter-Facility Interface
The SNGS shall use NISN networks services between SN and NASA affiliated entities as defined in the SGSS-NISN/NOMC Services IRD's (458-IRD-0001 and 458-IRD-0002).
Rationale: Per NASA policy NISN networks should be used for all mission data communication services between SN and other NASA facilities including SN Users.

SGSS.007502 SN Intra-Facility Interface
The SNGS shall use NISN network services for communication among non-collocated SN ground facilities as defined in the SGSS-NISN/NOMC Services IRD's (458-IRD-0001 and 458-IRD-0002).
Rationale: Per NASA policy NISN networks should be used for all mission data communication services between SN and other NASA facilities including SN Customers/Users.

SGSS.007503 NASCOM Operations Management Center (NOMC)
The SNGS shall interface with the NISN Operations Management Center (NOMC) located at GSFC as defined in SGSS-NISN/NOMC Services IRD's (458-IRD-0001 and 458-IRD-0002).
Rationale: This interface is needed to exchange NISN network status and performance data between SGSS monitor and control functions and NISN Operations Centers. It is meant to improve (compared to current manual process) situational awareness of the SNGS intra-facility communication status and facilitate automatic reporting of network problems (trouble ticket issue), as well as improved troubleshooting by NISN staff.

SGSS.007504 FDF Interface
The SNGS shall interface with the Flight Dynamic Facility (FDF) at GSFC as defined in the SGSS-FDF IRD (458-IRD-0003).
Rationale: The SNGS needs to communicate with FDF which provides orbit determination services for TDRS and SN Users. TDRS ranging data (based on BRTS tracking) will be sent to the FDF; while the FDF will send TDRS and User space platform state vectors to SNGS.

SGSS.007505 SN User Interface
The SNGS shall interface with SN Users as defined in the SGSS-User MOC IRD (458-IRD-0004).
Rationale: This is a key interface that provides functional and terrestrial physical connection between SN Users and SNGS. It enables SN Users to schedule a service and provides "final leg" of the SN User's mission data relay and space platform tracking services. Legacy interface will be supported while new interfaces will be developed and be compatible to CxP project requirements. This functional interface requirement includes interfaces to SN User MOCs. The physical layer of the interface is provided by NISN services.

SGSS.007506 NEN Interface
The SNGS shall interface with the NEN as defined in the SGSS-NEN IRD (458-IRD-0006).
Rationale: This interface is needed for contingence S-band TDRS TT&C communication and is also utilized during TDRS longitudinal repositioning and SN antenna maintenance.

SGSS.007507 DSN Interface
The SNGS shall interface with the Deep Space Network (DSN) as defined in the SGSS-DSN IDD (458-IDD-0004).
Rationale: This interface is needed for contingency S-band TDRS TT&C communication. This is also utilized during TDRS repositioning and SN antenna maintenance.

SGSS.007508 GSFC Network Integration Center (NIC) Interface
The SNGS shall allow remote access to the operational SN ground systems at the primary SNOC from the NIC.
Rationale: The NIC must be able to access the operational side of the SNGS to support human space flight and provide scheduling capability for NIMO in support of test services for new missions. NIC access is controlled by the same security rules that govern all other remote access attempts.

SGSS.007516 ULE Interface
The SNGS shall interface with the User Local Equipment (ULE) as defined in the SGSS-ULE IRD (458-IRD-0005).
Rationale: The ULE customer interfaces are a unique and separate interface at the WSC, GRGT and BPGT. This key interface provides functional and terrestrial physical connection between ULE users and SNGS. This functional interface requirement includes interfaces to the user MOCs. The physical layer of the interface is provided via User Local Equipment (ULE).

17.2 Internal SN Interfaces

SGSS.007510 ATF Interface
The SGSS system shall interface with the Australian TDRS Facility (ATF) as defined in the SGSS-ATF IDD (458-IDD-0002)
Rationale: SGSS is required to monitor and control all SN operational resources including ATF. Because ATF is out of scope for SGSS, an interface to legacy equipment must be developed for monitor and control of ATF resources.

SGSS.007511 BRTS Interface
The SGSS system shall interface with the Bilateration Ranging and Transponder System (BRTS) as defined in the SGSS-BRTS IDD (458-IDD-0003)
Rationale: SGSS is required to monitor and control all SN operational resources including each of the four BRTS stations. Because BRTS is out of scope for SGSS, a monitor and control interface to legacy equipment must be developed.

SGSS.007512 SN Ground Antenna Mechanical System Interface
The SGSS system shall interface with the ground antenna mechanical systems as defined in the SGSS-Ground Antenna Mechanical System IDD (458-IDD-0001).
Rationale: SGSS is required to monitor and control SN ground antenna resources including operational antennas and test antennas. Because existing antenna mechanical systems are out of SGSS scope, an interface to what will be considered legacy equipment after SGSS implementation must be developed for monitor and control of ground antenna resources.

SGSS.007513 SNE-East Interface
The SGSS system shall interface with the Space Network Expansion - East (SNE-E) as defined in SGSS-SNE East IRD (458-IRD-0009).
Rationale: SGSS is required to monitor and control SN resources including SNE-E. While SNE-E is in scope for SGSS, it will be the last system upgraded. A monitor and control interface must be developed to legacy SNE-E equipment and systems until SNE-E is upgraded.

SGSS.007514 TDRS Telemetry Tracking & Command (TT&C) Interface
The SGSS system shall interface with TDRS spacecraft as defined in the TDRS RF ICD (TDRS F1-F7 RF ICD STDN 220.29; TDRS F-7 ICD for the TDRS Spacecraft/Ground Segment (10/1993) 405-F7-ICD-001; and TDRS F8-F10 RF ICD DS80409-H00-003 Rev D).
Rationale: This is a key interface that enables RF link between ground and space segment and is used to support SN services.

SGSS.007515 SN Facilities Interface
The SGSS system shall interface with the SN facilities at WSC, BPGT, GSFC, GRGT.
Rationale: Since facilities are out of SGSS scope, the SGSS system will interface with the existing SN facilities at WSC, BPGT, GSFC, GRGT. This interface will include power plant (electric power, HVAC), physical structure, phone and dedicated mission voice systems.

SGSS.007517 Collimation Equipment Interface at WSC
The SGSS system shall interface with the collimation tower located at Blue Mesa.
Rationale: The collimation equipment is necessary for SN ground segment SGL antenna calibrations after corrective and preventive maintenance activities on the antenna.

17.3 Internal SGSS Interfaces

Reserved

Section 18. Reserved

Appendix A Acronyms

Acronym	Description
8PSK	8-Phase Shift Key
ACN	Ascension Island
ADR	Achievable Data Rate
ALS	Alice Springs, Australia
AM	Amplitude Modulation
AMS	Antenna Mechanical System
AOR	Atlantic Ocean Region
AOS	Advanced Orbiting System
API	Application Program Interface
ATF	Australian TDRS Facility
AWE	Alarm, Warning & Event
AZ/EL	Azimuth/Elevation
Ao	Operational availability
BER	Bit Error Rate
BPGT	Blossom Point Ground Terminal
BPSK	Binary Phase Shift Key(ing)
BRTS	Bilateration Ranging Transponder System
BRTSA	Bilateration Ranging Transponder System Augmentation
CCB	Configuration Control Board
CCSDS	Consultative Committee for Space Data Systems
CDMA	Code Division Multiple Access
CF	Center Frequency
CLTU	Command Link Transmission Unit
CM	Configuration Management
CMD	Command
CMM	Capability Maturity Model
COOP	Continuity of Operations Plan
COTS	Commercial Off The Shelf
CRC	Cyclic Redundancy Check
CTV	Compatibility Test Van (GSFC)

Acronym	Description
CW	Continuous Wave
CxP	Constellation Program
DARPA	Defense Advanced Research Projects Agency
DAS	Demand Access Service
DDoS	Distributed Denial of Service
DIS/USSR	Data Interface System / User Service Subsystem Replacement
DSN	Deep Space Network
DVB-S2	Digital Video Broadcasting – Satellite
DoS	Denial of Service
DoS	Denial of Service
EET	End-To-End Test
EIRP	Effective Isotropic Radiated Power
ETGT	Extended TDRSS Ground Terminal
ETO	Emergency Time Out
Eb/No	Energy per Bit-To-Noise Power Spectral Density Ratio
F<number>	TDRS Flight Number
FDF	Flight Dynamics Facility
FDM	Frequency Division Multiplex
FEC	Forward Error Correction
FSW	Flight Software
G/T	Gain-To-Noise Temperature Ratio
GBBF	Ground-Based Beam Forming
GCI	Geocentric Inertial
GCMR	Ground Control Message Request
GHz	Gigahertz
GN	Ground Network
GPD	Goddard Procedural Directive
GPR	Goddard Procedural Requirements
GPS	Global Positioning Satellite
GRGT	Guam Remote Ground Terminal
GSFC	Goddard Space Flight Center
HDLC	High-Level Data Link Control
HPA	High Power Amplifier
HVAC	Heating, Ventilation, and Air Conditioning

