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Ground Network (GN) Users' Guide

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Goddard Space Flight Center
Greenbelt, Maryland

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Ground Network Users' Guide

Revision 2

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Initiated by:

Paul Garza 5/7/07
Date
Ground Network Project, Code 453
Goddard Space Flight Center

Approved by:

Roger N. Clason 5/11/07
Date
Ground Network Project Manager, Code 453
Goddard Space Flight Center

The contents of this document have been revised and supersede the Ground Network Users' Guide, 453-GNUG Revision 1, dated February 2005, and all changes thereto. Destroy any previously issued copies.

Goddard Space Flight Center
Greenbelt, Maryland

Preface

This document is under the configuration management of the Code 453 Ground Network Project Office Configuration Control Board (GN CCB).

Proposed changes to this document should be submitted to the Ground Network Project Office along with supportive material justifying the change. Changes to this document shall be made by document change notice (DCN) or by complete revision. Questions and proposed changes concerning this document shall be addressed to:

Ground Network Project Office
Code 453
Building 12, Room E-218
Goddard Space Flight Center
Greenbelt, Maryland 20771

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Section 1. Introduction

1.1 Purpose

The purpose of this document is to describe the technical capabilities of the ground stations that comprise the National Aeronautics and Space Administration (NASA) Ground Network (GN).

This document provides sufficient information to enable project engineers and support personnel to begin interfacing with the GN. It is not intended to be a technical description of network equipment; rather, it defines GN capabilities and identifies those parameters of particular interest to the user. For more detailed information, see the documents cited in Section 1.3.

Because GN capabilities may change (due to budgetary constraints or management decisions, for example), the information presented in this document does not obligate NASA in any way.

1.2 Scope

For the purpose of this document, the GN consists of NASA ground stations located in Norway, Florida, Alaska, Antarctica, and Virginia. The GN also includes support from the Network Integration Center (NIC) located at GSFC and the GN scheduling, WS1 Ka-band and VHF systems at the White Sands Complex, New Mexico.

For each GN station, this document provides the following information:

- General characteristics, including geographic location, transmit/receive capabilities, and scheduling capabilities.
- Detailed performance characteristics.
- User tracking capabilities.
- Baseband data interfaces.

Detailed information on frequency management considerations and link budget parameters is also provided.

1.3 Reference Documents

The following documents are referenced herein and/or provide background information:

a. EOS Polar Ground Station Project Phase I Functional and Performance Requirements, 452-F&PR1-EPGS, May 1998.

b. Radio Frequency and Modulation Systems, Part 1, Earth Stations, CCSDS 401.0-B-17 , Blue Book. Issue 17. July 2006.

c. AOS Space Data Link Protocol. CCSDS 732.0-B-2, Blue Book. Issue 2. July 2006.

d. Radio Frequency and Modulation Systems—Spacecraft-Earth Station Compatibility Test Procedures, CCSDS 412.0-G-1, Green Book. Issue 1. May 1992.

e. NISN Services Document (NSD), NISN 001-001 (Rev. 4-C).

f. Earth Observing System (EOS) Data and Information System (EOSDIS) Backbone Network (EBnet) Operations Concept, 540-028, Revision 1, GSFC, May 1996.

g. Wallops Capability Matrix, WFF, Microwave Systems Branch, Daniel A. Mullinix, Code 567, 23 February 1998.
h. GN Compatibility Matrix, Version 8, September 2005.
i. NASA Policy Directive (NPD) 2570.5, NASA Radio Frequency Spectrum.
j. Tracking and Acquisition Data Handbook for the Ground Network, 453-HDBK-GN (DRAFT), April 2007.
k. NASA Procedural Requirement (NPR) 2570.1, NASA Radio Frequency (RF) Spectrum Management Manual.
l. NTIA Manual of Regulations & Procedures for Federal Radio Frequency Management.
m. Interface Control Document Between Landsat 7 Mission Operations Center (MOC) and the Landsat 7 Ground Network (LGN), L7-ICD-40.1, February 2004...
n. Radio Frequency (RF) Interface Control Document (ICD) Between the ICESat Spacecraft and the EOS Polar Ground Station (EPGS), 452-RFICD-EPGS/ICEsat, January 2000.
o. Efficient Spectrum Utilization for Space Science Services on Space-To-Earth Links, SFCG Recommendation 17-2R1, 17 September 1998.
p. Wallops Flight Facility Range User's Handbook, 840-HDBK-0001, Version F, dated June 2003.
q. 450-Catalog-Services, GSFC Mission and Data Services 2003 Catalog.
r. 450-OIP-DSMC, Data Services Management Center (DSMC) Interface Procedures (OIP), dated June 24, 2005.
s. Space Link Extension – Forward CLTU Service Specification. CCSDS 912.1-B-2 Blue Book. Issue 2. November 2004.
t. TM Synchronization and Channel Coding, CCSDS 131.0-B-1, Blue Book. Issue 1. October 2003.

1.4 Document Organization

The remaining portions of this document are organized as follows:

- Section 2 provides an overview of the entire GN.
- Section 3 describes the Norway ground station (SGS).
- Section 4 describes the Wallops Flight Facility (WFF) ground stations in Virginia.
- Section 5 describes the McMurdo Ground Station in Antarctica.
- Section 6 describes the Alaska ground stations.
- Section 7 describes the Florida ground stations.
- Section 8 describes the White Sands Complex VHF ground stations.
- Section 9 describes the scheduling process.
- Section 10 describes baseband data interfaces.

- Section 11 describes frequency management considerations.
- Section 12 describes link budget parameters.
- Appendix A is the acronym list.
- Appendix B Ground Network New Project Questionnaire.

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Section 2. Ground Network Overview

This section provides an overview of the GN, its antenna ground stations, and customer support services. The antenna overview provides general characteristics of GN antenna tracking, telemetry, and command functions and capabilities. Further details on GN antennas are addressed on a station-by-station basis in the following chapters. The customer service overview describes GN support services and how to obtain GN services. Further details on support services are available from the Exploration and Space Communications (ESC) Projects Division Network Integration Management Office (GSFC Code 450.1).

To help a flight project quickly examine, evaluate, and compare capabilities of GN ground station antennas, this section contains several tables summarizing antenna capabilities and specifications.

- *Table 2-1* summarizes general antenna specifications
- *Table 2-2* summarizes antenna command and telemetry data rates and coding
- *Table 2-3* summarizes telemetry support, sorted by frequency band and data rate
- *Table 2-4* summarizes command support, sorted by frequency band and data rate

2.1 Ground Network Overview

The NASA Ground Network is a customer driven organization that provides comprehensive communications services to space assets. The GN provides telemetry, commanding, and tracking services for orbital missions and occasionally sub-orbital missions. The GN provides services to a wide variety of mission customers, at various low-earth orbits (LEO), geosynchronous orbits (GEO), highly elliptical orbits, lagrange orbits, lunar and sub-orbital and launch trajectories, at multiple frequency bands through all phases of a mission's lifetime. This diversity of service is listed in Figure 2-1.

GN Customer Diversity Examples		
	Customers	• NASA • Other Government • International • Commercial
	Phases	• On-orbit • Launch • Early Orbit • Disposal
	Orbits	• LEO Polar • LEO Low Inclination • GEO • Highly Elliptical • Launch • Sub-orbital
	Frequency	• X-Band • S-Band • UHF • VHF

Figure 2-1. GN Services

2.2 GN Ground Stations Overview

The GN provides services from a diverse collection of antenna assets located around the world. Many of the GN sites are located in prime polar locations to provide service to high-inclination polar orbiting spacecraft. Because polar orbiting spacecraft pass over the Earth's poles each orbit, stations in near polar locations, such as Norway, Alaska, and Antarctica, can provide communications to polar orbiting spacecraft nearly every orbit.

NASA's mid-latitude and equatorial ground stations provide support to low-inclination orbital missions, provide contingency support to geosynchronous (GEO) spacecraft, and are located near launch ranges to provide effective launch range tracking support. The Merritt Island

Launch Annex (MILA) station in Florida is located to provide launch support to shuttle missions launching from Kennedy Space Center (KSC). The ground station assets located at Wallops, Virginia, are in a prime location to provide orbital support to low-inclination customers and launch tracking services to the launch range at Wallops, as well as to provide some coverage to launches from KSC. Stations are distributed around the globe to provide mission-critical event coverage to missions.

This GN Users' Guide addresses NASA owned and maintained stations that are dedicated to NASA customer missions. The stations listed in the GN Users' Guide include:

- Svalbard Ground Station (SGS) in Norway, operated by KSAT
- Wallops Ground Stations (WGS) in Virginia
- McMurdo Ground Station (MGS) in Antarctica
- Alaska Ground Stations (AGS) in Poker Flat Alaska
- Florida Ground Stations
- White Sands Complex ground stations in New Mexico

These GN stations are summarized in Tables 2.1, 2.2, and 2.3, and detailed in following chapters. Additional information can be found at the following NASA URL http://scp.gsfc.nasa.gov/gn/index.htm, including hours of operations (Link Commitment Schedule).

NASA provides a significant portion of its space communications services by contracting commercial ground station providers to support NASA missions. The commercial antennas provided by these contractors are available to NASA GN customers through existing contracts with the GN. Commercial data service providers currently available through the NASA GN include:

- Al.aska Satellite Facility (ASF) in Alaska
- Honeywell's DataLynx™ station in Alaska
- Kongsberg Satellite Services (KSAT) at Svalbard, Norway
- Universal Space Network (USN) with stations in Alaska, Hawaii, and Australia
- University of Chile (UdC) in Santiago, Chile

These providers and their antennas assets are not discussed in detail in this GN Users' Guide Information about commercial sites may be acquired on the respective provider's web site:

- Kongsberg Satellite Services –http://www.ksat.no
- Honeywell Datalynx™ – www.honeywell.com/datalynx
- Alaska Satellite Facility – http://www.asf.alaska.edu/index.html
- Universal Space Network – http://www.uspacenetwork.com/
- University of Chile – http://www.cee.uchile.cl/public/home_en.html

2.3 GN Customer Support Services Overview

The Network Integration Management Office (NIMO) in conjunction with the GN performs analysis, testing, and simulation services that are of direct benefit to the user flight project. Some are mandatory to validate compatibility and to meet launch readiness requirements. Analysis will address such preliminary questions as projected GN loading, RF link margins, geometric coverage analyses, and preliminary funding and staffing requirements. Appendix B contains a new project questionnaire to assist the initial analysis. The results of such analyses will enable an early assessment of the project's compatibility with the GN.

2.3.1 Network Loading Analysis

To ensure that sufficient GN resources are available to meet commitments to current and future users, the NIMO provides a representative to each customer flight project as early as possible during mission planning to assist in the definition of customer flight project needs for ESC services. Typical information needed for analyses includes the projected requirements for communications timeline, data rates, and number of data channels. Although this information may initially be of a preliminary nature, the best available information is needed for projecting GN loading.

2.3.2 RF Link Margin and Coverage Analysis

Information exchange between the customer mission and the NIMO for the RF link margin and coverage analysis begins during the initial flight segment mission analysis phase and continues until firm coverage requirements and flight segment designs are finalized in the mission execution phase. The Communications Link Analysis and Simulation System (CLASS) analysis tool can be used to help achieve a flight segment telecommunications design which is compatible with the GN, and will achieve the desired level of performance. Design deficiencies and possible trade-offs are defined during these analyses. The results of CLASS are used early in the mission analysis phase to aid in the development of the RF Interface Control Document (ICD), which is a controlling input to the flight segment telecommunications specifications.

2.3.3 Compatibility Testing

Compatibility testing is performed as early as possible after fabrication of the user spacecraft (either the flight model, which is preferred, or the prototype model) is completed. Compatibility tests are normally rerun following resolution of significant problems encountered during the original test or following post-test flight segment design modification. Results of these tests are formally published in the mission-specific Compatibility Test Report. Satisfactory completion of this testing and certification is required to meet the NASA readiness-for-launch criteria.

2.3.4 GN Interface Testing and Operational Simulations

Mutually agreed upon end-to-end tests are conducted to validate all telecommunications system functions, as defined in the applicable ICDs and Customer Integration and Test Plans. In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines.

2.3.5 Orbit Support Analysis

Pre-launch orbital error analyses are performed to determine the frequency with which user spacecraft state vectors are needed to achieve the orbital accuracies required by the user flight project.

2.4 Ground Network Directive and Reporting

The Ground Network Directive procedure provides a formal means of efficiently alerting and/or directing Ground Network elements to ensure continuity of reliable support in situations that management deems appropriate and/or where other notification methods may not suffice. The GN Directive will used as a tool to notify sites of potential systemic conditions that could affect the safety of operations, equipment or personnel and directs sites to implement associated mitigating actions. (Note decision to implement the mitigating action at the commercial sites remains under the commercial sites management)

The Significant Event Reporting System (SERS) is used to notify management and network users of site/system failures. An email is generated that details the anomaly, repair efforts and current/future impacts. The email distribution is controlled by the GN manager.

2.5 Obtaining Ground Network Services

For all GN stations, flight projects should request GN support through NASA/GSFC, Code 450.1, Network Integration Management Office. The Network Integration Management Office provides its spacecraft and scientific customers with a broad complement of services. The group provides best value tracking and data acquisition, communications, flight operations, flight dynamics, data processing options, and assistance in requirements definition. Also provided are Principal Investigators and Mission Formulation Managers with options and planning assistance to effectively meet the mission needs.

The Office supports the mission throughout the life cycle for its communications, flight operations, and data processing needs - from trade studies and cost analysis during the formulation phase, to project management during development and operations. Provides Mission Project Managers with the ability to secure contract vehicles and services to implement and operate their mission most effectively. Additional information can be found at http://scp.gsfc.nasa.gov/cco/index.htm.