Acronym	Description
HW	Hardware
I/F	Interface
IDD	Interface Definition Document
IETF	Internet Engineering Task Force
IF	Intermediate Frequency
IIRV	Improved Inter-Range Vectors
IOR	Indian Ocean Region
IPSec	IP Security
IRD	Interface Requirements Document
IRT	Independent Review Team
IRU	Inertial Reference Unit
IT	Information Technology
JPL	Jet Propulsion Laboratory
KaSA	Ka-band Single Access
KaSAF	Ka-Band Single Access Forward
KaSAR	Ka-Band Single Access Return
KuSA	Ku-band single access
KuSAF	Ku-Band Single Access Forward
KuSAR	Ku-Band Single Access Return
LDPC	Low Density Parity Check
LNA	Low Noise Amplifier
LOR	Line Outage Recorder
LRU	Line-Replaceable Unit
M&C	Monitor and Control
MA	Multiple Access
MAR	Multiple Access Return
MET	Mission Elapsed Time
MHz	Megahertz
MILA	Merritt Island Launch Annex
MOC	Mission Operations Center
MSRD	Mission Systems Requirements Document
MTRS	McMurdo TDRS Relay System
MTTR	Mean Time to Repair
Mbps	Mega bits per second

Acronym	Description
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
NEN	Near Earth Network
NIC	Network Integration Center
NISN	NASA Integrated Services Network
NIST SP	National Institute of Standards Technology Specification
NOMC	NASCOM Operations Management Center
NPR	NASA Procedural Requirement
NRZ	Non-Return to Zero
NSA	National Security Agency
NTP	Network Time Protocol
OD	Orbit Determination
ODMs	Operations Data Messages
OMB	Office of Management and Budget
OPM	Operations Message
OSHA	Occupational Safety and Health Administration
OTS	Operational Test System
PDD	Presidential Decision Directive
PKI	Public Key Infrastructure
PM	Phase Modulation
PN	Pseudo-Noise
POPs	Points of Presence
POR	Pacific Ocean Region
PSK	Phase Shift Key
PSNOC	Primary SNOC
QPSK	Quadrature Phase Shift Keying
QUASARs	Quasi Stellar Radio Sources
RAF	Return All Frames
RAM	Random Access Memory
RCF	Return Channel Frames
RCTD	Return Channel Time Delay
RF	Radio Frequency
RFICD	Radio Frequency Interface Control Document
RFP	Request for Proposal

Acronym	Description
RFSOC	Radio Frequency Simulation Operations Center
RHC	Right-Hand Circular (antenna Polarization)
RLSNOC	Redundant Local SNOC
RMA	Reliability/Maintainability/Availability
ROCF	Return Operational Control Frames
RS	Reed Solomon
SA	Single Access
SAF	Single Access Forward
SBBF	Satellite-Based Beam Forming
SCCS	Space Communications Cross Support
SCaN	Space Communication and Navigation
SD	Sweep Duration
SGL	Space-Ground Link
SGSS	Space Network (SN) Ground Segment Sustainment
SLE	Space Link Extension
SMA	S-band Multiple Access
SMAF	S-band Multiple Access Forward
SMAR	S-Band Multiple Access Return
SN	Space Network
SNE	Space Network Expansion
SNEF	Space Network Engineering Facility
SNGS	Space Network Ground Segment
SNMP	Simple Network Management Protocol
SNOC	Space Network Operations Center
SNUG	Space Network Users Guide
SOC	Simulations Operations Center
SPTR	South Pole TDRSS Relay
SQPN	QPSK with staggered chip direct sequence PN spreading
SQPSK	Staggered Quad Phase Shift Keying
SR	Sweep Range
SRD	Systems Requirements Document
SRR	Systems Requirements Review
SSA	S-band Single Access
SSAF	S-band Single Access Forward

Acronym	Description
SSAR	S-band Single Access Return
SSL	Space-To-Space Link
STD	Standard
STDN	Space Tracking and Data Network
STGT	Second TDRSS Ground Terminal
STS	Space Transportation System
SW	Software
TBD	To Be Determined
TBR	To Be Resolved
TC	Telemetry Command
TCP	Transmission Control Protocol
TDM	Tracking Data Message
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TFR	Time and Frequency Reference
TLM	Telemetry
TT&C	Tracking, Telemetry, and Command
TUT	TDRS Unscheduled Time
TVA	Threat and Vulnerability Assessments
TWT	Traveling Wave Tube
UDP	User Datagram Protocol
UDP/MC	User Datagram Protocol/Multicast
ULE	User Local Equipment
UPD	User Performance Data
USA	User Service Access
USN	Universal Space Networks
USSR	User Service Subsystem Replacement
UTC	Universal Time Coordinated
UTDF	Universal Tracking Data Format
VPN	Virtual Private Network
WSC	White Sands Complex
WSGT	White Sands Ground Terminal
dB	Decibel
kbps	kilobits per second

Appendix B Glossary

Term	Definition
Acquisition Data	Spacecraft orbit data used to determine TDRS antenna pointing and Doppler compensation. This includes IIRVs.
Active Scheduling Phase	The Active Scheduling Phase follows the Planning Schedule Phase and begins with the publishing of scheduled events and any unscheduled TDRS time. SN Users are notified of the status of their service requests (accepted/scheduled, rejected, modified) and when their service is scheduled. Unscheduled time pertinent to the User's profile is identified in that User's scheduling view. Operators can override the scheduling system for arbitration of schedule conflicts that are not readily resolved by the system's de-confliction algorithms. The Active Scheduling Phase ends when events are assigned to the monitor and control system for execution in the Operational Scheduling Phase.
Advanced Orbiting System (AOS)	The CCSDS Recommendations which cover the telemetry protocol stack and services used on most robotic NASA space missions
Alarms, Warnings and Events (AWE)	Triggered alerts for operators in response to limit violations and/or events. Three categories (alarm, warning, event) are used to distinguish audible and visual cues, as well as response requirements.
Authentication	The process of ensuring the user (i.e., customer or operator) of system or a service is in fact allowed to be using or accessing the system or service. The most common example of user authentication is the user password, but there are other methods available to authenticate a user.
Baseband	A communication system in which information is carried in digital form on a single unmultiplexed signal channel on the transmission medium.
Channel	Link subdivision used for information transfer and/or two-way range measurement.
Collimation Tower	A tower on which a visual and a radio target are mounted for use in calibrating the electrical axis of an antenna. WSC personnel perform periodic antenna calibration utilizing the Blue Mesa Collimation Tower.
Configuration System	Maintenance of an up-to-date record of configuration item (CI) status and characteristics.
Critical Service Request	A request for service that does not constitute an emergency, but involves one of the following: launch and early orbit phase support, human spaceflight mission support, spacecraft operations (e.g., maneuvers), human spaceflight mission Critical Pre-mission Testing, or science (e.g., target of opportunity). Support to Special Programs and Missions per Partner Agreements are also considered to be Critical Services, although scheduling for these services is handled in a different fashion.
Critical Software Command	A command that either removes a safety inhibit or creates a hazardous condition.
Cross Support	The utilization of one TDRS spacecraft to supply different forward and return link telecommunications services (e.g., MA forward and SSA return)

Term	Definition
	simultaneously. See SNUG Rev. 9, Section 3.2.3.
Data Group 1 (DG1)	Uses spread spectrum
Data Group 1, Mode 1	DG1 mode 1 must be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service low-rate data transmission. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate to identify each data channel unambiguously without requiring a unique PN code for each channel.
Data Group 1, Mode 2	DG1 mode 2 will be used when WSC return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS (MA or SSA)Forward service (noncoherent transponder operation). For DG1 mode 2, the I and Q channel PN codes are unique 211-1 Gold Codes.
Data Group 1, Mode 3	DG1 Mode 3 can be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service high-rate data transmission. In DG1 mode 3, the Q channel must contain only data and no PN code.
Data Group 2	Does not use spread spectrum
Data Rate	Rate of a digital information data signal before convolutional encoding and/or conversion to biphase format
Emergency Service Request	A request for service that involves an imminent hazard to humans or a spacecraft emergency.
End to End Test (EET)	Use of SNGS test antennas and systems to simulate User platform Ku-, Ka- and S-band communications.
Event	The scheduled occurrence of support consisting of a group of services and activities for one User for one TDRS for one contiguous time interval. The event includes pre-service (e.g., set-up, pre-service test) and post-service(e.g., rate buffered data transmission) activities
Extensibility	The system's ability to satisfy users through its lifespan depends upon the degree of extensibility architected in the original design. Areas of expected capability expansion may include modulation, data types, automation, signal processing techniques, protocols, and emerging interface standards. Extensibility implies a system design principle where the implementation takes into consideration future growth. It is a systemic measure of the ability to extend a system and the level of effort required to implement the extension. Extensions can be through the addition of new functionality or through modification of existing functionality. The central theme is to provide for change while minimizing impact to existing system functions.
Flexibility	Uncertainty within the ground system domain includes concepts such as adaptable operator interfaces, individual spacecraft idiosyncrasies, generational spacecraft idiosyncrasies, and user demands. Flexibility allows for adaptations to these uncertainties, or more specifically allows for adaptations that can support decisions made regarding these uncertainties.
Forward Link	The uplink from a User ground site via SN to a User platform. Forward denotes the direction from the TDRS to the user platform.
Guam Remote Ground Terminal	This is s combination of the facilities and equipment located in the SN facilities on Guam. These are commonly referred to as SGLT-6 and SGLT-7 (SNE-W)

Term	Definition
(GRGT)	in the legacy system.
Hazardous Command	A command whose execution (including inadvertent, out-of-sequence, or incorrectly executed) could lead to an identified critical or catastrophic hazard, or a command whose executions can lead to a reduction in the control of a hazard (including reduction in failure tolerance against a hazard or the elimination of an inhibit against a hazard).
I Channel	Data channel supported by 0 degree and 180 degree phase modulation of the reference carrier
Inherent availability (Ai)	The inherent availability is the probability that a system or equipment, when used under stated conditions in an ideal support environment (i.e., using available tools, spares, and personnel) will operate within specifications at all times. It excludes preventive maintenance actions, logistics supply time, and administrative downtime and is expressed as Ai = MTBF/(MTBF + MTTR) where MTBF = mean time between failures and MTTR = mean time to repair.
Interface	1) A boundary between system of interest (SOI) and external entity (or between two or more internal subsystems of the SOI) that enables functional interactions and physical connectivity between them. 2) An interface is the performance, functional, and physical attributes required to exist at a common boundary.
Interface Control Document	Interface Control Document are developed from the IRDs. The purpose of the ICD is to control the interfaces between interrelated components of the system under development, as well as between the system under development and any external systems that comprise a total architecture. An ICD describes the detailed implementation of the requirements contained in the IRD.
Interface Definition Document	An Interface Definition Document, sometimes referred to as a one-sided ICD (see ICD definition), is maintained and signed by a single organization. In the SGSS context, IDDs are used to capture functional and performance interface requirements along with interface constrains and a general description of the interface.
Interface Requirements Document	The intention of an IRD is to define interface requirements without specifying design solutions. An IRD provides the basis for subsequent development of corresponding Interface Control Documents (ICDs). An IRD is composed of physical and functional requirements and constraints imposed on system interfaces. IRDs are used when separate organizations develop components of the system or when the system must levy requirements on other systems outside program/project control.
Interface Stakeholder	An organization external to SGSS that is responsible for maintaining an interface to the SGSS system, or an organization that is affected by a change to the existing SNGS interface, requiring SGSS coordination.
Jerk	Rate of change of range acceleration between TDRS and customer platform (meter/second3).
Legacy	Characteristics and Users of the SN which exist at the time of SGSS deployment.
Link	Includes either all data and/or range channels provided by a TDRS forward or return service to a customer platform. In the case of SA service, a link is defined relative to a specific antenna on a particular TDRS. In the case of MA

Term	Definition
	service, a link is defined relative to a particular TDRS.
Loop Test, End-to-End	End-to-End Test (EET) Service provides customer projects the capability of testing the end-to-end SN data communications through a ground-based simulation of the customer platform to MOC link via TDRSS thus eliminating the need for the actual customer platform.
Loop Test, Long	Test Service or pretest conducted through IF to RF at the antenna front end and back without radiating through the antenna.
Loop Test, Medium	Test Service or pretest conducted through Intermediate frequency (IF) loop (Back end) only.
Loop Test, Short	Subsystem-specific built-in self test (e.g., test of the MODEM using its Built In Test Equipment).
Maintainability	Maintainability is characterized by the mean time to repair (MTTR) and the maximum time to repair. In software systems, based on the definition given in ISO 9126, the ease with which a software product can be modified in order to correct defects, meet new requirements, make future maintenance easier, or cope with a changed environment
Mission Essential SN Operations	Monitoring and control of TDRS spacecraft sufficient to ensure TDRS spacecraft health and safety, plus the capability to provide SN User Services for all mission priority levels greater than "Normal Operations" (i.e., Emergency and Critical services). See definitions for Emergency Service Requests and Critical Service Requests.
Operability, Maintainability, and Serviceability	These three themes combine to describe operational aspects of the system. Just as individual spacecraft have idiosyncrasies that need to be managed, ground system components also require management as a complex system of systems.
Operational Availability	The operational availability (Ao) for any system is a measure of the percentage of time the system is available to support the service or support function for which the system is intended, and to perform that function within all specifications defined by these functional and performance requirements. Operational availability is calculated as: (Time service is available) divided by (Time service is available + Time service is not available)
Operational Scheduling Phase	The Operational Scheduling Phase begins when the schedule is ready for execution and made available to the monitoring and control system for physical allocation of assets to scheduled events, and continues until configuration of SN resources supporting an event begins. Requests for unscheduled TDRS time are still processed so long as they are received sufficiently before the event timeline.
Operator	Any person involved in the operation of the SN, including line operators, engineers, maintenance personnel, and managers.
Planning Scheduling Phase	The Planning Scheduling Phase is the first phase of scheduling SN resources for a future time period. Receipt of each User request is validated and acknowledged, but no commitment is made to the User submitting the request that the request will be fulfilled. The scheduling engine will process the service requests, allocate resources and produce one or more draft schedule. The schedule during the planning phase is made available for internal (operator) viewing only and is very dynamic. Each schedule is evaluated based on a configurable set of Figures of Merit and the requests associated with the “best” schedule are promoted to the Active Scheduling Phase.

Term	Definition
Playback	Transmission (or re-transmission) of a stream of data as if it were being received in real-time, with rate buffering as required/scheduled.
Point Of Presence	The physical point of presence within a facility, enabling the physical communications interface between the SN and an external entity.
Primary Operations	The first set of equipment, resources, and facilities used to provide SN services and maintain the SN in an available state. Differentiates from backup equipment, resources and facilities used to provide SN services and maintain the SN in the situation where the primary capability is unavailable.
Privileged Functions	Computer system functions or programs that are critical to the security and stability of the entire operating system and are therefore restricted from general use. Access to privileged functions are limited to a select number of individuals with a legitimate purpose to view or process them (e.g. System Administrator).
Project Reference Dataset	The collection of parameters used to configure the basic operation of the SNGS system. This includes command, telemetry, and flight software table definitions, along with their associated limit and constraint definitions. This also includes the definition of the hardware configuration and the software defined capacities (buffer sizes etc) of the SNGS system.
Provisioning	Allocation and configuration of resources and all related activities required to satisfy the requested service, including post-event service completion (e.g., rate buffering/ playback) and delivery of performance data as compared to the scheduled service.
Q Channel	Data channel supported by +90 degree phase modulation of the reference carrier.
Radio Frequency Interference	RFI occurs when two or more simultaneously transmitting radiations of identical polarity with overlapping bandwidths are received by a supporting antenna.
Reconfiguration	A real-time change in one or more parameters of a service.
Reliability	The measure of reliability for SN ground systems shall be the mean time between failures (MTBF).
Retrieval	Ability to obtain recorded data via some means of file transfer (physical or FTP download).
Return Link	The downlink from a User platform via TDRS to a User ground site. Return denotes the direction from the User Platform to the TDRS.
SLE Provider	Per CCSDS 910.4-B-2: An entity [The SN] that offers a service to another by means of one or more of its ports is called a service provider (provider). The other entity [SN Customer] is called a service user (user).
SLE User	Per CCSDS 910.4-B-2: An entity [The SN] that offers a service to another by means of one or more of its ports is called a service provider (provider). The other entity [SN Customer] is called a service user (user).
SN Resource	Any SN-owned space or ground hardware or software asset that can be scheduled or allocated to support SN Services.
SN Services	Any schedulable service provided by the SN including Users telecommunications services, i.e., (SSA, MA, SMA, KSA forward, return and tracking services including cross-support services).

Term	Definition
SN User	An entity external to the SN allowed to schedule and use SN services. Also referred to "SN Customer" in other documentation.
Scalability	Property of a system, a network, or a process, which indicates its ability to either handle growing amounts of work in a graceful manner, or to be readily enlarged. For example, it can refer to the capability of a system to increase total throughput under an increased load when resources (typically hardware) are added. For the modernized ground system to be scalable, it needs to be able to increase resources needed to control more spacecraft and more generations of spacecraft, process more data, distribute data streams to more users, respond to more scientific events, and balance its processing capacity across more service chains. Capacity overhead has to be monitored and the system designed such that its capacity can be increased gracefully
Service Accountability	The act of reporting to SN Users the performance of individual SN service instances in a post service report
Service Accounting	The process by which the SN tracks the performance of individual SN service instances by User
Service Availability	Service Availability is defined as the percentage of time that operational services are available for customer support. Availability = (Tmax - Tdown)/Tmax, where Tmax is the total amount of time that the service is expected to be available (i.e. 24x7) and Tdown is the time that the service is not available. Tdown includes outages due to events controlled by the system (e.g. system maintenance, software deliveries, engineering changes and configuration) and events outside of the control of the system (e.g. acts of God, undetectable hardware failures and environmental interference
Service Configuration	The parameters required to define a service instance (e.g., service type, data rate, FEC codes to use, etc).
Service Management	Management information must be exchanged between space missions and the Space Network for the purposes of negotiating, configuring and executing the SN services that are provided to customer space missions. The various processes that generate, exchange, ingest and act upon this management information are collectively referred to as "Service Management".
Service Monitoring	The process of real time monitoring and reporting to the customer of key service performance and configurations parameters. Can be initiated cyclically or upon request.
Service Performance Data	The data that describes the service performance and is used to perform service monitoring and service accounting (e.g., errors detected, errors corrected, frames processed, etc)
Shall	Indicates a requirement that must be implemented and its implementation formally verified (verification requirements are not a part of this document).
Space Link Extension (SLE)	A CCSDS Recommendation that describes standardized services and protocols for moving frame level, forward and return data, between space link providers and their remote customer ground systems
Space-Ground Link	The bi-directional Ku-Band or S-band RF connection between the SNGS and a TDRS spacecraft.
Space-Space Link	The bi-directional Ku-band, Ka-band or S-band RF connection between a TDRS spacecraft and a User Platform (normally on orbit, but in some instances ground-based or sub-orbital, such as the South Pole TDRS Relay or