Table 2-1. GN Overview

Station Location	Antenna Name	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
Norway	**SGS**	11.3 m	2025-2120	66	2200-2400 8025-8400	23 35.4	78°N 15°E	1- & 2-Way Dop, Angle
Wallops, Virginia	**WGS 11.3 m**	11.3 m	2025-2120	66	2200-2400 8025-8400	23 35	38°N 75°W	1- & 2-Way Dop, Angle
	LEO-T	4.7 m	2025-2120	59	2200-2300	17	38°N 75°W	—
	WFF VHF-1	N/A (Yagi)	139.208	45.4	143.625	N/A	38°N 75°W	—
	WFF VHF-2	N/A (Yagi)	130.167	45.4	121.750	N/A	38°N 75°W	—
	WFF UHF	NA (Quad Helix)	259.7 Prime 296.8 B/U	34.0	259.7 Prime 296.8 B/U	N/A	37°N 75°W	—

Table 2-1. GN Overview (cont'd)

Station Location	Antenna Name	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
McMurdo, Antarctica	**MGS**	10 m	2025-2120	63	2200-2400 8025-8400	21.1 32.5	78°S 193°W	—
Alaska	**LEO-T**	4.7 m	2025-2120	59.2	2200-2300	17	65°N 147°W	—
	AGS	11.3 m	2025-2120	66	2200-2400 8025-8400	23 36	65°N 147°W	1- & 2-Way Dop, Angle
	ASF	11.3m	2025-2120	66	2200-2400 8025-8400	23 35	64°N 147°W	1- & 2-Way Dop, Angle
	ASF	10m	N/A	63	2200 -2400 8025 -8350	21 31	64°N 147°W	—
Florida	**MILA**	9 m (2)	2025-2120	63	2200-2300	24	29°N 81°W	1- & 2-Way Dop, Angle, 2-Way Ranging
	MILA	4.3 m	2025-2120	58	2200-2300	11	29°N 81°W	—
	MILA	Quad-Helix UHF	2025-2120	58	2200-2300	11	29°N 81°W	—
	MILA	MILA Relay System	2025-2120	58	2200-2300	11	29°N 81°W	—
	PDL	4.3 m	2025-2120	58	2200-2300	11	29°N 81°W	—
White Sands, New Mexico	**WSC VHF-1**	N/A (Yagi)	139.208	43.4	143.625	N/A	32°N 106°W	—
	WSC VHF-2	N/A (Yagi)	130.167	45.4	121.750	N/A	32°N 106°W	—
	WS1 (future)	18 m	2025-2120	80 dBW	2200-2300, 2565	29 45	32°N 106°W	1- & 2-Way Dop, Angle

Table 2-2. Command and Telemetry Support by Station

Station Location	Antenna Name	Data Type	Band	Carrier or Subcarrier	Maximum Data Rate	Coding
Norway	SGS	Command	S-band	Carrier	200 kbps	—
				Subcarrier	32 kbps	
		Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
			X-band	Carrier	150 Mbps	
Wallops, Virginia	WGS	Command	S-band	Carrier	200 kbps	—
				Subcarrier	32 kbps	—
		Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
			X-band	Carrier	150 Mbps	
	LEO-T	Command	S-band	Carrier	200 kbps	—
				Subcarrier	32 kbps	
		Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
				Subcarrier	32 kbps	
		Telemetry	S-band	Carrier	5 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
				Subcarrier	1 Mbps	
	MGTAS	Telemetry	L-band	Carrier	6.6 Mbps	Viterbi and/or R-S
				Subcarrier	1.3 Mbps*	
			S-band	Carrier	6.6 Mbps	
				Subcarrier	1.3 Mbps*	

* The data rate of the telemetry subcarrier must be less than 2/3 the frequency of the subcarrier.

Table 2-2. Command and Telemetry Support by Station (cont'd)

Station Location	Antenna Name	Data Type	Band	Carrier or Subcarrier	Maximum Data Rate	Coding
McMurdo, Antarctica	MGS	Command	S-band	Carrier	200 kbps	—
				Subcarrier	32 kbps	—
		Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
			X-band	Carrier	110 Mbps	
Alaska	AGS	Command	S-band	Carrier	200 kbps	—
				Subcarrier	32 kbps	—
		Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
			X-band	Carrier	150 Mbps	
	LEO-T	Command	S-band	Carrier	200 kbps	—
				Subcarrier	32 kbps	—
		Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
				Subcarrier	1 Mbps	
				Subcarrier	1 Mbps	
Florida	MILA	Command	S-band	Carrier	216 kbps	—
				Subcarrier	8 kbps	—
		Telemetry	S-band	Carrier	10 Mbps	Viterbi and/or R-S
				Subcarrier	2 Mbps	
	PDL	Command	S-band	Carrier	—	—
				Subcarrier	8 kbps	—
		Telemetry	S-band	Carrier	2 Mbps	Viterbi and/or R-S
				Subcarrier	1.3 Mbps*	

* The data rate of the telemetry subcarrier must be less than 2/3 the frequency of the subcarrier.

Table 2-3. Telemetry Support – Sorted by Frequency Band and Data Rate

Band	Maximum Data Rate	Carrier or Subcarrier	Coding	Station
S-band	10 Mbps	Carrier	Viterbi and/or R-S	MILA
	2 Mbps	Subcarrier	Viterbi and/or R-S	
	8 Mbps	Carrier	Viterbi and/or R-S	SGS WGS MGS AGS LEO-T (WFF and Alaska) WS1
	1 Mbps	Subcarrier	Viterbi and/or R-S	
	6.6 Mbps	Carrier	Viterbi and/or R-S	MGTAS
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	
	1 Mbps	Subcarrier	Viterbi and/or R-S	
	2 Mbps	Carrier	Viterbi and/or R-S	PDL
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	

Table 2-3. Telemetry Support – Sorted by Frequency Band and Data Rate (cont'd)

Band	Maximum Data Rate	Carrier or Subcarrier	Coding	Station
X-band	150 Mbps	Carrier	Viterbi and/or R-S	SGS WGS AGS
	110 Mbps	Carrier	Viterbi and/or R-S	MGS
Ka-band	100 Mbps			WS1
L-band	6.6 Mbps	Carrier	Viterbi and/or R-S	MGTAS
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	

* The data rate of the telemetry subcarrier must be less than $^2/_3$ the frequency of the subcarrier.

Table 2-4. Command Support – Sorted by Frequency Band and Data Rate

Band	Maximum Data Rate	Carrier or Subcarrier	Station
S-band	216 kbps	Carrier	MILA
	8 kbps	Subcarrier	MILA, WS1
	200 kbps	Carrier	SGS WGS MGS LEO-T (WFF) AGS LEO-T (Alaska)
	32 kbps	Subcarrier	
	2 kbps	Subcarrier	
	—	Subcarrier	
UHF	IRIG Standard Tones	Carrier	UHF Command Systems (WFF)

Section 3. Norway Ground Station (SGS)

This section describes the EOS Polar Ground Station located in Svalbard, Norway, known as the Svalbard Ground Station (SGS). Three apertures are available at Norway; SG1, SG2, SG3. The SG1 antenna is described in the text below. This URL http://www.ksat.no/Downloads can be used to link to the characteristics of the remaining apertures.

The general characteristics of the station are as follows:

- Location: 78° 13′ 57″ N
  15° 23′ 23″ E
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 3-1 is a photograph of the SGS antenna.
- Automatically scheduled by GN schedulers using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: Internet Protocol (IP), serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 3.1 through 3.3 describe S- and X-band performance characteristics. Sections 3.4 and 3.5 describe the tracking services and baseband data interfaces, respectively.

Figure 3-1. SGS Antenna

3.1 S-Band Command

Table 3-1 identifies the S-band command characteristics of the SG1 antenna.

3.2 S-Band Telemetry

Table 3-2 identifies the S-band telemetry characteristics of the SG1 antenna.

Table 3-1. SG1 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

3.3 X-Band Telemetry

Table 3-3 identifies the X-band telemetry characteristics of the SG1 antenna.

3.4 Tracking Services

3.4.1 Doppler Tracking

The SG1 antenna generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the SGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 3-4*.

Table 3-2. SG1 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 8 Mbps Biϕ: 100 bps - 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

3.4.2 Antenna Autotracking Angle Data

The SG1 antenna can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as Universal Tracking Data Format (UTDF) messages. (See Table 4-1 of Reference [a] in Section 1.3, above.)

3.5 Baseband Data Interfaces

The SG1 antenna can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). SGS currently has a T-1 (1.544 Mbps) communications link and OC-1 (52 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. SGS will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 3-3. SG1 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T (See Section 11 for detailed measurement data)	≥ 35.4 dB/K with radome (at 60° elevation)
System Noise Temperature	150 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	57.6 dBi
Modulation	QPSK, SQPSK, UQPSK, or AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

Table 3-4. SG1 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (f/f)	4 x 10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	1000 ($f_{transmit}$ × [240/221] – $f_{received}$) + f_{bias}

Section 4. Wallops Flight Facility (WFF) Ground Stations

This section describes the GN stations located at WFF.

The primary orbital stations consist of the following ground stations:

- WGS (Section 4.1)
- LEO-T – WFF (Section 4.2)

The other GN station located at WFF is the following:

- VHF Ground Stations (Section 4.3)

4.1 WGS

The general characteristics of the WGS ground station at WFF are as follows:

- Location: 37º 55′ 28″ N
75º 28′ 35″ W
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 4-1 is a photograph of the WGS antenna.
- Automatically scheduled by GN schedulers using WOTIS (see Section 11.3).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 4.1.1 and 4.1.2 describe S-band and X-band performance characteristics. Sections 4.1.3 and 4.1.4 describe the tracking services and baseband data interfaces, respectively.

S-Band Command Table *4-1* identifies the S-band command characteristics of the WGS.

Figure 4-1. WGS Antenna

Table 4-1. WGS S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

4.1.1 S-Band Telemetry

Table 4-2 identifies the S-band telemetry characteristics of the WGS.

Table 4-2. WGS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23 dB/K
System Noise Temperature	165 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ-L : 100 bps - 8 Mbps Biφ-L : 100 bps - 4 Mbps QPSK: 6 – 100Mbps
Carrier Data Format	NRZ-L, M, S or Biφ-L, M, S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L or Biφ-S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

4.1.2 X-Band Telemetry

Table 4-3 identifies the X-band telemetry characteristics of the WGS.

4.1.3 Tracking Services

4.1.3.1 Doppler Tracking

WGS generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the WGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 4-4*.

Table 4-3. WGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 35 dB/K
System Noise Temperature	170 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	QPSK, UQPSK, SQPSK, AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

4.1.3.2 Antenna Autotracking Angle Data

The WGS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

4.1.4 Baseband Data Interfaces

The WGS can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). WGS currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

WGS mails high-rate tape-recorded X-band telemetry data to the user if necessary.

Table 4-4. WGS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000\,(f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

4.2 LEO-T – WFF

The general characteristics of the LEO-T ground station at WFF are as follows:

- Location: 37º 55′ 25″ N
75º 28′ 34″ W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 4-2 is a photograph of the LEO-T antenna.
- Manually scheduled by GN operations personnel.
- Tracking services: None.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 4.2.1 and 4.2.2 describe S-band performance characteristics, and Section 4.2.3 describes the baseband data interfaces.

4.2.1 S-Band Command

Table 4-5 identifies the S-band command characteristics of the LEO-T – WFF station.

4.2.2 S-Band Telemetry

Table 4-6 identifies the S-band telemetry characteristics of the LEO-T – WFF station.

Figure 4-2. LEO-T WFF Antenna

Table 4-5. LEO-T – WFF S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 59.2 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1.8°
Antenna Gain	38.6 dBi
Output Power	200 W
Carrier Modulation	PM, BPSK, or FM
Modulation Index	PM: 0.2 - 1.5 radians (peak)
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biφ-L, M, or S

Table 4-6. LEO-T – WFF S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 17 dB/K
System Noise Temperature	174 K
Polarization	RHC or LHC
Antenna Beamwidth	1.83°
Antenna Gain	39.4 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	Uncoded: 8 Mbps Rate-½ coded: 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

4.2.3 Baseband Data Interfaces

The LEO-T – WFF station can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). The station currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

4.3 VHF Ground Stations

The two VHF Air/Ground (A/G) Ground Stations at WFF are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice. The general characteristics of the two VHF A/G Ground Stations at WFF are as follows:

- Location: 37° N
  75° W
- Two Quad Yagi antennas (VHF-1 and VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.
- Manual scheduling by GN schedulers, but only JSC-MCC is allowed to request support.
- Tracking services: None.
- Baseband interfaces: Dedicated NISN communications voice loops.

Sections 4.3.1 and 4.3.2 describe the VHF-1 and VHF-2 A/G characteristics, respectively. Section 4.3.3 describes the baseband interfaces.

4.3.1 VHF-1 A/G Voice Ground Station

Tables 4-7 and 4-8 identify the A/G Full Duplex uplink and downlink characteristics of the WFF VHF-1 Ground Station, respectively.

Table 4-7. WFF VHF-1 A/G Uplink Characteristics

Characteristic	Value
Frequency	139.208 MHz
EIRP	≥ 45.4 dBWi
Polarization	N/A
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on the uplink)

Table 4-8. WFF VHF-1 A/G Downlink Characteristics

Characteristic	Value
Frequency	143.625 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

4.3.2 VHF-2 A/G Voice Ground Station

Tables 4-9 and 4-10 identify the A/G Full Duplex voice uplink and downlink characteristics of the WFF VHF-2 Ground Station, respectively.

Table 4-9. WFF VHF-2 A/G Uplink Characteristics

Characteristic	Value
Frequency	130.167 MHz
EIRP	≥ 45.4dBWi
Polarization	N/A
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on the uplink)

Table 4-10. WFF VHF-2 A/G Downlink Characteristics

Characteristic	Value
Frequency	121.750 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

4.3.3 Baseband Voice Interfaces

The WFF VHF-1 ground station can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NISN communications voice loops. The WFF VHF-2 ground station can send and receive baseband voice only from the JSC-MCC via dedicated NISN communications voice loops.

Section 5. McMurdo Ground Station (MGS)

This section describes the MGS in Antarctica. The general characteristics of the station are as follows:

- Location: 77° 50′ 21″ S
  193° 19′ 59″ W
- One 10-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 5-1 is a photograph of the MGS antenna.
- Automatically scheduled by GN schedulers using WOTIS.
- Tracking services: Future planned capability.
- Baseband data interfaces: IP, 4800-bit blocks encapsulated in IP packets, and mail.
- MGS cannot be a launch MANDATORY project required site.

Sections 5.1 through 5.3 describe S- and X-band performance characteristics. Section 5.4 describes the baseband data interfaces.

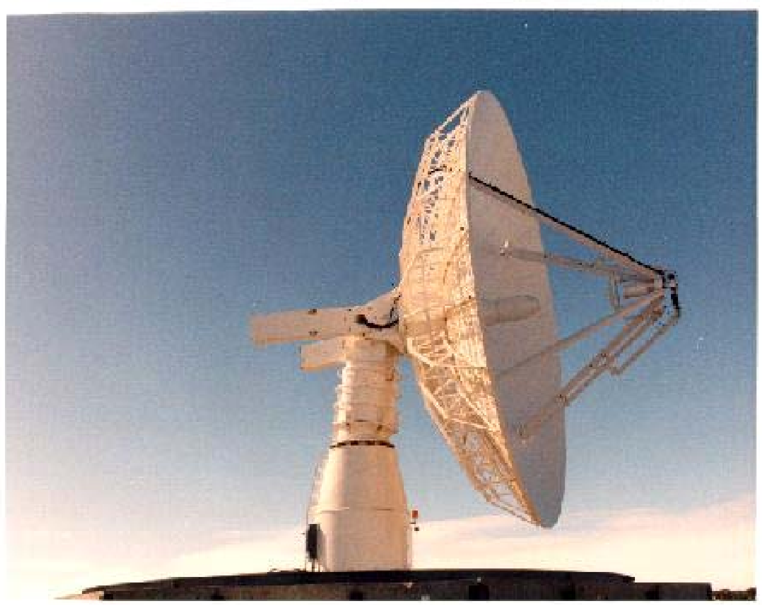

Figure 5-1. MGS Antenna

5.1 S- and X-Band Command

Table 5-1 identifies the S-band command characteristics of the MGS.