Term	Definition
	Ultra-Long Duration Balloons).
Stationkeeping	All TDRS spacecraft are subject to East-West stationkeeping to ± 0.5 degree about their assigned longitude by ITU regulation. Certain spacecraft are station kept more tightly, including North-South to ± 0.1 degree at certain times and for certain applications. For the most part, NASA does not require stringent North-South stationkeeping to maintain TDRSS Services. Current TDRS operations (specification) allows N/S inclination growth to ± 7 degrees.
Symbol Rate	The number of symbols per second transferred between the transmitter and receiver.
TDRS Unscheduled Time (TUT)	Time within SN active schedule that has not been allocated for customer support. Representations of that portion of the TUT applicable to a specific User per their User Profile is distributed to that User to assist them in performing schedule updates.
Telecommunications	Includes voice and data communications, the transmission or reception of signals, writing, sounds, or intelligence of any nature by wire, radio, light beam, or any other electromagnetic means.
Test Services	User Service tests to support User pre-launch system compatibility and performance verification. These test service capabilities also facilitate system validation / calibration / performance characterization internal to the SN. The test services include End-to-End Test (EET) capabilities as well as simulation / emulation capabilities for tests that do not require RF radiation.
Tracking	Range signal generation, Doppler compensation or inhibit, range extraction, Doppler extraction, tracking operations control, timing system as it relates to radiometric data, and the transfer of information associated with tracking.
User	Any entity that makes use of the SN for operations, simulations, or testing.
User Local Equipment	Equipment provided by an SN User located in an SN operations facility for which SN responsibility is limited to providing facility services (e.g., electric, HVAC) except by special arrangement.
User Profile	Provides sets of default service parameters for a User's services.
User Service Agreement	An agreement between the SN and a User that describes the type, number and performance of SN services available to a User. The User Service Agreement specifies the range of agreed upon services and limits of service allowed by users.
User Services	SSA, MA, SMA, KSA forward, return and tracking services, including cross support services.
Virtual user platforms	Utilization of a single TDRS SA antenna by two user platforms in close physical proximity to one another by defining a virtual platform using the S-band characteristics of one platform and the K-band characteristics of the other. See SNUG Rev. 9, Section 3.2.2.1.

Appendix C Reserved

Appendix D Aggregate Signal Distortion Characteristics

This Appendix provides the estimated Return Service aggregate signal distortion characteristics up to the receiver input. These estimated aggregate distortions are offered to better enable the implementation contractor to estimate and verify implementation loss performance.
Table D-1 provides estimated aggregate distortions for SSAR service. Table D-2 provides estimated aggregate distortions for KuSAR service. Table D-3 provides estimated aggregate distortions for KaSAR service.

Table D-1 Estimated Aggregate Distortions for SSAR Service(1)

Parameter	DG1 Modes 1 and 2; DG1 Mode 3 I Channel; DG1 Mode 3 Q Channel ≤ 1.024 Msps; DG2 BPSK, QPSK, SQPSK Per Channel Symbol Rate ≤ 1.024 Msps	DG1 Mode 3 Q Channel >1.024 Msps; DG2 BPSK, QPSK, SQPSK Per Channel Symbol Rate > 1.024 Msps	DG2 8PSK	Rationale
AM/AM, dB/dB	> 0.0	> 0.0	> 0.0	Customer AM/AM not constrained
AM/PM, deg/dB	≤ 21 (convolutionally coded service) ≤ 12 (all other service modes)	≤ 18 (convolutionally coded service) ≤ 12 (all other service modes)	≤ 12	Ground Terminal Allocation: ≤ 0.5 deg/dB TDRS Spec: ≤ 5.5 deg/dB Customer Constraints(2): ≤ 15, 12, 6 deg/dB
Channel Bandwidth	≥ 10 MHz or compliance with NTIA mask, whichever is worse	≥ 10 MHz or compliance with NTIA mask, whichever is worse	≥ 10 MHz or compliance with NTIA mask, whichever is worse	Ground Terminal Allocation: ≥ 10 MHz TDRS Spec: ≥ 10 MHz Customer Constraint(2): NTIA mask compliance
Gain Flatness (peak-to-peak), dB	≤ 1.42 over ± 2.1 MHz	≤ 1.32 over ± 3.5 MHz	≤ 1.32 over ± 3.5 MHz	Ground Terminal Allocation: ≤ 0.6 dB over ± 3.5 MHz TDRS Spec: ≤ 1.0 dB over ± 3.5 MHz(3) Customer Constraints(2): ≤ 0.8, 0.6, 0.6 dB
Gain Slope, dB/MHz	≤ 0.17	≤ 0.17	≤ 0.17	Ground Terminal Allocation, TDRS Spec, Customer Constraint(2): ≤ 0.1 dB/MHz each
Phase Nonlinearity (peak-to-peak), deg.	≤ 14.1 over ± 2.1 MHz	≤ 13.1 over ± 3.5 MHz	≤ 13.1 over ± 3.5 MHz	Ground Terminal: ≤ 6 deg over ± 3.5 MHz TDRS Spec: ≤ 10 deg over ± 3.5 MHz(3) Customer Constraints(2): ≤ 8, 6, 6 deg

Parameter	DG1 Modes 1 and 2; DG1 Mode 3 I Channel; DG1 Mode 3 Q Channel ≤ 1.024 Msps; DG2 BPSK, QPSK, SQPSK Per Channel Symbol Rate ≤ 1.024 Msps	DG1 Mode 3 Q Channel >1.024 Msps; DG2 BPSK, QPSK, SQPSK Per Channel Symbol Rate > 1.024 Msps	DG2 8PSK	Rationale
Incidental AM, %	≤ 5.1	≤ 5.1	≤ 5.1	Ground Terminal Allocation: Negligible TDRS Spec: ≤ 1 % Customer Constraint(2): ≤ 5 %
Spurious PM, deg. rms	≤ 3.0	≤ 2.5	≤ 2.5	Ground Terminal Allocation: Negligible TDRS Spec: ≤ 2.24 deg rms Customer Constraints(2): ≤ 2, 1 deg rms
Spurious Output, dBc	≤ -22.2	≤ -27.0	≤ -27.0	Ground Terminal Allocation: Negligible TDRS Spec: ≤ -30 dBc Customer Constraints(2): ≤ -23, -30 dBc
I/Q Symbol Skew, %	≤ 3.0	≤ 3.0	≤ 3.0	Customer Constraint(2): ≤ 3%
Symbol Asymmetry, %	≤ 3.0	≤ 3.0	≤ 3.0	Customer Constraint(2) ≤ 3%
Symbol Jitter, %	≤ 0.1	≤ 0.1	≤ 0.1	Customer Constraint(2): ≤ 0.1%
Gain Imbalance, dB	≤ 0.5 (DG1 and DG2 QPSK/SQPSK); ≤ 1.0 (DG2 BPSK)	≤ 0.25	≤ 0.25	Customer Constraint(2): ≤ 1.0, 0.5, 0.25, 0.25 dB
Phase Imbalance, deg	≤ 5 (DG1 and DG2 QPSK/SQPSK); ≤ 9 (DG2 BPSK)	≤ 3	≤ 3	Customer Constraint(2): ≤ 9, 5, 3, 3 deg
PN Power Suppression, dB	≤ 0.3	N/A	N/A	Customer Constraint(2): ≤ 0.3 dB
Phase Noise, deg rms	Expect aggregate untracked phase noise ≤ 6.2 deg rms(4)	Expect aggregate untracked phase noise ≤ 6.2 deg rms(4)	Expect aggregate untracked phase noise ≤ 4.1 deg rms(4)	• CEV C&T S-band implementation loss analysis • SNUG Rev 9 Phase Noise Analysis
Other Distortions	See SNUG	See SNUG	See SNUG	See remaining SNUG customer constraints

Notes:
1. Estimated aggregate distortions at the receiver input. Aggregate distortions include customer transmitter, TDRS satellite and ground segment equipment up to the receiver.
2. "Customer constraint" may mean SNUG constraint or candidate proposed constraint.
3. Excludes consideration of additional gain and phase distortions allowed via the amplitude and phase equalization bounds. Implementation loss specifications of this document derived excluding consideration of the additional allowed distortions because of the tremendous variation in implementation loss which results depending upon the exact manner in which the distortions were rendered in the analysis or simulation.
4. Due to the large number of possible phase noise scenarios, an untracked phase noise value is stated assuming a receiver carrier tracking loop bandwidth selection algorithm appropriate for the SN user services.

Table D-2 Estimated Aggregate Distortions for KuSAR Service[1]

Parameter	DG1 Modes 1 and 2	DG2 BPSK, QPSK, SQPSK	DG2 8PSK	Rationale
AM/AM, dB/dB	> 0.0	> 0.0	> 0.0	Customer AM/AM not constrained
AM/PM, deg/dB	≤ 17.9 (uncoded and convolutionally coded service) ≤ 8.9 (all other service modes)	≤ 14.9 (uncoded and convolutionally coded service) ≤ 8.9 (all other service modes)	≤ 8.9	Ground Terminal Allocation: ≤ 0.5 deg/dB TDRS worst-case actual: ≤ 2.4 deg/dB Customer Constraints[2]: ≤ 15, 12, 6 deg/dB
Channel Bandwidth	≥ 239 MHz or compliance with NTIA mask, whichever is worse	≥ 239 MHz or compliance with NTIA mask, whichever is worse	≥ 239 MHz or compliance with NTIA mask, whichever is worse	Ground Terminal Allocation: ≥ 240 MHz TDRS worst-case actual: ≥ 239 MHz Customer Constraints[2]: NTIA mask compliance
Gain flatness (peak-to-peak), dB	≤ 1.6 over ± 2.1 MHz	≤ 1.5 over ± 80 MHz	≤ 1.5 over ± 80 MHz	Ground Terminal Allocation: ≤ 0.6 dB TDRS Spec: ≤ 1.2 dB[3] Customer Constraints[2]: ≤ 0.8, 0.6 dB
Gain slope, dB/MHz	≤ 0.17	≤ 0.17	≤ 0.17	Ground Terminal Allocation, TDRS Spec, Customer Constraint: ≤ 0.1 dB/MHz each
Phase nonlinearity (peak-to-peak), deg	≤ 15.6 over ± 2.1 MHz	≤ 14.7 over ± 80 MHz	≤ 14.7 over ± 80 MHz	Ground Terminal Allocation: ≤ 6 deg TDRS Spec: ≤ 12 deg[3] Customer Constraints[2]: ≤ 8, 6 deg
Incidental AM, %				Ground Terminal Allocation: Negligible TDRS Spec: ≤ 1 % Customer Constraint[2]: ≤ 5, 3 %
For open-loop pointing	≤ 5.1	≤ 5.1	≤ 5.1	
For autotrack pointing	≤ 3.2	≤ 3.2	≤ 3.2	
Spurious PM, deg rms	≤ 3.0	≤ 3.0	≤ 3.0	Ground Terminal Allocation: Negligible TDRS Spec: ≤ 2.24 deg rms Customer Constraint[2]: ≤ 2 deg rms
Spurious Outputs, dBc	≤ -22.2	≤ -27	≤ -27	Ground Terminal Allocation: Negligible TDRS Spec: ≤ -30 dBc Customer Constraints[2]: ≤ -23, -30 dBc
I/Q Symbol Skew, %	≤ 3	≤ 3	≤ 3	Customer Constraint[2]: ≤ 3%
Symbol Asymmetry, %	≤ 3	≤ 3	≤ 3	Customer Constraint[2]: ≤ 3%
Symbol jitter, %	≤ 0.1	≤ 0.1	≤ 0.1	Customer Constraint[2]: ≤ 0.1%
Gain imbalance, dB	≤ 0.5	≤ 0.25	≤ 0.25	Customer Constraints[2]: ≤ 0.5, 0.25 dB
Phase imbalance, deg	≤ 5	≤ 3	≤ 2	Customer Constraints[2]: ≤ 5, 3, 2 deg

Parameter	DG1 Modes 1 and 2	DG2 BPSK, QPSK, SQPSK	DG2 8PSK	Rationale
Phase noise, deg rms	Expect aggregate untracked phase noise ≤ 6.1 deg rms(4)	Expect aggregate untracked phase noise ≤ 6.1 deg rms(4)	Expect aggregate untracked phase noise ≤ 3.0 deg rms(4)	SNUG Rev 8 phase noise analysis
Other Distortions	See SNUG	See SNUG	See SNUG	See remaining SNUG customer constraints

Notes:

1. Estimated aggregate distortions at the receiver input. Aggregate distortions include customer transmitter, TDRS satellite and ground segment equipment up to the receiver.
2. "Customer constraint" may mean SNUG constraint or candidate proposed constraint.
3. Excludes consideration of additional gain and phase distortions allowed via the amplitude and phase equalization bounds. Implementation loss specifications of this document derived excluding consideration of the additional allowed distortions because of the tremendous variation in implementation loss which results depending upon the exact manner in which the distortions were rendered in the analysis or simulation.
4. Due to the large number of possible phase noise scenarios, an untracked phase noise value is stated assuming a receiver carrier tracking loop bandwidth selection algorithm appropriate for the SN user services.

Table D-3 Estimated Aggregate Distortions for KaSAR Service[1]

Parameter	225 MHz Service		650 MHz Service		Rationale
	DG2 BPSK, QPSK, SQPSK	DG2 8PSK	DG2 BPSK, QPSK, SQPSK	DG2 8PSK	
AM/AM, dB/dB	> 0.0	> 0.0	> 0.0	> 0.0	Customer AM/AM not constrained
AM/PM, deg/dB	≤ 14.9 (uncoded and convolutionally coded service) ≤ 8.9 (all other service modes)	≤ 8.9	≤ 14.9 (uncoded and convolutionally coded service) ≤ 8.9 (all other service modes)	≤ 8.9	Ground Terminal Allocation: ≤ 0.5 deg/dB TDRS worst-case actual: ≤ 2.4 deg/dB Customer Constraints[2]: ≤ 12, 6 deg/dB
Channel Bandwidth	≥ 239 MHz or compliance with NTIA mask, whichever is worse	≥ 239 MHz or compliance with NTIA mask, whichever is worse	≥ 650 MHz or compliance with NTIA mask, whichever is worse	≥ 650 MHz or compliance with NTIA mask, whichever is worse	Ground Terminal Allocation: ≥ 240 MHz TDRS worst-case actual: ≥ 239 MHz Customer Constraints[2]: NTIA mask compliance
Gain flatness (peak-to-peak), dB	≤ 1.5 over ± 80 MHz	≤ 1.5 over ± 80 MHz	≤ 1.5 over ± 230 MHz	≤ 1.5 over ± 230 MHz	Ground Terminal Allocation: ≤ 0.6 dB TDRS Spec: ≤ 1.2 dB[3] Customer Constraint[2]: ≤ 0.6 dB
Gain slope, dB/MHz	≤ 0.17	≤ 0.17	≤ 0.17	≤ 0.17	Ground Terminal Allocation, TDRS Spec, Customer Constraint[2]: ≤ 0.1 dB/MHz each
Phase nonlinearity (peak-to-peak), deg	≤ 14.7 over ± 80 MHz	≤ 14.7 over ± 80 MHz	≤ 14.7 over ± 230 MHz	≤ 14.7 over ± 230 MHz	Ground Terminal Allocation: ≤ 6 deg TDRS Spec: ≤ 12 deg [3] Customer Constraint[2]: ≤ 6 deg
Incidental AM, %					Ground Terminal Allocation: Negligible TDRS Spec: ≤ 1 % Customer Constraints[2]: ≤ 5, 3 %
For open-loop pointing	≤ 5.1	≤ 5.1	≤ 5.1	≤ 5.1	
For autotrack pointing	≤ 3.2	≤ 3.2	≤ 3.2	≤ 3.2	
Spurious PM, deg rms	≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0	Ground Terminal Allocation: Negligible TDRS Spec: ≤ 2.24 deg rms Customer Constraint[2]: ≤ 2 deg rms
Spurious Outputs, dBc	≤ -27	≤ -27	≤ -27	≤ -27	Ground Terminal Allocation: Negligible TDRS Spec: ≤ -30 dBc Customer Constraint[2]: ≤ -30 dBc
I/Q Symbol Skew, %	≤ 3	≤ 3	≤ 3	≤ 3	Customer Constraint[2]: ≤ 3%
Symbol Asymmetry, %	≤ 3	≤ 3	≤ 3	≤ 3	Customer Constraint[2]: ≤ 3%
Symbol jitter, %	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.1	Customer Constraint[2]: ≤ 0.1%
Gain imbalance, dB	≤ 0.25	≤ 0.25	≤ 0.25	≤ 0.25	Customer Constraint[2]: ≤ 0.25 dB