5.2 S-Band Telemetry

Table 5-2 identifies the S-band telemetry characteristics of the MGS.

5.3 X-Band Telemetry

Table 5-3 identifies the X-band telemetry characteristics of the MGS.

5.4 Baseband Data Interfaces

MGS can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Section 12). The station currently uses about 10% of a National Science Foundation T-1 communications link to support command, low-rate telemetry, and ground station control and monitor. MGS mails high-rate tape-recorded X-band telemetry data to the user.

Table 5-1. MGS S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 63 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1.05°
Antenna Gain	44 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or PSK
Modulation Index	FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 5-2. MGS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21 dB/K
System Noise Temperature	245 K
Polarization	RHC or LHC
Antenna Beamwidth	0.91°
Antenna Gain	45 dBi
Carrier Modulation	PM, FM, AM, or BPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ-L: 100 bps – 8 Mbps Biϕ-L: 100 bps – 4 Mbps
Carrier Data Format	NRZ-L or Biϕ-L
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

Table 5-3. MGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 35 dB/K
System Noise Temperature	225 K
Polarization	RHC or LHC
Antenna Beamwidth	0.26°
Antenna Gain	56 dBi
Modulation Type	QPSK or UQPSK
Data Rate	QPSK: 6 – 100 Mbps UQPSK: 10 – 23 Mbps 75 – 90 Mbps
Data Format	NRZ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

Section 6. Poker Flat Ground Station

This section describes the GN station at Poker Flat, Alaska. The station is operated by Datalynx and consists of NASA and Datalynx owned assets. See Datalynx Ground station page for additional details www.honeywell.com/datalynx

The station also has NASA Range antenna systems not covered in this document. URL can be found at: www.pfrr.alaska.edu

The NASA Ground Network owned systems at Poker Flat include:

- LEO-T – Alaska (Section 6.1)
- AGS – (Section 6.2)

The Datalynx owned assets include:

- PF1 - (Section 6.3)
- PF2 - (Section 6-4)

6.1 AGS

This section describes the Poker Flat, Alaska, ViaSat 11.3-meter system referred to as AGS.

The general characteristics of the station are as follows:

- Location: 65º 07′ 00″ N
147º 27′ 40″ W
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-1 is a photograph of the AGS antenna.
- Automatically scheduled by GN schedulers using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 6.1.1 through 6.1.3 describe S- and X-band performance characteristics. Sections 6.1.4 and 6.1.5 describe the tracking services and baseband data interfaces, respectively.

6.1.1 S-Band Command

Table 6-1 identifies the S-band command characteristics of the AGS.

6.1.2 S-Band Telemetry

Table 6-2 identifies the S-band telemetry characteristics of the AGS.

6.1.3 X-Band Telemetry

Table 6-3 identifies the X-band telemetry characteristics of the AGS.

Figure 6-1. AGS Antenna

Table 6-1. AGS S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-2. AGS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 8 Mbps Biφ: 100 bps - 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

6.1.4 Tracking Services

6.1.4.1 Doppler Tracking

The AGS generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the AGS S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 6-4*.

6.1.4.2 Antenna Autotrack Angle Data

The AGS can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

Table 6-3. AGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 36 dB/K (at 60° elevation)
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	57.6 dBi
Modulation	SQPSK, UQPSK, or AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.1.5 Baseband Data Interfaces

The AGS can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). AGS currently has a T-1 (1.544 Mbps) communications link and OC-1 (52 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. AGS will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 6-4. AGS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

6.2 LEO-T – Alaska

The general characteristics of the Poker Flat, Alaska LEO-T antenna system are as follows:

- Location: 65º 07′ 01″ N
  147º 27′ 44″ W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 6-2 is a photograph of the LEO-T antenna.
- Automatically scheduled by GN schedulers using WOTIS (see Section 9.3).
- Tracking services: None.
- Baseband data interface: IP.

Sections 6.2.1 and 6.2.2 describe S-band performance characteristics, and Section 6.2.3 describes the baseband data interface.

6.2.1 S-Band Command

Table 6-5 identifies the S-band command characteristics of the LEO-T – Alaska station.

6.2.2 S-Band Telemetry

Table 6-6 identifies the S-band telemetry characteristics of the LEO-T – Alaska station.

6.1.3 Baseband Data Interfaces

The LEO-T – Alaska station can send and receive baseband data in the IP format only (see Section 12). The station currently has a T-1 (1.544 Mbps) communications link with GSFC/WFF to support command, low-rate telemetry, and ground station control and monitor.

Figure 6-2. LEO-T - Alaska Antenna

Table 6-5. LEO-T – Alaska S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 59.2 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1.8°
Antenna Gain	38.6 dBi
Output Power	200 W
Carrier Modulation	PM, BPSK, or FM
Modulation Index	PM: 0.2 - 1.5 radians (peak)
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-6. LEO-T – Alaska S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 17 dB/K
System Noise Temperature	174 K
Polarization	RHC or LHC
Antenna Beamwidth	1.83°
Antenna Gain	39.4 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	Uncoded: 8 Mbps Rate-½ coded: 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

6.3 PF1

This section describes the Poker Flat, Alaska, ESSCO, 7.3-meter system referred to as PF1. The general characteristics of the station are as follows:

- Location: 65.1178º N
  212.5688º E

- One 7.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-3 is a photograph of the antenna.
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data,

Sections 6.3.1 through 6.3.3 describe S- and X-band performance characteristics. Sections 6.3.4 and 6.3.5 describe the tracking services and baseband data interfaces, respectively.

6.3.1 S-Band Command

Table 6-7 identifies the S-band command characteristics of the PF1.

6.3.2 S-Band Telemetry

Table 6-8 identifies the S-band telemetry characteristics of the PF1.

6.3.3 X-Band Telemetry

Table 6-9 identifies the X-band telemetry characteristics of the PF1.

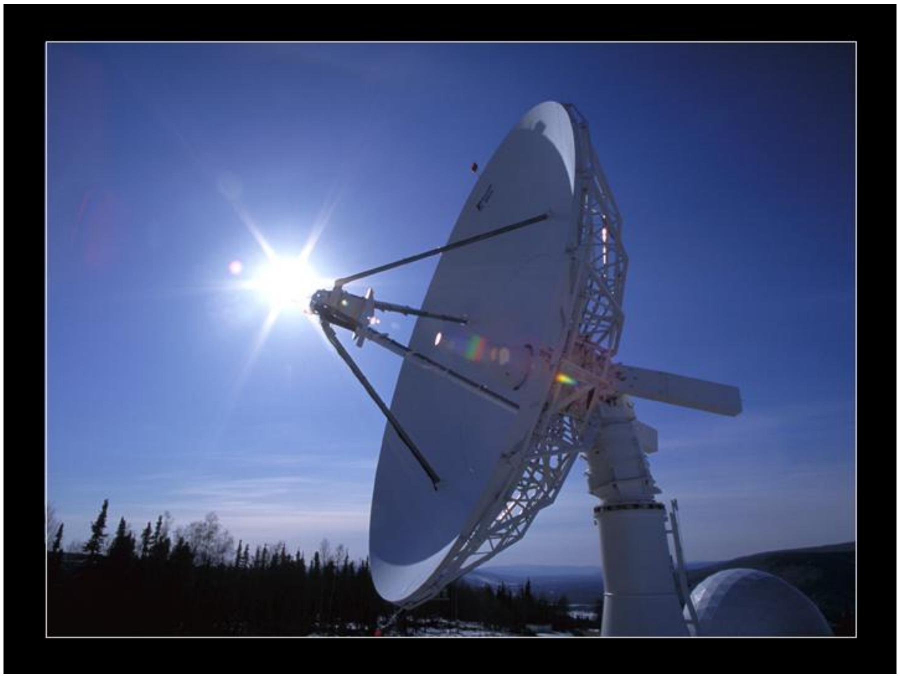

Figure 6-3. PF1 Antenna

Table 6-7. PF1 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 47.98 dBW
Polarization	RHC or LHC
Antenna Beamwidth	1.21°
Antenna Gain	41.7 dBi
Output Power	100 W
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	100 bps - 1 Mbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-8. PF1 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 19.65 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	1.21°
Antenna Gain	42.3 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ:100 bps - 20 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

6.3.4 Tracking Services

6.3.4.1 Doppler Tracking

The PF1 generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the PF1 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 6-10*

6.3.4.2 Antenna Autotracking Angle Data

The PF1 can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

Table 6-9. PF1 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 8500 MHz
G/T	≥ 32 dB/K (at 60° elevation)
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.34°
Antenna Gain	54.2 dBi
Modulation	BPSK, QPSK, SQPSK or PM
Data Rate	40 Mbps – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.3.5 Baseband Data Interfaces

The PF1 can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). PF1 currently has a T-1 (1.544 Mbps) communications link and OC-1 (52 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. PF1 will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 6-10. PF1 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

6.4 PF2

This section describes the Poker Flat, Alaska, ESSCO 11.3-meter system referred to as PF2.

The general characteristics of the station are as follows:

- Location: 65.1179º N
  212.5665º E
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-4 is a photograph of the PF2 antenna.
- Automatically scheduled by GN schedulers using WOTIS (see Section 9.3).
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 6.4.1 through 6.4.3 describe S- and X-band performance characteristics. Sections 6.4.4 and 6.4.5 describe the tracking services and baseband data interfaces, respectively.

6.4.1 S-Band Command

Table 6-11 identifies the S-band command characteristics of the PF2.

6.4.2 S-Band Telemetry

Table 6-12 identifies the S-band telemetry characteristics of the PF2.

6.4.3 X-Band Telemetry

Table 6-13 identifies the X-band telemetry characteristics of the PF2

Figure 6-4. PF2 Antenna

Table 6-11. PF2 S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 65 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	45.3 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or BPSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	100 bps - 1 Mbps
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 6-12. PF2 S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 23 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.81°
Antenna Gain	46 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 36 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

6.4.4 Tracking Services

6.4.4.1 Doppler Tracking

The PF2 generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the PF2 S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 6-14*.

6.4.4.2 Antenna Autotrack Angle Data

The PF2 can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

Table 6-13. PF2 X-Band Telemetry Characteristics

Characteristic	Value
Frequency	7000 - 9000 MHz Receive 8100 – 8400 MHz Autotrack
G/T	≥ 34.5 dB/K
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.86 dBi
Modulation	BPSK,QPSK,SQPSK or AQPSK
Data Rate	40 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

6.4.5 Baseband Data Interfaces

The PF2 can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Section 12). PF2 currently has a T-1 (1.544 Mbps) communications link and OC-1 (52 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. PF2 will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 6-14. PF2 Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

Section 7. Alaska Satellite Facility

This section describes the University of Alaska Ground Station in Fairbanks, Alaska known as the Alaska Satellite Facility (ASF). The station is operated by the University and consists of 2 NASA antenna systems. The NASA owned systems at ASF include:

- ASF 10 – (Section 7.1) additional information available at http://www.asf.alaska.edu/about_asf/receiving_10m.html
- ASF 11 – (Section 7.2) additional information available at http://www.asf.alaska.edu/about_asf/receiving_11m.html

7.1 ASF 10-meter

The general characteristics of the ASF 10-meter antenna system are as follows:

- Location: 65º N
212º E
- 10-meter antenna for receiving at S-band and X-band. Figure 7-1 is a photograph of the ASF 10-meter antenna.
- Manually scheduled by GN schedulers using WOTIS (see Section 11).
- Tracking services: None.
- Baseband data interface: IP.

Sections 7.1.1 through 7.1.3 describe the S-band and X-band performance characteristics, and Section 7.1.4 describes the baseband data interface.

7.1.1 S-Band Command

N/A.

7.1.2 S-Band Telemetry

Table 7-2 identifies the S-band telemetry characteristics of the ASF 10-meter antenna.

7.1.3 X-Band Telemetry

Table 7-3 identifies the X-band telemetry characteristics of the ASF 10-meter antenna

Figure 7-1. ASF 10-meter Antenna

Table 7-1. ASF 10-meter S-Band Command Characteristics

N/A to ASF 10-meter space held for table for future needs

Table 7-2. ASF 10 – Alaska S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21.1 dB/K
System Noise Temperature	174 K
Polarization	RHC or LHC
Antenna Beamwidth	.91°
Antenna Gain	45 dBi
Carrier Modulation	PM, FM, BPSK, or QPSK
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	100 bps – 8 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

Table 7-3. ASF 10-meter X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 32.5 dB/K (at 60° elevation)
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.26°
Antenna Gain	56 dBi
Modulation	BPSK, QPSK, or UQPSK,
Data Rate	6 – 110 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

7.1.4 Baseband Data Interfaces

The ASF-10-meter can send baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 12). ASF 10-meter currently has a T-1 (1.536 Mbps) communications link with GSFC to support telemetry, ASF 10-meter can also mail high-rate, tape-recorded X-band telemetry data to the user as required.

7.2 ASF 11-meter

This section describes the Alaska Satellite Facility 11.3-meter system referred to as ASF 11-meter

The general characteristics of the system are as follows:

- Location: 64.8587º N
  212.1424º E
- The 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 7-2 is a photograph of the ASF 11-meter antenna.
- Automatically scheduled by GN schedulers using WOTIS (see Section 11).
- Tracking services: 1- & 2-way Doppler and antenna auto tracking Angles.
- Baseband data interfaces: IP, serial clock and data, 4800-bit blocks encapsulated in IP packets, and mail.

Sections 7.2.1 through 7.2.3 describe S- and X-band performance characteristics. Sections 7.2.4 and 7.2.5 describe the tracking services and baseband data interfaces, respectively.

7.2.1 S-Band Command

Table 7-4 identifies the S-band command characteristics of the ASF 11-Meter.

7.2.2 S-Band Telemetry

Table 7-5 identifies the S-band telemetry characteristics of the ASF 11-Meter.

7.2.3 X-Band Telemetry

Table 7-6 identifies the X-band telemetry characteristics of the ASF 11-Meter.

Figure 7-2. ASF 11-Meter Antenna

Table 7-4. ASF 11-Meter S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	0.95°
Antenna Gain	44.8 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or PSK
Modulation Index	PM: 1.5 radians (peak) FM: 50 kHz – 50 MHz deviation BPSK: ±90°
Carrier Data Rate	≤ 200 kbps
Subcarrier Frequency	1Khz- 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 32 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 7-5. ASF 11-Meter S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 8 Mbps Biϕ: 100 bps - 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

7.2.4 Tracking Services

7.2.4.1 Doppler Tracking

The ASF 11-Meter generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the ASF 11-Meter S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 7-7*. (future capability)

7.2.4.2 Antenna Autotrack Angle Data

The ASF 11-Meter can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See *Table 4-1* of Reference [j] in Section 1.3, above.)