Parameter	225 MHz Service		650 MHz Service		Rationale
	DG2 BPSK, QPSK, SQPSK	DG2 8PSK	DG2 BPSK, QPSK, SQPSK	DG2 8PSK	
Phase imbalance, deg	≤ 3	≤ 2	≤ 3	≤ 2	Customer Constraints(2): ≤ 3, 2 deg
Phase noise, deg rms	Expect aggregate untracked phase noise ≤ 6.1 deg rms(4)	Expect aggregate untracked phase noise ≤ 3 deg rms(4)	Expect aggregate untracked phase noise ≤ 3 deg rms(4)	Expect aggregate untracked phase noise ≤ 3 deg rms(4)	• CEV C&T Ka-band implementation loss analysis • SNUG Rev 9 Phase Noise Analysis
Other Distortions	See SNUG	See SNUG	See SNUG	See SNUG	See remaining SNUG customer constraints

Notes:

1. Estimated aggregate distortions at the receiver input. Aggregate distortions include customer transmitter, TDRS satellite and ground segment equipment up to the receiver.
2. "Customer constraint" may mean SNUG constraint or candidate proposed constraint.
3. Excludes consideration of additional gain and phase distortions allowed via the amplitude and phase equalization bounds. Implementation loss specifications of this document derived excluding consideration of the additional allowed distortions because of the tremendous variation in implementation loss which results depending upon the exact manner in which the distortions were rendered in the analysis or simulation.
4. Due to the large number of possible phase noise scenarios, an untracked phase noise value is stated assuming a receiver carrier tracking loop bandwidth selection algorithm appropriate for the SN user services.

Appendix E Customer Signal Distortions Constraints

Table E-1 states customer constraints for DG1 and DG2 BPSK/QPSK/SQPSK/8PSK SSAR. For legacy service modes, constraints are traceable to the SNUG. For service modes introduced with the USSR project, stated constraints are candidate constraints.

Table E-1 SSAR Data Service Customer Signal Distortion Constraints

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Minimum channel data bit transition density (required for acquisition/reacquisition)	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Consecutive channel data bits without a bit transition (required for acquisition/reacquisition)	≤ 64
Minimum channel symbol transition density (Note 3)	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤64 symbols
Symbol asymmetry (peak)	≤ ±3 percent
Symbol jitter and jitter rate (note 3)	≤ 0.1 percent
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ ± 5 degrees
Q channel baud rate > 1.024 Msps	≤ ± 3 degrees
DG2	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 9 degrees
Baud rate > 1.024 Msps	≤ ± 3 degrees
QPSK/SQPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 5 degrees
Baud rate per channel > 1.024 Msps	≤ ± 3 degrees
8PSK	≤ ± 3 degrees
Gain Imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ ± 0.50 dB
Q channel baud rate > 1.024 Msps	≤ ± 0.25 dB
DG2	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 1.0 dB
Baud rate > 1.024 Msps	≤ ± 0.25 dB
QPSK/SQPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 0.50 dB
Baud rate per channel > 1.024 Msps	≤ ± 0.25 dB
8PSK	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 4 degrees over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 3 degrees over ±3.5 MHz

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
DG2	
BPSK/QPSK/SQPSK	
Baud rate per channel ≤ 1.024 Msps	≤ 4 degrees over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 3 degrees over ±3.5 MHz
8PSK	≤ 3 degrees over ±3.5 MHz
Gain flatness (peak)	
DG1 modes 1 and 2	≤ 0.4 dB over ±2.1 MHz
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 0.4 dB over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 0.3 dB over ±3.5 MHz
DG2	
BPSK/QPSK/SQPSK	
Baud rate per channel ≤ 1.024 Msps	≤ 0.4 dB over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 0.3 dB over ±3.5 MHz
8PSK	≤ 0.3 dB over ±3.5 MHz
Gain slope (peak)	
DG1 modes 1 and 2	Not specified
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	Not specified
Q channel baud rate > 1.024 Msps	≤ 0.1 dB/MHz over ±3.5 MHz
DG2	
BPSK/QPSK/SQPSK	
Baud rate per channel ≤ 1.024 Msps	Not specified
Baud rate per channel > 1.024 Msps	≤ 0.1 dB/MHz over ±3.5 MHz
8PSK	≤ 0.1 dB/MHz over ±3.5 MHz
AM/PM	
Convolutionally Coded Service	
DG1 modes 1 and 2	≤ 15 degrees/dB
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 15 degrees/dB
Q channel baud rate > 1.024 Msps	≤ 12 degrees/dB
DG2	
Baud rate per channel ≤ 1.024 Msps	≤ 15 degrees/dB
Baud rate per channel > 1.024 Msps	≤ 12 degrees/dB
All Other Services	≤ 6 degrees/dB
Noncoherent frequency stability (peak) (Note 4)	
±700 Hz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
± 3 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4.3 \times 10^{-7}$
48-hr observation time	$\leq 1.29 \times 10^{-6}$
± 35 kHz customer oscillator frequency uncertainty	
1-sec average time	
Baud rate per channel ≤ 12.5 ksps	$\leq 7.37 \times 10^{-9}$
Baud rate per channel > 12.5 ksps	$\leq 26 \times 10^{-9}$
5-hr observation time	$\leq 3.77 \times 10^{-6}$
48-hr observation time	$\leq 11.3 \times 10^{-6}$

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Incidental AM (peak)	
At frequencies >10 Hz for data rates <1 kbps;	
At frequencies >100 Hz for data rates ≥1 kbps	≤5 percent
Spurious PM (rms)	
DG1	≤ 2 degrees
DG2	
BPSK	≤ 2 degrees
QPSK	
I/Q = 4:1	≤ 2 degrees
I/Q = 1:1	≤ 1 degree
8PSK	≤ 1 degree
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥4.5 MHz or two times maximum baud rate, whichever is larger
DG2	≥2 times maximum channel baud rate
Phase noise (rms)	
DG1 Mode 1	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤1.5° rms
Doppler Tracking NOT Required (Note 5)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤1.5° rms
Channel baud rate ≥ 18 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 2.2° rms
1 kHz – 6 MHz	≤ 2.0° rms
DG1 Mode 2	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms
Doppler Tracking NOT Required (Note 5)	
Channel baud rate < 40 ksps	
1 Hz – 10 Hz	≤ 7.5° rms
10 Hz – 100 Hz	≤ 2.0° rms
100 Hz – 1 kHz	≤ 1.5° rms
1 kHz – 6 MHz	≤ 1.5° rms
Channel baud rate ≥ 40 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.5° rms
1 kHz – 6 MHz	≤ 2.5° rms
DG1 Mode 3	
Doppler Tracking Required	

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
All baud rates	
1 Hz – 10 Hz	≤ 1.0° rms
10 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms
Doppler Tracking NOT Required (Note 5)	
Channel baud rate < 222.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 1 kHz	≤ 2.8° rms
1 kHz – 6 MHz	≤ 1.4° rms
Channel baud rate ≥ 222.5 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 1 kHz	≤ 5.5° rms
1 kHz – 6 MHz	≤ 1.8° rms
DG2 Coherent BPSK/QPSK/SQPSK	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤2.0° rms
Doppler Tracking NOT Required (Note 5)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤3.8° rms
10 Hz – 1 kHz	≤2.3° rms
1 kHz – 6 MHz	≤2.0° rms
18 ksps ≤ Channel baud rate ≤ 1.024 Msps	
1 Hz – 10 Hz	≤25.0° rms
10 Hz – 1 kHz	≤2.5° rms
1 kHz – 6 MHz	≤2.0° rms
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤5.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤0.5° rms
DG2 Noncoherent BPSK/QPSK/SQPSK	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 2.0° rms
Doppler Tracking NOT Required (Note 5)	
Channel baud rate < 12.5 ksps	
1 Hz – 10 Hz	≤ 5.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 2.0° rms
12.5 ksps ≤ Channel baud rate ≤ 1.024 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 6 MHz	≤ 2.4° rms

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Doppler Tracking NOT Required (Note 5)	
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤ 10.0° rms
10 Hz – 100 Hz	≤ 1.5° rms
100 Hz – 1 kHz	≤ 0.5° rms
1 kHz – 6 MHz	≤ 0.5° rms
DG2 8PSK	
1 Hz – 10 Hz	≤ 10.0° rms
10 Hz – 100 Hz	≤ 1.5° rms
100 Hz – 1 kHz	≤ 0.5° rms
1 kHz – 6 MHz	≤ 0.5° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≥ 23 dBc
Q channel baud rate > 1.024 Msps	≥ 30 dBc
DG2	
BPSK/QPSK/SQPSK	
Baud rate per channel ≤ 1.024 Msps	≥ 23 dBc
Baud rate per channel > 1.024 Msps	≥ 30 dBc
8PSK	≥ 30 dBc
Out-of-band emissions	See Appendix D of the SNUG Rev 9 for NASA/GSFC Recommended Filtering in the 2290-2300 MHz band and allowable limits on out-of-band emissions, including spurs
I/Q symbol skew (relative to requirements for I/Q data synchronization where appropriate) (peak)	≤3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤0.01 chip
PN chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
PN power suppression (noncoherent and coherent)	≤0.3 dB
Customer Antenna-Induced AM	≤3 dB
Customer Antenna-Induced PM	≤10 degrees
Data rate tolerance	≤+0.1 percent
I/Q power ratio tolerance	≤+0.4 dB

Notes:

1. The definitions and descriptions of the customer constraints are provided in SNUG Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. The symbol jitter and jitter rate are defined as the customer transmitted signal peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3 random) as a percent of the symbol clock rate.
4. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
5. Applicable for customers that have no Doppler tracking requirement or can tolerate a total Doppler tracking error (system + customer) greater than 0.2 rad/sec (1σ, channel data rate > 1 kbps) or 0.4 rad/sec (1σ, channel data rate ≤ 1 kbps) assuming an averaging time of 1 second.