Table 7-6. ASF 11-Meter X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 9000 MHz
G/T	≥ 35 dB/K
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	SQPSK, UQPSK, or AQPSK
Data Rate	6 – 110 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

7.2.5 Baseband Data Interfaces

The ASF 11-Meter can send and receive baseband data in any of the following formats: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets (see Sections 12). ASF 11-Meter currently has a T-1 (1.536 Mbps) communications link with GSFC to support command, telemetry, and ground station control and monitor. ASF 11-Meter will also mail high-rate, tape-recorded X-band telemetry data to the user as required.

Table 7-7. ASF 11-METER Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.004 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift (Δf/f)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{transmit} \times [240/221] - f_{received}) + f_{bias}$

Section 8. Florida Ground Station

This section describes the two GN stations in Florida:

- MILA (Section 8.1)
- PDL (Section 8.2)

8.1 MILA

This section describes the MILA ground station, located in the Kennedy Space Center (KSC) on Merritt Island, Florida. MILA is a part of NASA's Ground Network, and was formerly part of the Spaceflight Tracking and Data Network (STDN).

The general characteristics of the station are as follows:

- Location (each antenna): 28º 30′ 29″ N
  80º 41′ 34″ W

  28º 30′ 29″ N
  80º 41′ 36″ W
- Two 9-meter antennas for simultaneously transmitting and receiving at S-band. Figure 8-1 is a photograph of the MILA Ground Station.
- 4.3M S-band (See *Tables 8-5 and 8-6*).

  (Also: two UHF antennas, one Quad-Helix and one Teltrac, for voice communications with the Space Shuttle Orbiter. For further information, telephone the MILA Operations Manager: 321-867-1068.)
- MILA Relay System (MRS) consisting of two 3M antennas (one User and one TDRS Relay) capable of spacecraft pre-launch testing and relaying data through TDRS to WSC. The user antenna support S and Ku-band forward and return).
- Scheduled by the GN schedulers at WSC (see Section 11).
- Tracking services: 1- & 2-way Doppler, ranging, and antenna autotracking angle.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 8.1.1 and 8.1.2 describe the S-band performance characteristics. Sections 8.1.3 and 8.1.4 describe the tracking services and baseband data interfaces, respectively.

8.1.1 S-Band Command

Table 8-1 identifies the S-band command characteristics of MILA.

8.1.2 S-Band Telemetry

Table 8-2 identifies the S-band telemetry characteristics of MILA.

Figure 8-1. MILA Ground Station

Table 8-1. MILA S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	16 W: ≥ 55 dBWi 200 W: ≥ 63 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1°
Antenna Gain	44 dBi
Output Power	16 W and 200 W (continuously variable from 100 W to 200 W)(variable from 200 mW to 2nW for testing)
Carrier Modulation	PM, FM, or PSK
Modulation Index	PM: 1 – 3 radians (peak) FM: 1 MHz
Carrier Data Rate	32 kbps, 72 kbps, 96 kbps, or 216 kbps
Carrier Data Format	NRZ-L, M, or S; Biϕ-L, M, or S
Subcarrier Frequency	2 – 16 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 8 kbps
Subcarrier Data Format	NRZ-L, M, or S; Biϕ-L, M, or S

8.1.3 Tracking Services

8.1.3.1 Doppler Tracking

MILA generates both 1- and 2-way S-band Doppler tracking data. Two-way data is derived from a coherent downlink carrier, a turn-around of the MILA S-band uplink signal. Doppler tracking characteristics are shown in *Table 8-3*.

8.1.3.2 Range Tracking

MILA range tracking service is available only for coherent two-way operation using a ranging code. Range tracking characteristics are shown in *Table 8-4*.

Table 8-2. MILA S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	24 dB/K (at zenith)
System Noise Temperature	100 K
Polarization	RHC or LHC
Antenna Beamwidth (3-dB)	1°
Antenna Gain	44 dBi
Carrier Modulation	PCM/PSK/PM, PCM/PSK/FM, PSK/FM, PCM/FM, PCM/PM, or FM/FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	NRZ: 100 bps – 10 Mbps Biϕ: 100 bps – 5 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	1 – 5000 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	100 bps – 2 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v) and/orSTS-TDRS mode Viterbi decoders (Rate-$^1/_3$)

Table 8-3. MILA Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz

Table 8-4. MILA Range Tracking Characteristics

Characteristic	Value
Operational Mode	Coherent
Range Code Waveform	Sine wave
Modulation Index	0.2 – 1.5 radians (peak) on main carrier 0.3 – 1.2 radians (peak) on 1.7-MHz subcarrier
Major Tone Frequencies	500 kHz, 100 kHz, and 20 kHz
Minor Tone Frequencies	100 kHz, 20 kHz, and 4 kHz on carrier 800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz subcarrier (800-Hz tone transmitted single-sideband suppressed, other tones transmitted double-sideband suppressed)
$C_{received}/N$	≥ 10 dB
Acquisition Sequence	Major tone first, then high-to-low for minor tones
Acquisition Threshold, Range Tone SNR	15 dB-Hz
Accuracy	1.0 m
Unambiguous Range	≤ 644,000 km (one-way)

8.1.3.3 Antenna Autotracking Angle Data

MILA can record the angle of the ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [j] in Section 1.3, above.)

8.1.4 Baseband Data Interfaces

MILA can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 12). MILA currently has two 224 kbps communications links with GSFC to support commanding, low-rate telemetry, and ground station control and monitor.

8.2 PDL

This section describes the PDL ground station in Florida. Like MILA, PDL is a part of the GN. The station provides communications to the Space Shuttle Orbiter during launch, when the plume from the solid rocket motor blocks radio signals to MILA.

The general characteristics of the station are as follows:

- Location: 29º 4′ 00″ N
  80º 54′ 47″ W
- One 4.3-meter antenna for simultaneously transmitting and receiving at S-band. Figure7-2 is a photograph of the PDL Ground Station.

  (Also: one fixed UHF cross-dipole antenna, optimized for high inclination launches, backup voice communications with the Space Shuttle Orbiter. The UHF system is used to backup the S-band system. For further information, telephone the MILA Operations Manager: 321-867-3515.)
- Scheduled by the GN schedulers at WSC (see Section 11).
- Tracking services: None.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 8.2.1 and 8.2.2 describe the S-band performance characteristics, and Section 8.2.3 describes the baseband data interfaces.

8.2.1 S-Band Command

Table 8-5 identifies the S-band command characteristics of PDL.

8.2.2 S-Band Telemetry

Table 8-6 identifies the S-band telemetry characteristics of the PDL.

8.2.3 Baseband Data Interfaces

PDL can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 12). The station currently has two 224 kbps communications links with the GSFC to support command.

Figure 8-2. PDL Ground Station

Table 8-5. MILA and PDL 4.3M S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	16 W: ≥ 47 dBWi 200 W: ≥ 58 dBWi
Polarization	RCP or LCP
Antenna Beamwidth	2.5°
Antenna Gain	37 dBi
Output Power	16 W and 200 W (continuously variable from 100 W to 200 W)
Carrier Modulation	PM
Modulation Index	0 – 3.0 radians (peak)
Subcarrier Frequency	2 kHz, 4 kHz, 8 kHz, or 16 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	16 bps – 8 kbps
Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S

Table 8-6. MILA and PDL 4.3M S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	11 dB/K (at 45°)
System Noise Temperature	250 K
Polarization	RCP or LCP
Antenna Beamwidth	2.5°
Antenna Gain	35 dBi
Carrier Modulation	PCM/PSK/PM, PCM/PM, PCM/PSK/FM, PSK/FM, PCM/FM, or FM/FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	4 bps – 2000 kbps
Carrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Subcarrier Frequency	1 – 2000 kHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	(Subcarrier Frequency)/(Subcarrier Data Rate) > 1.5
Subcarrier Data Format	NRZ-L, M, or S; or Biϕ-L, M, or S
Decoding	Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v) and/or STS-TDRS Mode Viterbi decoders (Rate-1/3)

Section 9. Universal Space Network Stations

The Universal Space Network (USN) is a commercial service provider with 4 primary stations with a collaboration of 15 other stations. Details concerning these sites are available at http://www.uspacenetwork.com/sites.html

Section 10. White Sands Complex VHF Ground Stations

The two VHF Air/Ground (A/G) Ground Stations at the White Sands Complex (WSC) are used only to support the International Space Station and Soyuz spacecraft. The VHF-1 system can transmit and receive voice and support packet data on the uplink. The VHF-2 system supports only voice. The general characteristics of the two VHF A/G Ground Stations at WSC are as follows:

- Location: 32° N
  106° E
- Single Yagi antenna (VHF-1) and Quad Yagi (VHF-2) for simultaneously transmitting voice at VHF while receiving voice at VHF.
- Manual scheduling, but only JSC-MCC is allowed to request support.
- Tracking services: None.
- Baseband interfaces: Dedicated NISN communications voice loops.

Sections 10.1 and 10.2 describe the VHF-1 and VHF-2 A/G characteristics, respectively. Section 10.3 describes the baseband interfaces.

10.1 VHF-1 A/G Ground Station

Tables 10-1 and 10-2 identify the A/G Full Duplex uplink and downlink characteristics of the WSC VHF-1 Ground Station, respectively.

Table 10-1. WSC VHF-1 A/G Uplink Characteristics

Characteristic	Value
Frequency	139.208 MHz
EIRP	≥ 43.4 dBWi
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	TBD for packet data

Table 10-2. WSC VHF-1 A/G Downlink Characteristics

Characteristic	Value
Frequency	143.625 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	18.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only on downlink)

10.2 VHF-2 A/G Voice Ground Station

Tables 10-3 and 10-4 identify the A/G Full Duplex voice uplink and downlink characteristics of the WSC VHF-2 Ground Station, respectively.

Table 10-3. WSC VHF-2 A/G Uplink Characteristics

Characteristic	Value
Frequency	130.167 MHz
EIRP	≥ 45.4dBWi
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	12.0 dBi
Output Power	350 W
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only)

Table 10-4. WSC VHF-2 A/G Downlink Characteristics

Characteristic	Value
Frequency	121.750 MHz
G/T	N/A
System Noise Temperature	N/A
Polarization	RHC
Antenna Beamwidth	20°
Antenna Gain	12.0 dBi
Carrier Modulation	FM
FM Deviation	± 10 kHz
Carrier Data Rate	N/A (Voice only)

10.3 Baseband Voice Interfaces

The WSC VHF-1 ground station can send and receive baseband voice and receive packet data from only the JSC-MCC via dedicated NISN communications voice loops. The WSC VHF-2 ground station can send and receive baseband voice only from the JSC-MCC via dedicated NISN communications voice loops.

Section 11. Scheduling

11.1 Scheduling Purpose and Need

With the GN supporting a wide variety of spacecraft on a diverse collection of shared GN antennas, effective scheduling of mission passes on those antennas is critical. Ground Network Scheduling Office (GNSO) strives to meet all of its customer requirements as efficiently as possible, while also responding to issues such as spacecraft emergencies and antenna maintenance needs. GNSO collects user requirements and requests, considers antenna loading, antenna status, and weighs mission customer priority. The GNSO then develops a schedule of antenna pass supports that efficiently supports customer needs.

The Ground Network Performance Analyst Office (GNPAO) is located at Wallops Island, Virginia. The GNPAO works with the GNSO to coordinate launch support schedules and testing activities. The office also assists both the projects and ground station sites in scheduling downtime for preventive or corrective maintenance activities and spacecraft special support requests.

11.2 GN Scheduling System

In order to schedule all of its assets, the GN relies on schedulers and a scheduling system located at the White Sands Complex (WSC) in New Mexico. The scheduling system is called the Wallops Orbital Tracking Information System (WOTIS). WOTIS, depicted in Figure 9-1, is composed of three elements: an interface/message handling system, a core scheduling system, and a database.

In addition to scheduling antenna time, scheduling staff at White Sands handle equipment configurations, conflict resolution, emergency scheduling, scheduling of network testing support, and forwarding MOC-provided Improved Interrange Vectors (IIRVs) to the ground stations. The GNSO can utilize either manual or automated processes to schedule customer contacts.

11.3 Scheduling Process

11.3.1 Mission pass requirements development and input

The scheduling process is initiated when missions specify their pass requirements. Missions can establish generic (rule-based) scheduling requirements, which is the recommended method for requesting passes. Missions may also request specific antennas and pass times.

Generic scheduling requirements establish a prearranged minimum level of service, yet enable flexibility in meeting requirements, and allow for schedule optimization across all missions. Typical generic scheduling requirements include a subset of the following:

- Minimum number of supported passes per day.
- Minimum amount of time supported per pass (specified separately for telemetry and command).
- Minimum and/or maximum amount of time between supported passes.

- GN station(s) providing support.
- Minimum number of GN stations required to support a pass during a specified time interval (for example: "At least two different GN stations for the period between 2200Z and 0500Z").
- Minimum ground antenna elevation angle.

For missions unable to establish generic requirements, the Mission Operations Center (MOC) may submit a weekly schedule request for a specific GN station and the specific start and end time of each pass. If making specific requests, the MOC must submit a requested schedule every week, three weeks ahead of schedule execution. The GN prefers generic scheduling to specific scheduling because it optimizes the use of shared GN resources.

11.3.2 Weekly schedule development

GNSO develops weekly pass schedules starting weeks in advance of when the schedules will be executed, and refine them through an ongoing iterative process that allows for customer feedback. A schematic of the general schedule development timeline is shown in Figure 9-2.

The three-week advance schedule is called the "Strawman Schedule". Schedulers begin to build the Strawman Schedule on a Monday, three weeks before it is to begin execution. The Strawman Schedule is a rough schedule that collects mission requirements and identifies all possible antenna view periods.

The two-week advance schedule is called the "Forecast Schedule". Schedulers compile customer requirements and specific requests and deconflict the schedules, seeking workable schedules that enable antennas to meet customer requirements. Mission priority is factored into scheduling to ensure that higher priority missions meet their scheduling requirements first in the case where multiple missions seek the same antenna pass. Mission priority is defined in the GN Priority List, which is maintained by the Space Communications Program Customer Commitment Office.

The one-week advance schedule is called the "Operations Schedule". The Operations Schedule is compiled from the de-conflicted Forecast Schedule. Only changes due to absolute priorities listed in the GN Priority List (e.g., spacecraft emergencies, launch support, critical support) are accommodated.

The current weeks schedule for execution is called the "Real-Time Schedule". No changes may be made to the Real-Time Schedule except during spacecraft emergency or ground station emergency situations.

11.3.3 Customer review

Customers typically receive draft schedules for each of the next three weeks, once a week (generally Thursday). Customers may provide feedback on the schedules and request changes. Changes should ideally be submitted by the following Monday, and not later than close of business on Wednesday of the week before schedule execution. No response is considered to be schedule acceptance.

11.3.4 Schedule execution

The GN implements the Real-Time schedule, sending schedules to the antennas. The antenna ground stations send post-pass results information to GN scheduling, which is then sent to the customer MOC. Figure 11-1 shows WOTIS inputs and outputs.

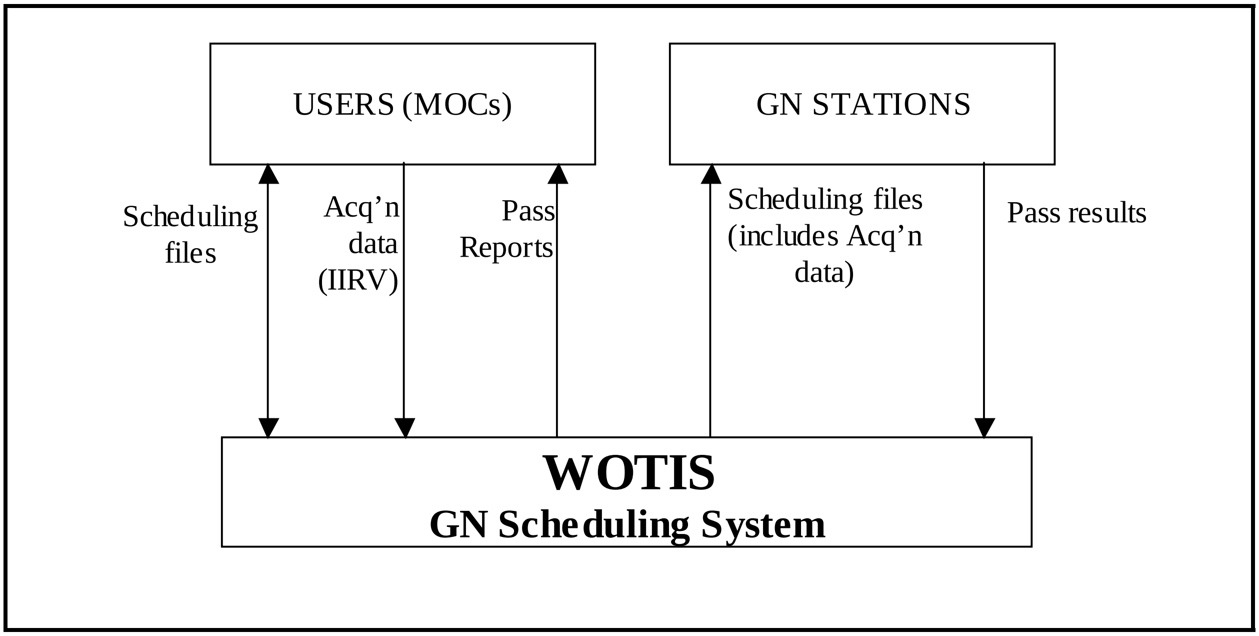

Figure 11-1. WOTIS Functional Interfaces

11.3.5 Scheduling During Emergency Situations

Emergency situations, such as evacuations at WSC, spacecraft emergencies, and changes in GN resource (e.g., antenna) availability may impact scheduling. In emergency cases, GN customers will be notified so that appropriate responses can be taken.

If an emergency evacuation or other unplanned event occurs at WSC and the WOTIS network is shut down, scheduling files will not be sent automatically. If such an event occurs, the scheduling office will notify the GN Performance Analyst Office (GN PAO) or the Wallops ground station controllers who will notify customer MOCs. Each MOC will need to directly communicate its scheduling requirements to the ground stations via telephone and/or e-mail. Spacecraft post-pass results files will not be sent to the MOC until the WOTIS network is restored. However, post-pass results files are not mission critical.

If a minor evacuation event causes GN scheduling personnel to leave WOTIS unattended, but the WOTIS network is still running, automated scheduling files will still be processed and sent to the ground stations. However, if the customer MOC requires any additions, deletions, or other final changes to the schedule when GN scheduling personnel are not available, the MOC will need to directly contact the ground station by telephone.

If a customer MOC declares a spacecraft emergency, the White Sands Complex Operations Supervisor (WSCOS) will send a "Spacecraft Emergency Notification" message to the Network Control Center Communications (NCC COMM) Center at GSFC, which will distribute the notification to all required customers and network elements. The WSCOS will send a "Spacecraft Emergency Termination" notice when the emergency is over.

If a GN resource changes state or a contingency affects a site's ability to provide support, the WSCOS will send a "GNSTAT Report" to the NCC COMM Center at GSFC, which will distribute the notification to all required customers and network elements.

If a spacecraft or GN emergency requires a change to the Real-time Schedule, GN schedulers will immediately contact those customers whose schedules over the next 24 hours (48 hours during the weekend) will be impacted. GN schedulers will then work interactively with impacted customers to best accommodate customer needs. For schedule impacts beyond the next 24 hours (or 48 on the weekends) GN schedulers will work to reschedule mission customers to meet standing requirements.

11.3.6 Manual Scheduling

With manual scheduling, GNSO personnel perform the scheduling without automated support from WOTIS. The WFF Range and Mission Management Office manually schedules range support. The process for manual scheduling is as follows:

1. MOC and GN scheduling personnel agree on the schedule via e-mail and telephone
2. GN scheduling personnel e-mail the schedule to the GN station operators
3. GN station operators manually configure the equipment for the scheduled pass.

11.3.7 Scheduling Pre-Mission Test and Launch Support

GN PAO schedules GN resources for pre-mission test and launch support as follows:

a. Scheduling Pre-Mission Test Support

Depending on the type of pre-mission test that the user requests, the Network Operations Manager (NOM), STDN Mission Manager (SMM) and/or the Test Director (TD), in conjunction with the user, determine the pre-mission test technical details. Then the NOM, SMM, and/or TD provide GN PAO with the relevant technical details, including schedule requirements, supporting stations, and support requirements. GN PAO identifies and resolves resource conflicts pre-mission tests may have with activities already on GN schedules.

b. Scheduling Launch Support

When scheduling launch support, the Customer Service Representative and NOM, in conjunction with the customer, provide GN PAO and GN Scheduling with the following:

1. Launch schedule requirements
2. GN stations required by the mission during launch
3. Launch and early orbit support requirements.

11.3.8 Schedule Format – Comma Delimited

All schedule requests and responses (Schedule Request, Strawman Schedule, Update Schedule, Confirmed Schedule, Daily Schedule) are formatted in the same manner, as shown in *Table 11-1*.

Table 11-1. Request/Response Record Format

Item No.	Name	Format	Max Size (bytes)	Value(s)
1	Support Activity Tag	ASCII	15	Empty[1] (Initial Request File) or ID number assigned by WOTIS
2	Project	ASCII	3	Fixed alphanumeric assigned by WOTIS for each mission
3	Facility	ASCII	3	one of the following: • "AGS" • "SGS" • "WGS" • "MGS"
4	Beginning of Track	GMT Field[2]	13	station equipment "on" time
5	End of Track	GMT Field[2]	13	station equipment "off" time
6	Support Activity Code	ASCII	4	TR1 to TR99
7	Orbit	ASCII	10	Monotonically increasing orbit counter

8	Band	ASCII	2	one of the following: • "X0" = delete request[3] • "X1" to "Xn" (n possible X-band downlink frequencies • "S1" = S-Band downlink

1. This field is empty in the Initial Request File that the MOC sends to WOTIS. For all other schedule files, a WOTIS-generated identification number is used.
2. See Table 11-2 for format.
3. A value of "X0" in this field indicates that the particular X-band component of the contact should be deleted; this feature is only used in the Daily Schedule file.

Table 11-2. UTC (GMT) Field Definition

Field: yyyy/ddd:hh:mm:ss		Format (Size): ASCII (17 bytes)	Range:
yyyy	Year	ASCII (4 bytes)	1996 through 2100
ddd	Day of Year	ASCII (3 bytes)	001 through 366
hh	Hour	ASCII (2 bytes)	00 through 23
mm	Minute	ASCII (2 bytes)	00 through 59
ss	Second	ASCII (2 bytes)	00 through 59

11.3.9 Schedule File Descriptions & Names

The Schedule Request file is only employed in Specific Scheduling, and uses the Request/Response Format defined in *Table 11-1*. Records are included for each requested S-Band and X-Band contact. The key field in each record is set to zero by the MOC since this value is assigned by WOTIS later in the scheduling process. The period to be scheduled is Monday, 00:00:00z, through Sunday, 23:59:59z. However, the file may cover one week plus a day of overlap on each end to allow continuity from one scheduling period to the next. The following naming convention is used for the Schedule Request File:

iUbB1dD.C

where the definitions in *Table 11-3* apply.

Table 11-3. Schedule Request File Name Definition

Filename Segment	Definition	Values
i	Initial Schedule designator	**i**
U	3 character Mission Identifier	Assigned by WOTIS (Ex. eo1)
b	Beginning period separator	**B**
B1	Year (YYYY) Day of Year (DoY) for first support in file	1999, 2000, etc. and 001 – 366
d	Duration separator	**D**
D	Duration in days (dd)	01 - 99
C	File Creation Time (hhmmss)	000000 – 235959

Note: All times in UTC

An example of a Schedule Request file name is: ***iam1b1999205d7.012345***

11.3.10 Strawman Schedule

The Strawman Schedule file is FTP'd from WOTIS to the MOC approximately 2.5 weeks before the first day of the week being scheduled. Like the Schedule Request File, the Strawman Schedule File covers one Monday-through-Sunday scheduling period. This file contains two Request/Response Format records for each available contact where both an X-Band and an S-Band downlink are requested, and one for an S-Band only downlink. The Strawman Schedule uses the Request/Response Format record as defined in *Table 11-1*.

The filename for the Strawman Schedule File follows this format:

sUbB1dD.C

where the definitions in *Table 11-4* apply.

Table 11-4. Strawman Schedule File Name Definition

Filename Segment	Definition	Values
s	Strawman Schedule designator	**s**
U	3 character Mission Identifier	Assigned by WOTIS (Ex. eo1)
b	Beginning period separator	**b**
B1	Year (YYYY) Day of Year (DoY) for first support in file	1999, 2000, etc. and 001 - 366
d	Duration separator	**d**
D	Duration in days (dd)	01 - 99
C	File Creation Time (hhmmss)	000000 – 235959

Note: All times in UTC

An example of a Strawman Schedule file name is: ***sam1b1999205d7.012345***

11.3.11 Update Schedule

The Update Schedule file is FTP'd from the MOC to the WOTIS. Like the Schedule Request File, the Update Schedule File covers one Monday-through-Sunday scheduling period. The purpose of the Update Schedule is to allow the MOC to revise any parameters in any of the supports, to delete entire supports (by not returning them in the schedule), or to delete or add an X-Band component to an existing support. An add of an X-Band component will, of course, contain no Support Activity Tag; WOTIS will assign a tag upon ingestion of the Update Schedule File. The Update Schedule uses the Request/Response Format record as defined in Table 9-1.

The filename for the Update Schedule file follows this format:

uUbB1dD.C

where the definitions in *Table 11-5* apply.

Table 11-5 Update Schedule File Name Definition

Filename Segment	Definition	Values
u	Update Schedule designator	**u**
U	3 character Mission Identifier	Assigned by WOTIS (Ex. eo1)
b	Beginning period separator	**b**
B1	Year (YYYY) Day of Year (DoY) for first support in file	1999, 2000, etc. and 001 - 366
d	Duration separator	**d**
D	Duration in days (dd)	01 - 99
C	File Creation Time (hhmmss)	000000 – 235959

Note: All times in UTC

An example of an Update Request file name is: **uam1b1999205d7.012345**

11.3.12 Confirmed Schedule

The Confirmed Schedule file, transmitted (if requested) from WOTIS, covers the same time period as the Strawman Schedule. That is, it runs from Monday through Sunday. It contains a data- and requirements-driven list of events that PROJECT requires of the GN sites, and is a subset of the contacts in the Strawman Schedule. The Confirmed Schedule confirms the supports which the GN has scheduled, and is a final verification of the ingestion and processing of the Update Schedule. In most all instances the Confirmed Schedule will match the Update Schedule. Each event, again, is formatted as a Request/Response record defined in Table 9-1.

The naming convention for the confirmed schedule is the same as the Strawman Schedule (Section 11.3.10), where the definitions in *Table 11-4* apply.

Section 12. Baseband Data Interfaces and Storage

12.1 Introduction

This section describes the baseband data interface and storage equipment options at the GN stations:

a. IONet Network

b. Serial Clock and Data

c. Mail Delivery of Recorded Data

d. Standard Autonomous File Server (SAFS)

Table 12-1 summarizes the baseband data interfaces available at each station; an “X” means that capability is offered. Figure 12-1 summarizes the IONet networks.

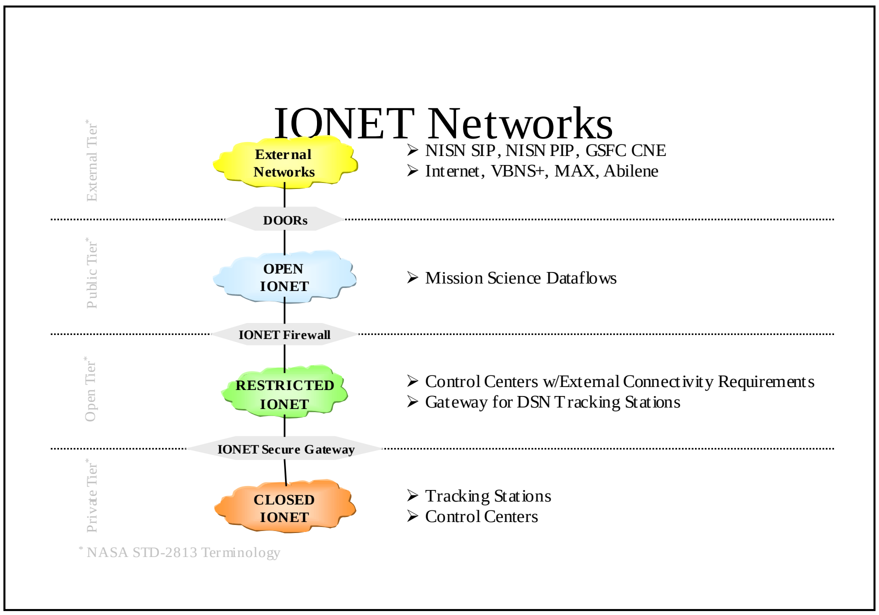

Figure 12-1. IONet Networks

12.2 IONet Network

For those GN stations that support it, the IONet Network can be used by MOCs to send commands to and receive telemetry data from a GN station.

a. <u>Open and Closed Networks</u>

The IONet Network uses open, restricted and closed NASA IP networks. “Open” and “closed” are relative. The closed IONet is completely controlled while the open and restricted IONet has limited access. Although the closed network provides more security, the open network is still inaccessible to the public. A firewall (or “gateway”) is used when data crosses an open/closed boundary in either direction.

b. <u>TCP/IP and UDP/IP</u>

The IONet Network supports both Transmission Control Protocol/Internet Protocol (TCP/IP) and User Datagram Protocol/Internet Protocol (UDP/IP).