Table E-2 states customer signal distortions constraints for KuSAR DG1 and DG2. For legacy service modes, constraints are traceable to the SNUG. For service modes introduced with the USSR project, stated constraints are candidate constraints.

Table E-2 KuSAR Data Service Customer Signal Distortion Constraints

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Minimum channel symbol transition density (required for acquisition/reacquisition)	≥ 64 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition (required for acquisition/reacquisition)	≤ 64
Minimum channel symbol transition density	≥128 randomly distributed symbols transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤64 symbols
Symbol asymmetry (peak)	≤ ± 3 percent
Symbol (data) bit jitter and jitter rate	≤ 0.1 percent
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3	≤ ± 3 degrees
DG2	
BPSK/QPSK/SQPSK	≤ ± 3 degrees
8PSK	≤ ± 2 degrees
Gain imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3	≤ ± 0.25 dB
DG2	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3	≤ 3 degrees over ±4.2 MHz
DG2	≤ 3 degrees over ±80 MHz
Gain flatness (peak)	
DG1 modes 1 and 2	≤0.4 dB over ±2.1 MHz
DG1 mode 3	≤0.3 dB over ±4.2 MHz
DG2	≤0.3 dB over ±80 MHz
Gain slope	
DG1 modes 1 and 2	Not Specified
DG1 mode 3	≤0.1 dB/MHz over ±4.2 MHz
DG2	≤0.1 dB/MHz over ±80 MHz
AM/PM	
Uncoded and Convolutionally Coded Services	
DG1 modes 1 and 2	≤15 deg/dB
DG1 mode 3	≤12 deg/dB
DG2	≤12 deg/dB
All Other Service Modes	≤6 deg/dB
Noncoherent frequency stability (peak) (Note 3)	
±5 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
±20 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4 \times 10^{-7}$

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
48-hr observation time	≤ 1.2 x 10^{-6}
±55 kHz customer oscillator frequency uncertainty	
1-sec observation time	≤3 x 10^{-9}
Lifetime	≤2.1 x 10^{-6}
Incidental AM (peak)	
For open-loop pointing	
At frequencies ≥100 Hz	≤5 percent
For autotrack performance	
At frequencies: 10 Hz-10 kHz	≤3 percent
At frequencies: 10 Hz-2 kHz	≤0.6 percent
Spurious PM	≤2 degrees
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥4.5 MHz or two times maximum baud rate, whichever is larger
DG2	≥2 times maximum channel baud rate
Phase noise (rms) (Note 4)	
DG1 Mode 1	
Doppler Tracking Required	
All Baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤3.0° rms
1 kHz – 150 MHz	≤1.4° rms
Doppler Tracking NOT Required	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤4.0° rms
10 Hz – 1 kHz	≤3.0° rms
1 kHz – 150 MHz	≤1.4° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 3.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG1 Mode 2	
Doppler Tracking Required	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 3.0° rms
100 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 15.0° rms
10 Hz – 1 kHz	≤ 4.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
Doppler Tracking NOT Required	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 3.0 ° rms
100 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 16 ksps	

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 100 Hz	≤ 4.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG1 Mode 3	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤2.6° rms
1 kHz – 150 MHz	≤1.2° rms
Doppler Tracking NOT Required	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤3.5° rms
10 Hz – 1 kHz	≤2.6° rms
1 kHz – 150 MHz	≤1.2° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 3.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG2 Coherent (BPSK, QPSK, SQPSK)	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤1.8° rms
1 kHz – 150 MHz	≤1.0° rms
Doppler Tracking NOT Required	
Channel baud rate < 434 ksps	
1 Hz – 10 Hz	≤3.6° rms
10 Hz – 1 kHz	≤1.8° rms
1 kHz – 150 MHz	≤1.0° rms
434 ksps ≤ Channel baud rate ≤ 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 1 kHz	≤6.0° rms
1 kHz – 150 MHz	≤2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 1 kHz	≤5.5° rms
1 kHz – 150 MHz	≤1.1° rms
DG2 Noncoherent (BPSK, QPSK, SQPSK)	
Doppler Tracking Required	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 2.5° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 108.5 ksps	
1 Hz – 10 Hz	≤ 15.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Doppler Tracking NOT Required	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 2.5° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 150 MHz	≤ 1.4° rms
108.5 ksps ≤ Channel baud rate ≤ 6 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 150 MHz	≤ 2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 10.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG2 8PSK	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 10.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	≥ 30 dBc
DG2	≥ 30 dBc
Out-of-band emissions	See Appendix D of SNUG for allowable limits on out-of-band emissions, including spurs
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak)	≤3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤0.01 chip
PN chip rate (peak) DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
PN power suppression (noncoherent and coherent)	≤0.3 dB
Axial ratio for autotrack	≤3 dB
Data rate tolerance	≤+0.1 percent
I/Q power ratio tolerance	≤+0.4 dB

NOTES:

1. The definitions and descriptions of the customer constraints are provided in SNUG Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
4. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.

For KaSAR-225 MHz service, the customer constraints defined in Table E-3 are applicable. For KaSAR-650 MHz service, the customer constraints defined in Table E-4 are applicable.

Table E-3 KaSAR-225 MHz Data Service Customer Signal Distortion Constraints

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Minimum channel symbol transition density (required for acquisition only)	≥ 64 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition (required for acquisition only)	≤ 64
Minimum channel symbol transition density (Note 4)	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤64 symbols
Data asymmetry (peak)	≤ ± 3 percent
Symbol (data) jitter and jitter rate	≤ 0.1 percent
Phase imbalance	
BPSK/QPSK/SQPSK	≤ ± 3 degrees
8PSK	≤ ± 2 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	≤3 degrees over ±80 MHz
Gain flatness (peak)	≤0.3 dB over ±80 MHz
Gain slope	≤0.1 dB/MHz over ±80 MHz
AM/PM	
Uncoded and Convolutionally Coded Services	≤12 deg/dB
All Other Service Modes	≤6 deg/dB
Noncoherent frequency stability (peak) (Note 3)	
±6 kHz customer oscillator frequency uncertainty	
1-sec observation time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 7.2 \times 10^{-8}$
48-hr observation time	$\leq 2.18 \times 10^{-7}$
±21 kHz customer oscillator frequency uncertainty	
1-sec observation time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 2.54 \times 10^{-7}$
48-hr observation time	$\leq 7.64 \times 10^{-7}$
±55 kHz customer oscillator frequency uncertainty	
1-sec observation time	$\leq 3 \times 10^{-9}$
Lifetime	$\leq 2.1 \times 10^{-6}$
Incidental AM (peak)	
For open-loop pointing	
At frequencies ≥100 Hz	≤5 percent
For autotrack performance	
At frequencies: 10 Hz-10 kHz	≤3 percent
At frequencies: 10 Hz-2 kHz	≤0.6 percent
Spurious PM	≤2 degrees

Parameter (Notes 1 and 2)	Description (Notes 1 and 2)
Minimum 3-dB bandwidth prior to power amplifier	≥2 times maximum channel baud rate
Phase noise (rms) (Note 4)	
DG2 Noncoherent	
Doppler Tracking NOT Required (Note 5)	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤4.0° rms
10 Hz – 100 Hz	≤2.5° rms
100 Hz – 1 kHz	≤1.4° rms
1 kHz – 150 MHz	≤1.4° rms
108.5 ksps ≤ Channel baud rate ≤ 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 100 Hz	≤5.5° rms
100 Hz – 1 kHz	≤2.4° rms
1 kHz – 150 MHz	≤2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 100 Hz	≤10.0° rms
100 Hz – 1 kHz	≤2.0° rms
1 kHz – 150 MHz	≤2.0° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	≥30 dBc
Out-of-band emissions	See Appendix D of the SNUG for allowable limits on out-of-band emissions, including spurs
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak) (Note 4)	≤3 percent
Axial ratio for autotrack	≤1 dB
Data rate tolerance	≤+0.1 percent
I/Q power ratio tolerance	≤+0.4 dB

NOTES:

1. The definitions and descriptions of the customer constraints are provided in SNUG Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
4. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
5. KaSA service does not support Doppler tracking.