Figure 12-2 depicts the TCP/IP layer model. Each layer is encapsulated by the next lower level. "Encapsulation" is the addition of a control information header and/or trailer to a block of data. For example, in Figure 12-2, the Internet Protocol Data Unit (IPDU) packet encapsulates the Channel Access Data Unit (CADU) packet. For UDP/IP, the layering is identical to Figure 12-2, except the TCP layer is replaced by a UDP layer.

c. <u>Packets and Layers</u>

CADU and Command Link Transmission Unit (*CLTU*) packets are Consultative Committee for Space Data Systems (CCSDS)-compliant telemetry and command data unit protocols, respectively. (See Ref (u) for CLTU and Ref (n) for CADU in Section 1.3) For commands, the CADU layer in Figure 12-1 is replaced by a CLTU layer.

Table 12-1. Baseband Data Interface Options

Station	NISN IP Network	Serial Clock and Data	Mail Delivery
SGS	X	X	X
WGS	X	X	X
LEO-T – WFF	X	X	
MGTAS	X		
MGS	X		X
LEO-T – Alaska	X		
AGS	X	X	X
MILA	X		
PDL	X		
ASF	X		X

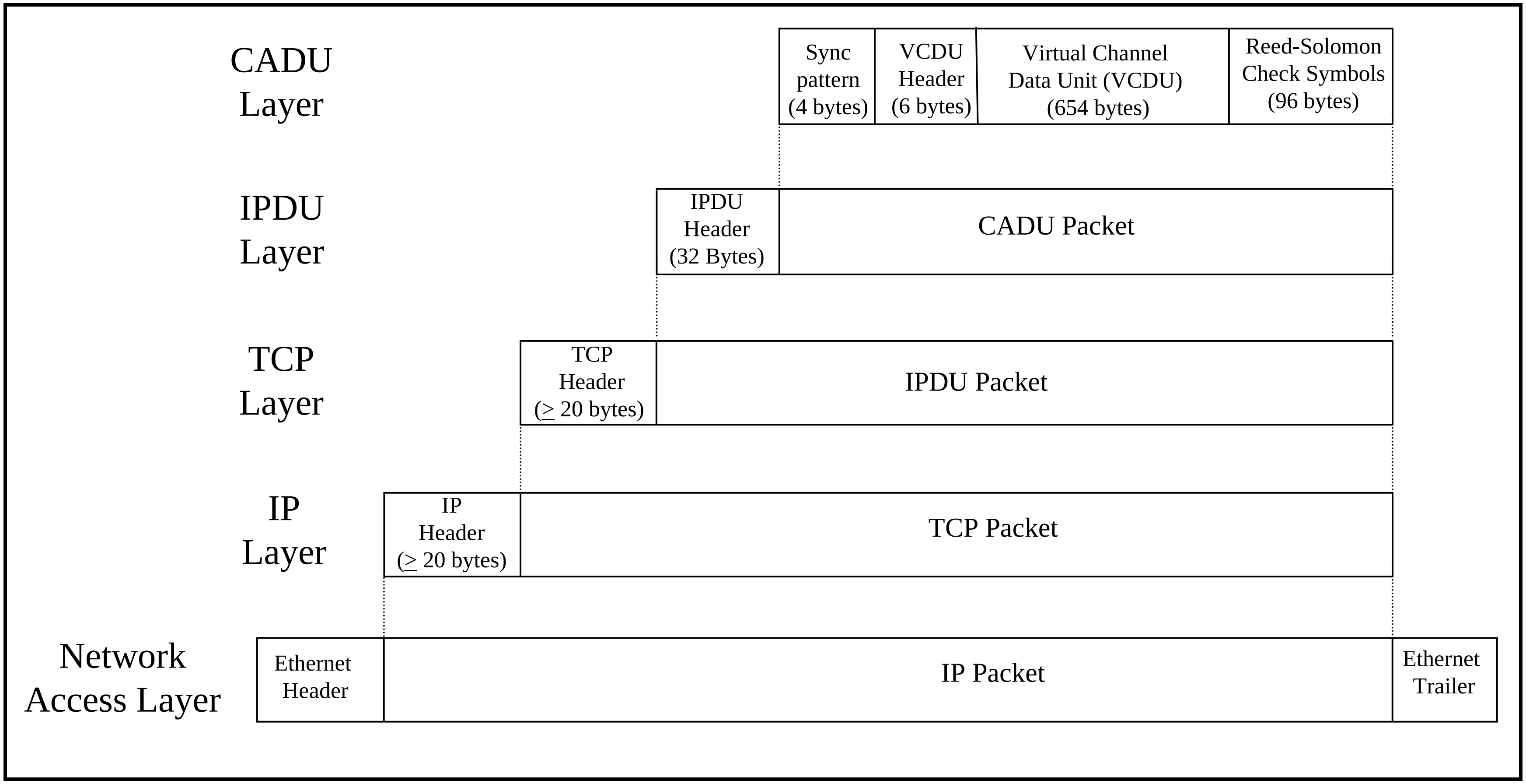

Figure 12-2. NISN IP Network Layers*

* TCP/IP layers are shown; UDP/IP is identical, except “TCP” is replaced by “UDP.”
Telemetry packets are shown; command packets are identical, except “CADU” is replaced by “CLTU.”

The *Network Access* Layer is a protocol format that provides physical access to NISN. For the GN stations that support IP data transfer, the Network Access Layer is the Ethernet protocol that interfaces the GN station to the Routers. The *IP Layer* allows data to traverse multiple networks between users and the GN station. IP alone does not ensure that the data will be delivered, but when IP is used with *TCP*, all data is guaranteed to be delivered. TCP is a virtual connection protocol designed to work with IP. It provides reliable communication across a variety of both reliable and unreliable networks and internets.

d. UDP

UDP is available to users who want faster data transfers than TCP provides. UDP is unreliable, however, because – unlike TCP – it doesn't provide the handshaking protocols that guarantee delivery in order without duplicate or missing packets.

e. PTP Encapsulation

Except for the two LEO-T stations, all GN stations that support IP use Programmable Telemetry Processors (PTPs) to perform encapsulation and de-encapsulation. In addition to IPDU, the PTP supports several other packet formats for encapsulating CLTUs or CADUs prior to the TCP or UDP layers. PTPs offer the following packet format choices:

- IPDU
- Advanced X-ray Astrophysics Facility (AXAF) Standard Formatted Data Unit (SFDU)
- Deep Space-Terminal (DS-T) SFDU
- Advanced Composition Explorer (ACE) SFDU
- LEO-T Telemetry Frame Delivery Header (TFDH)
- LEO-T Command Delivery Header (CDH)
- NASCOM Real-time Transmission Protocol (RTP)
- No extra encapsulation between the CADU or CLTU layer and the TCP or UDP layer

Instead of a PTP, the LEO-T stations use a front-end processor that offers encapsulation and format choices that are a subset of the PTPs.

12.2.1 Command Data (Real-Time)

The MOC sends real-time command data to the GN station via the IONet Network. Either TCP/IP or UDP/IP sockets may be used.

About fourteen minutes prior to each command service (assuming TCP/IP data transfer), the MOC initiates two TCP/IP socket connections with the GN station: one socket for command data, the other for command echoes. If the user does not require command echo service, the MOC need not initiate the second socket.

12.2.2 S-Band Telemetry Data

About fourteen minutes prior to each S-band telemetry service (assuming TCP/IP data transfer), the MOC initiates two independent TCP/IP socket connections with the GN station: one socket for telemetry data on the main carrier, the other for data on the subcarrier. The MOC needs to initiate only one socket if the user vehicle transmits only one stream of telemetry data.

12.3 Serial Clock and Data

The serial clock and data option is the transmission and/or reception of raw digital data streams with associated clock signals.

12.4 Mail Delivery of Recorded Data

When the telecommunication circuits at a GN station cannot support the electronic transfer of high-rate science data (X-band or S-band), the GN station will record the science data on magnetic, non-volatile media such as tape or disk. The station will then mail the recorded data to the user.

Operations agreements and support plans define the exact data-shipping criteria. *Table 12-2* identifies the recording capabilities at each GN station; an “X” means that capability is available. *Table 12-3* lists the capabilities of each digital tape recorder.

Table 12-2. GN Recording Capabilities

Station	Magnetic Disk Recording	Magnetic Tape Recording					
		Ampex DIS160	**Ampex DIS260I**	**Ampex DCSRi 170**	**Metrum VLDS**	**Sony**	**Analog Recorders**
SGS	X		X		X		
WGS	X	X			X	X	
LEO-T – WFF	X						
MGTAS					X		X
MGS	X			X	X		
LEO-T – Alaska	X						
AGS	X		X		X		
MILA	X				X		
PDL	X				X		
ASF	X					X	

Table 12-3. Digital Tape Recorder Capabilities

Tape Recorder	Tape Format	Maximum Recording Speed	Playback Speed	Tape Storage Capacity
Ampex DIS260I	D2	160 Mbps	Any	160 GB
Ampex DCSRi 170	D2	105 Mbps	Any	160 GB
Ampex DIS160	D2	160 Mbps	Any	160 GB
Sony	D2	160 Mbps	Any	160 GB
Metrum VLDS	S-VHS	32 Mbps	Any	10 GB

12.5 Standard Autonomous File Server

This section describes the Standard Autonomous File Server (SAFS). SAFS provides automated management of large data files without interfering with the assets involved in the acquisition of data. SAFS operates as a stand-alone solution, monitoring itself, and providing an automated level of fail-over processing to enhance reliability. By using an improved automated file transfer process, the SAFS system provides a quicker, more reliable file distribution for customers of near real-time data than has been realized by previous methods. Web reporting provides current status of system availability, file latency, and customer file distribution. More information is available via http://scp.gsfc.nasa.gov/websafs/.

12.5.1 SAFS Architecture and Operation

Initially, the SAFS was installed at some NASA GN sites for distributed acquisition of satellite data in support of QuikSCAT and ADEOS II missions. The SAFS has been installed at the following GN ground stations: SGS, AGS, ASF, WGS, and MGS. It has also been installed at GSFC to provide for centralized customer data distribution. Figure 12-3 depicts the SAFS configuration. The central SAFS provides a single point of contact for customers and isolates the GN ground stations from customer interactions. At each ground station, the telemetry processors accept raw downlinked satellite data and process the data into files (format for later customer consumption) that are sent to the ground station's SAFS via a standard network protocol. The ground station SAFS uses FASTCopy to automatically push the files to the central SAFS via a standard network protocol where the files are made available to each project's customers.

Customers can "pull" a file from the SAFS system once they receive a data ready notification (DRN) of its availability. Or if they are also using FASTCopy, the SAFS system can automatically "push" their files to them which would eliminate the delay inherent in the notification and reaction processes required for "pull" customers.

12.5.2 SAFS Hardware and Software

The SAFS system hardware is installed in a standard 19" rack and includes the following:

a. Redundant Array of Independent Disks (RAID) storage system

b. RAID monitoring/configuration system

c. SAFS server

d. Rack mounted keyboard, monitor, and touch pad

The SAFS software includes the following:

a. COTS FASTCopy file transmission software

b. Custom scripts for job control and monitoring

c. Web reporting software

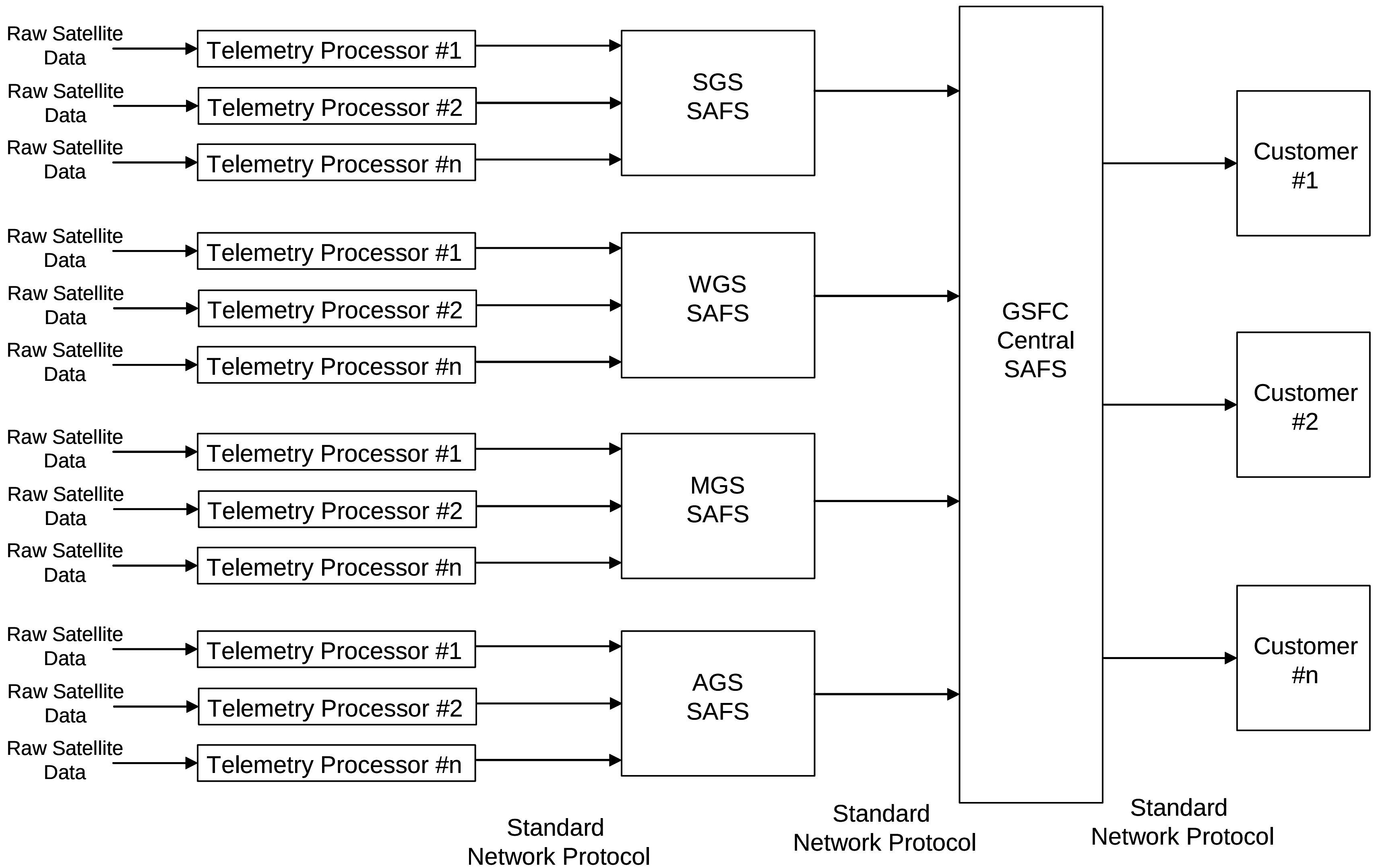

Figure 12-3. SAFS Architecture

Section 13. Frequency Management

13.1 Introduction

This section provides information to assist a flight project in determining its frequency spectrum requirements. It also describes the procedures for obtaining authorization for the required spectrum.

13.2 Determining Frequency Spectrum Requirements

13.2.1 International Spectrum Allocations

International frequency spectrum allocations are prepared by World Radiocommunication Conferences (WRCs) convened under the auspices of the International Telecommunications Union (ITU). These allocations become part of the ITU International Radio Regulations, a treaty that requires ratification by the United States (US).

Table 13-1 identifies the bands in which the GN is "primary" with respect to other services. Within these bands, GN operations are protected from unacceptable interference from other services.

Table 13-1. GN Primary Frequency Allocations

Band	Direction	Frequencies
S-band	Earth-to-space	2025 – 2120 MHz
S-band	Space-to-earth	2200 – 2290 MHz
X-band	Space-to-earth	8025 – 8400 MHz
Ku-band	Space-to-earth	25.5 – 27.0 GHz
Ka-band	Space-to-earth	13.5 – 14.2 GHz 14.5 – 15.35 GHz

Table 13-2 and *Table 13-3* list the ITU worldwide S- and X-band frequency allocations, respectively. They also identify the allocations for the NASA Deep Space Network (DSN) in the 2110 - 2120 MHz, 2290 – 2300 MHz, and 8400 – 8500 MHz bands. GN stations must control unwanted emissions in these DSN bands (see Section 13.2.3).

13.2.2 US Spectrum Allocations

Management of the radio frequency spectrum within the US is divided between government and non-government uses: the National Telecommunications and Information Agency (NTIA) administers government allocations (including NASA), and the Federal Communications Commission (FCC) manages non-government allocations.

Table 13-2. S-Band International Frequency Allocations

Frequency (MHz)	Service Allocation
2025 – 2110	SPACE OPERATION (earth-to-space and space-to-space) EARTH EXPLORATION-SATELLITE (earth-to-space and space-to-space) FIXED MOBILE SPACE RESEARCH (earth-to-space and space-to-space)
2110 – 2120	FIXED MOBILE SPACE RESEARCH (DSN) (earth-to-space)
2200 – 2290	SPACE OPERATION (space-to-earth and space-to-space) EARTH EXPLORATION-SATELLITE (space-to-earth and space-to-space) FIXED MOBILE SPACE RESEARCH (space-to-earth and space-to-space)
2290 – 2300	FIXED MOBILE SPACE RESEARCH (DSN) (space-to-earth)

Note: Uppercase letters indicate *primary* allocations.

NASA is a member of the NTIA's Interdepartment Radio Advisory Committee (IRAC), which coordinates US spectrum allocation issues. US allocations relevant to the GN are identical to the international allocations listed in *Table 13-2* and *Table 13-3*.

13.2.3 DSN Protection

As stated above, the DSN has primary allocations in the 2110 – 2120 MHz, 2290 – 2300 MHz, and 8400 – 8500 MHz bands. Each of these bands is adjacent to a GN allocation. GN operators are responsible for protecting DSN stations from unacceptable interference.

ITU limits on power-flux density in the DSN band from non-DSN transmitters are summarized in *Table 13-4*.

Table 13-3. X-Band International Frequency Allocations

Frequency (MHz)	Service Allocation
7075 – 7250	FIXED MOBILE
8025 – 8175	EARTH EXPLORATION-SATELLITE (space-to-earth) FIXED FIXED-SATELLITE (earth-to-space) MOBILE
8175 – 8215	EARTH EXPLORATION-SATELLITE (space-to-earth) FIXED FIXED-SATELLITE (earth-to-space) METEOROLOGICAL-SATELLITE (earth-to-space) MOBILE
8215 – 8400	EARTH EXPLORATION-SATELLITE (space-to-earth) FIXED FIXED-SATELLITE (earth-to-space) MOBILE
8400 – 8500	FIXED MOBILE SPACE RESEARCH (DSN) (space-to-earth)

Note: Uppercase letters indicate *primary* allocations.

13.2.4 In-Band Power-Flux Density Restrictions

GN users share the 2200 – 2290 MHz and 8025 – 8400 MHz receive bands with terrestrial services. Terrestrial services are protected by limiting the power-flux density at the surface of the earth from space-based transmitters; *Table 13-5* summarizes these limits.

Table 13-4. Interference Protection Requirements for DSN

Frequency (MHz)	Maximum Allowable Interference Spectral Power-Flux Density at Aperture of DSN Antenna (dBW/m^2 Hz)
2290 – 2300	-257.0
8400 – 8450	-255.1

Source: ITU Recommandation ITU-R SA.1273

Table 13-5. In-Band Protection Requirements for Terrestrial Services

Frequency (MHz)	Power-Flux Density Limit for Angles of Arrival (θ) Above the Horizontal Plane (dBW/m^2)			Reference Bandwidth
	$0^\circ \leq \theta \leq 5^\circ$	$5^\circ < \theta < 25^\circ$	$25^\circ \leq \theta \leq 90^\circ$	
2025 – 2110	-154	$-154 + 0.5 (\theta - 5)$	-144	4 kHz
2200 – 2290	-130	$-130 + 0.5 (\theta - 5)$	-120	1 MHz
8025 – 8400	-150	$-150 + 0.5 (\theta - 5)$	-140	4 kHz

Sources: ITU Recommandation ITU-R SA.1273
International Radio Regulations: Article S21 (Table S21-4)

13.3 Obtaining Frequency Spectrum Authorization

13.3.1 Regulations, Policies, and Instructions

NASA missions must comply with all US and international frequency spectrum requirements. Reference [l] in Section 1.3 states these requirements and other legal obligations mandated by NTIA. Reference [k] provides detailed instructions for obtaining frequency spectrum authorization in compliance with Reference [i].

13.3.2 GSFC Spectrum Management Office

The GSFC Spectrum Management Office is responsible for all spectrum-related activities associated with the GN. The Office is part of the Space Communications Program Office, Code 450.0. The responsibilities of the Spectrum Management Office include:

1. Coordinate RF spectrum requirements pertaining to GSFC and GN resources, in accordance with Chapter 3 of Reference [k] in Section 1.3.
2. Ensure interference-free operations between user vehicles and the GN, in accordance with Chapter 4 of Reference [k].
3. Assist the flight project in determining frequency requirements, including performing interference analyses.
4. Provide guidance in completing the Frequency Authorization Request Package to be sent to the NTIA. Chapter 10 of Reference [l] provides instructions for filling out the forms in the Package.
5. Coordinate with the NTIA's Space Systems Group, which conducts the frequency spectrum allocation review. Appendix F of Reference [l] describes the four-stage review process.

13.3.3 Flight Project Responsibilities

Flight projects that would like to use the GN should contact the GSFC Spectrum Management Office to begin the allocation request process as soon as possible (see Section 13.3.2 above). Each project must designate a point-of-contact for working with the Spectrum Management Office.

13.4 Space Frequency Coordination Group Recommendations

In order to more efficiently utilize the limited spectrum allocated for space-to-Earth data transmissions, the Space Frequency Coordination Group (SFCG) has recommended that space projects starting after the year 2001 comply with an emitted spectrum mask for space-to-Earth data transmissions in the bands 2200-2300 MHz and 8025-8500 MHz (SFCG Recommendation 17-2R1). Figure 13-1 depicts the SFCG 17-2R1 mask recommendation for suppressed carrier modulation systems with data rates greater than or equal to 2 Mbps. See reference [o] for additional information on the SFCG recommendations.

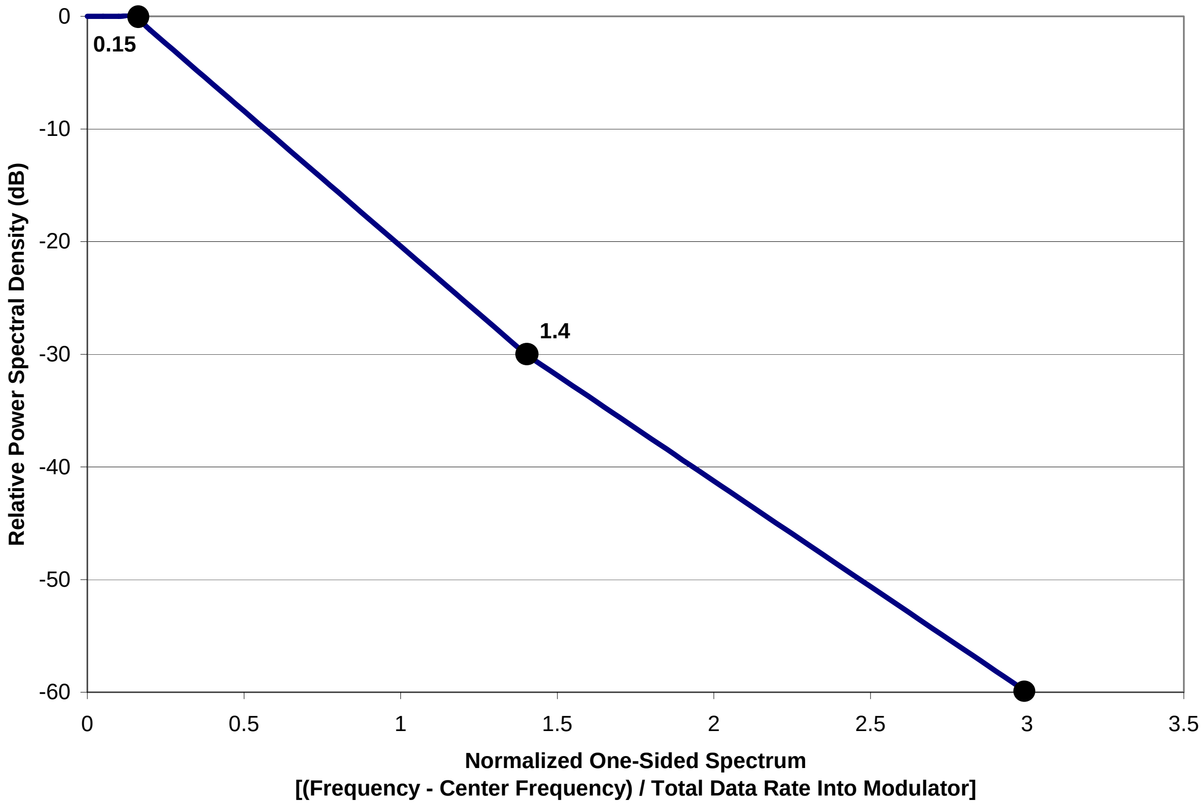

Figure 13-1. SFCG Spectral Limit Recommendation

Section 14. Link Budget Parameters

This section provides S-band and X-band link parameters that will assist flight projects with link budget calculations. The link budget parameters provided in this section are estimated values for example purposes only. For specific link budget calculations, contact the Space Communications Program Office. This section provides the following information:

- S-band atmospheric and rain attenuation constants.
- X-band atmospheric and rain attenuation constants.
- Example user spacecraft constraint losses and ground terminal losses for telemetry links.
- X-band G/T measurement data.
- Ground station line-of-sight coverage for spacecraft altitudes between 500 km and 1000 km.

14.1 S-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for S-band (2200 MHz – 300 MHz) GN stations using ITU models. For the GN stations listed in this document, the S-band atmospheric attenuation constant at a 5° elevation angle is 0.41 dB. The atmospheric attenuation constant includes scintillation effects.

Table 14-1 lists the S-band rain attenuation constants for the GN stations that have S-band capabilities.

14.2 X-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for the X-band (8000 MHz – 8500 MHz) GN stations using ITU models. For the GN stations listed in this document, the X-band atmospheric attenuation constant at a 5° elevation angle is 0.5 dB. The atmospheric attenuation constant includes scintillation effects.

Table 14-2 lists the X-band rain attenuation constants for the GN stations that have X-band capabilities.

14.3 Implementation Losses, Constraint Losses, and Ground Terminal Losses

Constraint loss is the link degradation due to linear and non-linear spacecraft transmitter distortions. Ground terminal loss is the link degradation due to ground terminal receive system distortions. The sum of the constraint loss and the ground terminal loss is typically stated as the implementation loss in GN link budgets.

Constraint losses and ground terminal losses vary with spacecraft and ground station design, and are usually analyzed on a case-by-case basis. There is no fixed constraint loss value for all spacecraft and no fixed ground terminal loss value for all GN stations. Variations in a spacecraft's transmitter signal characteristics from mission to mission can significantly impact the amount of constraint loss. Likewise, variations in the ground terminal's receive performance characteristics and operational data rate can significantly impact the amount of ground terminal loss. The Space Communications Program Office typically performs analytical modeling and simulation as required for specific flight project communications hardware and GN receivers to estimate the overall implementation loss for a mission link budget.

Paragraphs 14.3.1 and 14.3.2 provide example implementation losses, constraint losses, ground terminal losses, and distortion characteristics for X-band and S-band links, respectively.

The loss values and parameters discussed below in paragraphs 14.3.1 and 14.3.2 are intended to only provide the user an example of the expected link performances under specific scenarios. As previously stated, implementation loss for GN links should be analyzed on a case-by-case basis. The implementation loss assessment will determine the additional user spacecraft EIRP required to provide acceptable performance throughout the lifetime of the mission.

In addition to the distortion characteristics stated in paragraphs 14.3.1 and 14.3.2, the Consultative Committee for Space Data Systems (CCSDS) and Space Frequency Coordination Group (SFCG) provide recommended X-band and S-band spacecraft characteristics and distortion limits for space-to-Earth data transmissions. This information can be found in references [b and o].

14.3.1 X-Band Implementation Loss Examples

Table 14-3 lists the signal characteristics specified for the ICESat X-band transmitter. Simulation for the ICESat project resulted in an estimated constraint loss of 3.0 dB. The constraint loss is greatly dependent on the shape of the transmitter signal magnitude and phase response over the 3 dB bandwidth. Because the actual (measured) response was not available for the simulation, a response shape was assumed for the simulation. As test data becomes available for the flight hardware, the simulations can be repeated using measured distortion values to improve the accuracy of the constraint loss estimate.

The ground terminal loss for ICESat was estimated by performing characterization tests at the Wallops Ground Station using similar equipment to that implemented for ICESat. The test results indicated an estimated ground terminal loss of 2.0 dB. Thus, the resulting X-band implementation loss for the ICESat link budget was estimated at 5.0 dB.

Similar analyses for the PM-1 mission resulted in an estimated spacecraft constraint loss of 1.9 dB and a ground terminal loss of 2.5 dB for a total implementation loss of 4.4 dB. The difference in implementation loss between PM-1 and ICESat can be attributed to a number of factors including required BER (10E-3 for PM-1 versus 10E-5 for ICESat), the use of measured transmitter gain flatness and phase non-linearity values rather than specified values, and differences in other signal parameters such as data rate, phase noise, and AM/PM distortion.

14.3.2 S-Band Implementation Loss Examples

Table 14-4 lists the signal characteristics for a typical LEO spacecraft’s S-Band transmitter for the following two scenarios:

1. Suppressed carrier modulation, but no convolutional coding
2. Phase Modulation (PM) with a residual carrier, but no convolution coding.