Table E-4 KaSAR-650 MHz Data Service Customer Signal Distortion Constraints

Parameter (Note 1)	Requirement (Note 1)
Minimum channel state symbol transition density	≥ 128 randomly distributed channel state symbol transitions within any sequence of 512 channel state symbols
Consecutive I-channel or Q-channel channel state symbols without a state transition	≤ 64 channel state symbols
Channel state symbol asymmetry (peak)	≤ ± 3 percent
Channel state symbol jitter and jitter rate	≤ 0.1 percent
Phase imbalance	
a. BPSK/QPSK/SQPSK	≤ ± 3 degrees
b. 8-PSK	≤ ± 2 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak-to-peak)	≤ 12 degrees over ± 230 MHz
Gain flatness (peak-to-peak)	≤ 1.2 dB over ± 230 MHz
Gain slope	≤ 0.1 dB/MHz over ± 230 MHz
AM/PM	≤ 6 degrees/dB
Noncoherent frequency stability (peak) (Note 2) (± 300 kHz customer oscillator frequency uncertainty)	
1-sec observation time	≤ 3×10^{-9}
Lifetime	≤ 1.1×10^{-5}
Incidental AM (peak)	
a. For open-loop pointing at frequencies ≥ 100 Hz	≤ 5 percent
b. For autotrack performance	
At frequencies: 10 Hz – 10 kHz	≤ 3 percent
At frequencies: 10 Hz – 2 kHz	≤ 0.6 percent
Spurious PM	≤ 2 degrees
Minimum 3-dB bandwidth prior to power amplifier	≥ 2 times maximum channel baud rate (Note 3)
Phase noise	
1 Hz – 10 Hz	≤ 50.0 degrees rms
10 Hz – 100 Hz	≤ 20.0 degrees rms
100 Hz – 1 kHz	≤ 3.6 degrees rms
1 kHz – 400 MHz	≤ 2.0 degrees rms
In-band spurious outputs, where in-band bandwidth is twice the maximum channel symbol rate	≤ -30 dBc
Out-of-band emissions	See Appendix D of SNUG for allowable levels of customer out-of-band emissions, including spurs
I/Q channel state symbol skew (peak)	≤ 3 percent
Axial ratio	≤ 3 dB
Data rate tolerance	≤ ± 0.1 percent
I/Q power ratio tolerance	≤ ± 0.4 dB

NOTES:
1. The definitions and descriptions of the customer constraints are provided in SNUG, Appendix E.
2. The frequency stability requirements are valid at any constant temperature (± 0.5ºC) in the range expected during the mission. At a minimum, a temperature range of -10°C to +55°C shall be considered.
3. Baud Rate is defined as the rate at which the phase of the carrier wave is changed by the modulating signal.

Appendix F ALOS Ka-band Service Description

Appendix F. ALOS Ka-Band Service Description

F.1 Ka-Band General

F.1.1 Forward Service

The SN is not required to provide Ka-band forward service support to ALOS.

F.1.2 Return Service

The ALOS mission uses a balanced QPSK signal structure with modulo-4 differential encoding data formatting.

- Data Source: Dual data source
- Forward Error Correction Coding: None or (255,223) Reed-Solomon (32-bit compliant)
- Symbol Format Coding: Gray Code, Modulo-4 Differential Encoding
- Symbol Format: NRZ
- Modulation: QPSK (I/Q power ratio: 1:1)
- Data Rate: 138.76 Mbps per channel or 121.35 Mbps; equal data rate per channel.
- Symbol Rate: 138.76 Msps per channel
- I/Q Symbol Alignment: ALOS delays the Q-input data by 2 bits relative to the I-input data. This is provided for informational purposes only as the modulation, data formatting / coding (differential encoding), demodulation and data formatting / decoding (differential decoding) is transparent to this delay.

F.2 ALOS Modulation / Demodulation Scheme Description

The ALOS Ka-band return service provides dual service using QPSK with modulo-4 differentially encoding. Figure F-1 provides the state diagram for the ALOS modulo-4 differential encoding and decoding process.

The values inside the circles indicate the state corresponding to the phase of the QPSK signal; and the values on the arrows correspond to the state of the data symbols / bits.

It is important to maintain the alignment of two bits / symbols throughout the modulation / demodulation process.

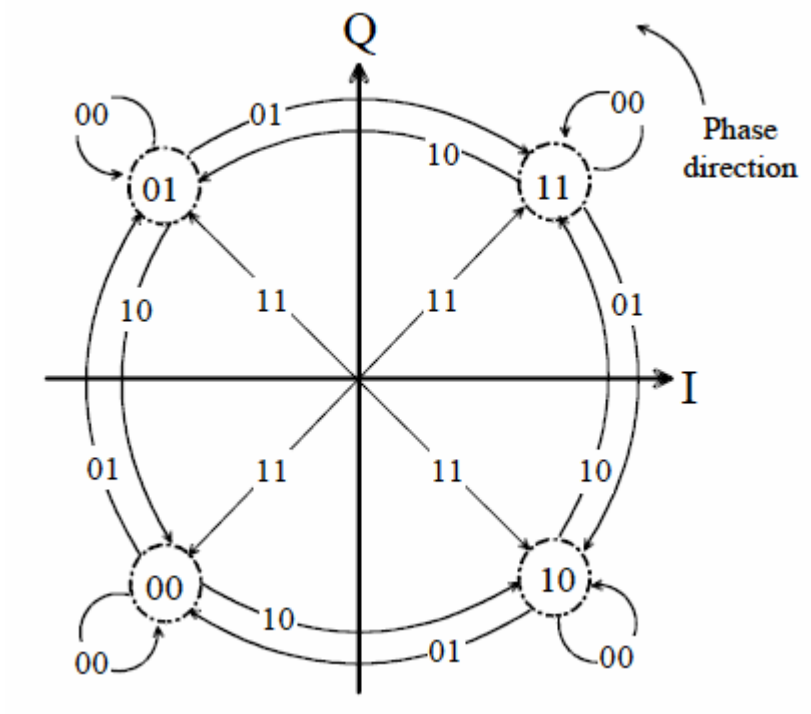
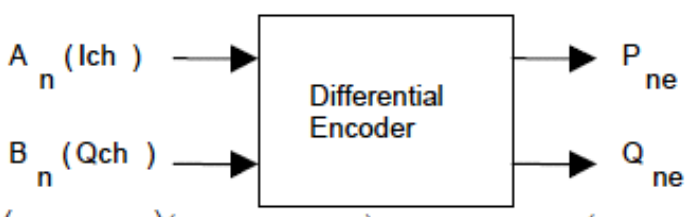


Figure F-1 ALOS Differential Encoding/Decoding State Diagram

F.2.1 Description of the ALOS Modulation

Before modulation, identical rate data bits / symbols (A and B) are presented to the modulator input I and Q channels. The state of the input data bits / symbols (A_n and B_n) determines the new state (phase) of the modulator output signal (P_n and Q_n) based on its previous state (P_{n-1} and Q_{n-1}).

A block diagram of the Differential Modulo-4 Encoder and the logical relationship between the I and Q input data bits / symbols (A and B) to the modulator output is shown in Figure F-2.



$$P_{ne} = \left(\overline{A_n \oplus B_n}\right)\left(A_n \oplus P_{(n-1)e}\right) + \left(A_n \oplus B_n\right)\left(A_n \oplus Q_{(n-1)e}\right)$$

$$Q_{ne} = \left(\overline{A_n \oplus B_n}\right)\left(B_n \oplus Q_{(n-1)e}\right) + \left(A_n \oplus B_n\right)\left(B_n \oplus P_{(n-1)e}\right)$$

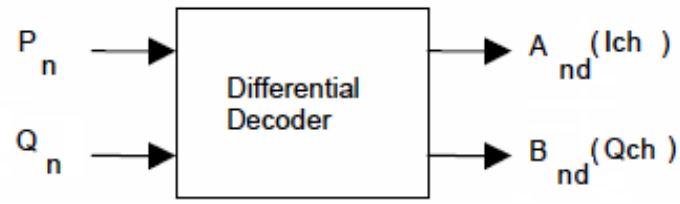
Note: $\oplus$ stands for XOR.

Figure F-2 Modulo 4 Differential Encoding Block Diagram and Logical Expression

F.2.2 Description of the ALOS Demodulation

With reference to state diagram Figure F-1, the state of the output I and Q signal data bits / symbols (A_n and B_n) is determined by the state (phase) of the modulator input signal (P_n and Q_n) and on its previous state (P_{n-1} and Q_{n-1}).

A block diagram of the Differential Modulo-4 Decoder and the logical relationship between the P and Q input signal state (P_n and Q_n) to the differential decoder output data bits / symbols (A_n and B_n) is shown in Figure F-3.



$$A_{nd} = \left(\overline{P_{(n-1)} \oplus Q_{(n-1)}}\right)\left(P_{(n-1)} \oplus P_n\right) + \left(P_{(n-1)} \oplus Q_{(n-1)}\right)\left(P_{(n-1)} \oplus \overline{Q}_n\right)$$

$$B_{nd} = \left(\overline{P_{(n-1)} \oplus Q_{(n-1)}}\right)\left(Q_{(n-1)} \oplus Q_n\right) + \left(P_{(n-1)} \oplus Q_{(n-1)}\right)\left(Q_{(n-1)} \oplus \overline{P}_n\right)$$

Note: $\oplus$ stands for XOR.

Figure F-3. Modulo 4 Differential Decoding Block Diagram and Logical Expression