Table 14-5 lists the signal characteristics for a typical LEO spacecraft's S-Band transmitter for the following two scenarios:

1. Suppressed carrier modulation with rate ½ convolutional coding
2. PM with a residual carrier with rate ½ convolution coding

Simulations were conducted to determine the implementation loss for S-Band using suppressed carrier modulation schemes and PM with a residual carrier. The simulations were conducted with and without ½ rate convolution. Ground station characteristics were included in the simulations. The ground station characteristics were assumed, but the fidelity scenarios assumed were a conservative representation for existing (or future) GN ground terminals.

Simulations using the *Table 14-4* and *Table 14-5* characteristics yielded the implementation losses listed in *Table 14-6*:

As an example of implementation loss for S-Band links with subcarriers, reference [n] states an implementation loss for the ICESat S-band subcarrier telemetry link (PCM, BPSK, PM) as 2.0 dB.

14.4 Ground Station Line-Of-Sight Coverage

Figures 14-1 through 14-6 depict each ground station's line-of-sight coverage for spacecraft altitudes of 500 km, 750 km, and 1000 km. All line-of-sight coverages are based on the local terrain. Line-of-sight coverage analyses for specific mission orbit parameters can be performed by the Space Communications Program Office.

Table 14-1. S-Band Rain Attenuation Constants (5° elevation angle)

Ground Station	Rain Attenuation for 99% Availability (dB)	Rain Attenuation for 99.9% Availability (dB)
SGS (Norway)	0.0	0.0
WGS (WFF)	0.01	0.06
LEO-T (WFF)	0.01	0.06
MGTAS (WFF)	0.01	0.06
MGS (Antarctica)	0.0	0.0
LEO-T (Alaska)	0.0	0.01
AGS (Alaska)	0.0	0.01
MILA (Florida)	0.05	0.23
PDL (Florida)	0.04	0.16

Table 14-2. X-Band Rain Attenuation Constants (5° elevation angle)

Ground Station	Rain Attenuation for 99% Availability (dB)	Rain Attenuation for 99.9% Availability (dB)
SGS (Norway)	0.0	0.11
WGS (WFF)	0.34	3.52
MGS (Antarctica)	0.0	0.76
AGS (Alaska)	0.0	0.24

Table 14-3. ICESat X-Band Transmitter Characteristics

Parameter	Value
Frequency	8100 MHz
Data Format	NRZ-M
Data Rate (I/Q Bit Rate)	20 Mbps on each channel (40 Mbps total)
Data Modulation	Staggered QPSK
Data Asymmetry [(1)]	≤ 3 percent
Data Rise Time [(1)]	≤ 2.5 nsec
Data Bit Jitter [(1)]	≤ 1 percent
I/Q Power Ratio	1:1
I/Q Data Skew [(1)]	0.5 ± 0.1 symbol period
QPSK Gain Imbalance	≤ 1.2 dB peak to peak
QPSK Phase Imbalance	≤ 5.0 degrees
AM/AM	≤ 1.0 dB/dB
AM/PM	≤ 10.0 degrees/dB
3 dB Bandwidth	60.0 MHz
Roll-off	0.62 dB/MHz
Gain Flatness	≤ 2.0 dB peak to peak
Gain Slope	≤ 0.4 dB/MHz
Phase Nonlinearity	≤ 5.0 dB peak to peak
Phase Noise [(1)] 100 Hz – 40 MHz offset from carrier	≤ 2.0 degrees RMS
Spurious Phase Modulation [(1)]	≤ 2.0 degrees RMS
Out-of-Band Spurious Output [(1)]	≤ -40 dBc
Incidental AM [(1)]	≤ 5 percent

(1) Parameter not simulated for ICESat constraint loss estimate

Table 14-4. USAT S-Band Transmitter Characteristics (Uncoded)

Parameter	Value
Frequency	2200-2400 MHz
Data Format	NRZ-L
Data Rate (I/Q Bit Rate)	4 Mb/sec (BPSK), 8 Mb/sec (QPSK)
Data Modulation	BPSK, QPSK
Data Asymmetry	3 percent
Data Rise Time	5 percent
Data Bit Jitter (1)	≤ 0.1 percent
I/Q Power Ratio	1:1
I/Q Data Skew	2.5 percent
Gain Imbalance	0.25 dB
Phase Imbalance	3.0 degrees
AM/AM	0 dB/dB (full saturation)
AM/PM	12 degrees/dB
3 dB Bandwidth	8.0 MHz
Roll-off	25 dB/MHz
Gain Flatness (peak-to-peak)	0.3 dB over ± 3.5 MHz
Gain Slope	0.1 dB/MHz
Phase Nonlinearity (peak-to-peak)	3.0 degrees over ± 3.5 MHz
Phase Noise (1)	1 Hz – 10 Hz: ≤ 50.0 degrees RMS 10 Hz – 100 Hz: ≤ 6.0 degrees RMS 100 Hz – 1 kHz: ≤ 2.5 degrees RMS 1 kHz – 6 MHz: ≤ 2.5 degrees RMS
Spurious Phase Modulation	2 degrees RMS @ 15.63 kHz (BPSK) 1 degree RMS @ 15.63 kHz (QPSK)
Spurious Outputs	-23 dBc @ 47.0 kHz -15 dBc @ 12.0 MHz
Incidental AM	5 percent @ 7.48 kHz

(1) Parameter not simulated, but impact on implementation loss determined via analysis techniques

Table 14-5. USAT S-Band Transmitter Characteristics (rate ½ convolutional coding)

Parameter	Value
Frequency	2200 – 2400 MHz
Data Format	NRZ-L
Data Rate (I/Q Bit Rate)	2 Mb/sec (BPSK), 4 Mb/sec (QPSK)
Data Modulation	BPSK, QPSK
Data Asymmetry	3 percent
Data Rise Time	5 percent
Data Bit Jitter(1)	0.1 percent
I/Q Power Ratio	1:1
I/Q Data Skew	2.5 percent
Gain Imbalance	1.0 dB (BPSK); 0.5 dB (QPSK)
Phase Imbalance	9.0 degrees (BPSK); 5.0 degrees (QPSK)
AM/AM	0 dB/dB (full saturation)
AM/PM	15 degrees/dB
3 dB Bandwidth	8.0 MHz
Roll-off	25 dB/MHz (BPSK), 50 dB/MHz (QPSK)
Gain Flatness (peak-to-peak)	0.4 dB over ± 3.5 MHz
Gain Slope	0.1 dB/MHz
Phase Nonlinearity (peak-to-peak)	4.0 degrees over ± 3.5 MHz
Phase Noise (1)	1 Hz – 10 Hz: ≤ 50.0 degrees RMS 10 Hz – 100 Hz: ≤ 6.0 degrees RMS 100 Hz – 1 kHz: ≤ 2.5 degrees RMS 1 kHz – 6 MHz: ≤ 2.5 degrees RMS
Spurious Phase Modulation	2 degrees RMS @15.6 kHz (BPSK) 1 degree RMS @ 15.6 kHz (QPSK)
Spurious Outputs	-23 dBc @ 23.5 kHz -15 dBc @ 12.0 MHz
Incidental AM	5 percent @ 3.74 kHz

(1) Parameter not simulated, but impact on implementation loss determined via analysis

Table 14-6. S-Band Implementation Losses

Modulation Scheme	Implementation Loss
PM, Residual Carrier	1.7 dB
BPSK	1.7 dB
QPSK	4.2 dB
PM, Residual Carrier (rate ½ coding)	1.9 dB
BPSK (rate ½ coding)	1.9 dB
QPSK (rate ½ coding)	2.3 dB

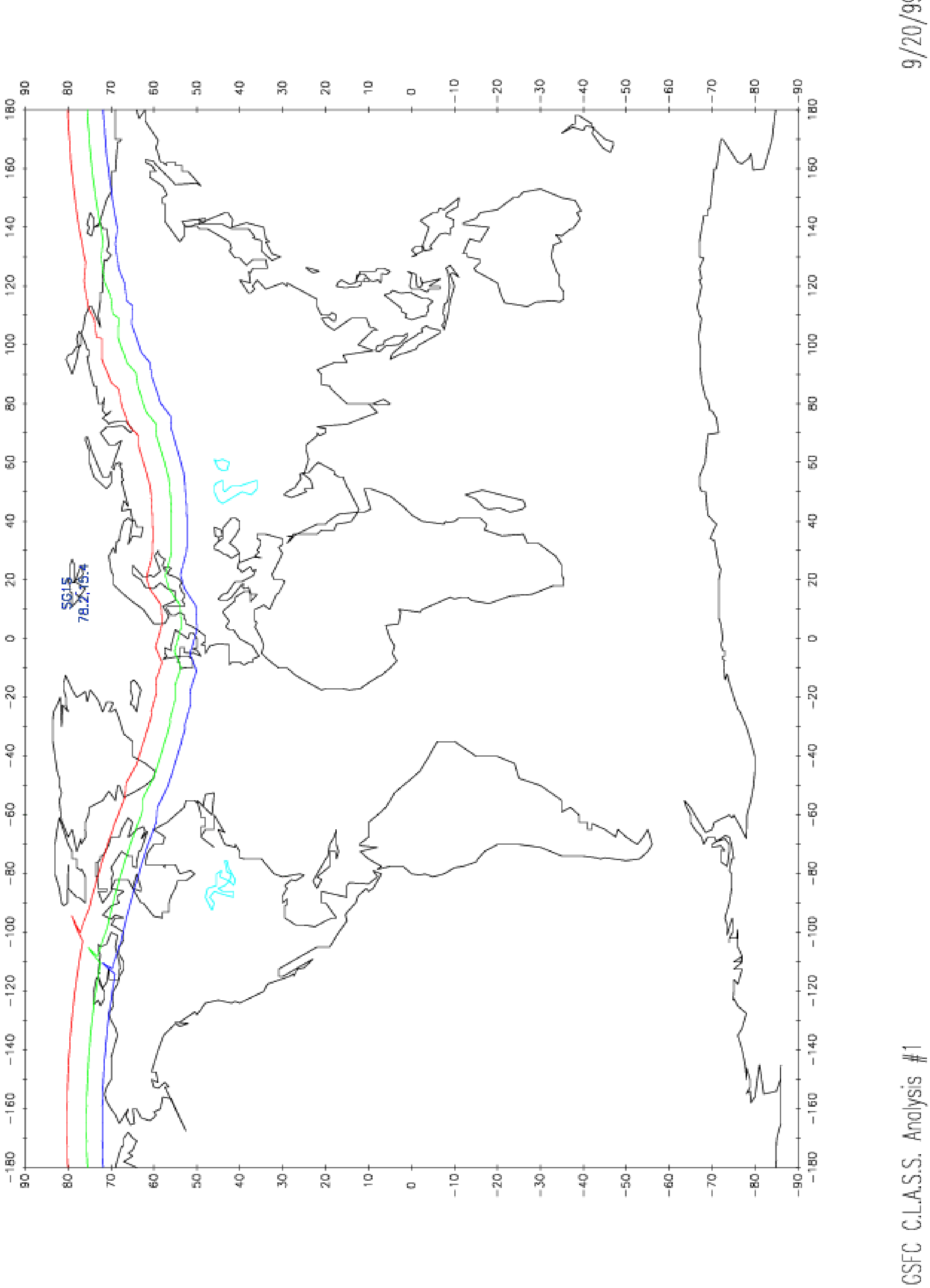

Figure 14-1. SGS Line-Of-Sight Coverage

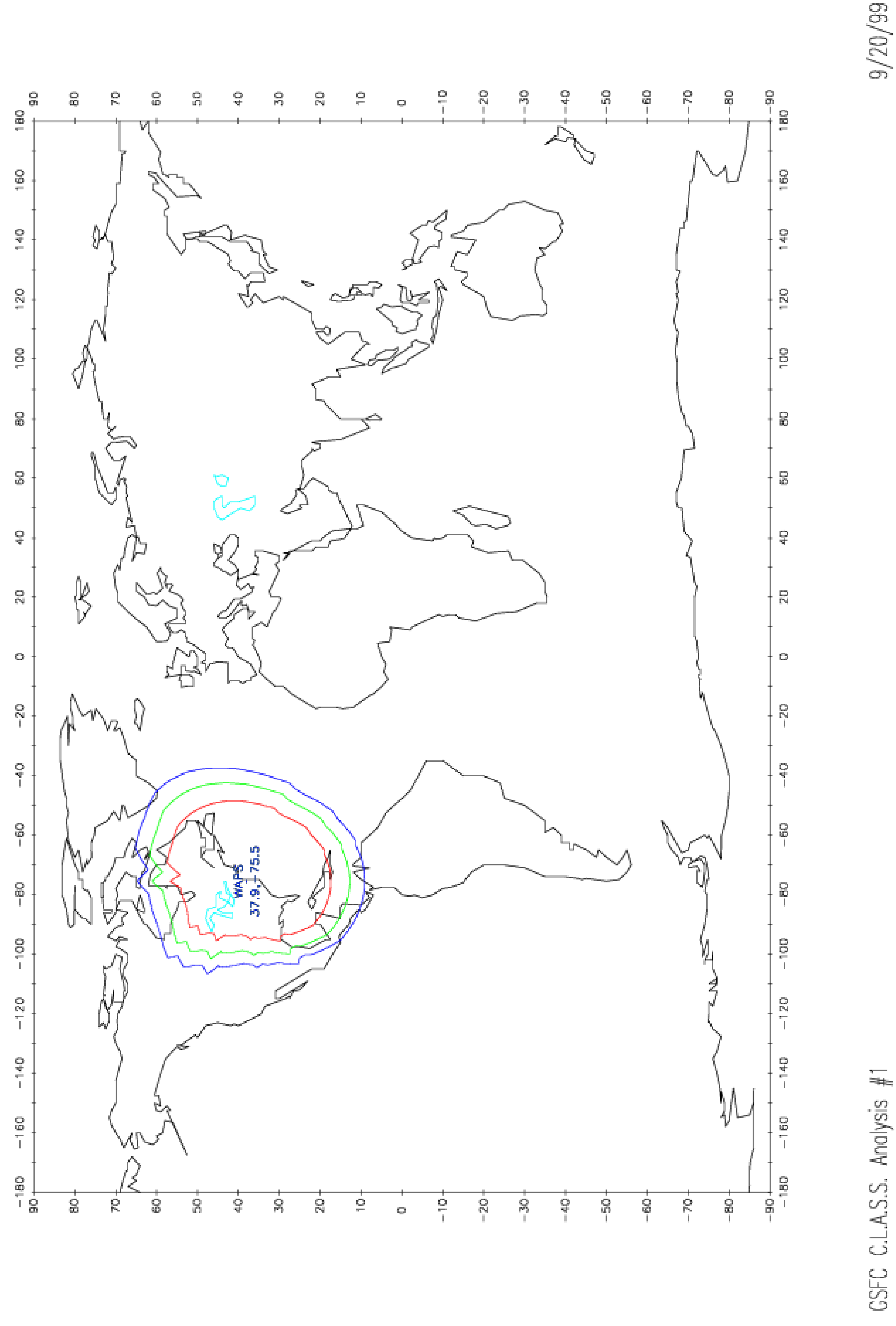

Figure 14-2. WGS Line-Of-Sight Coverage

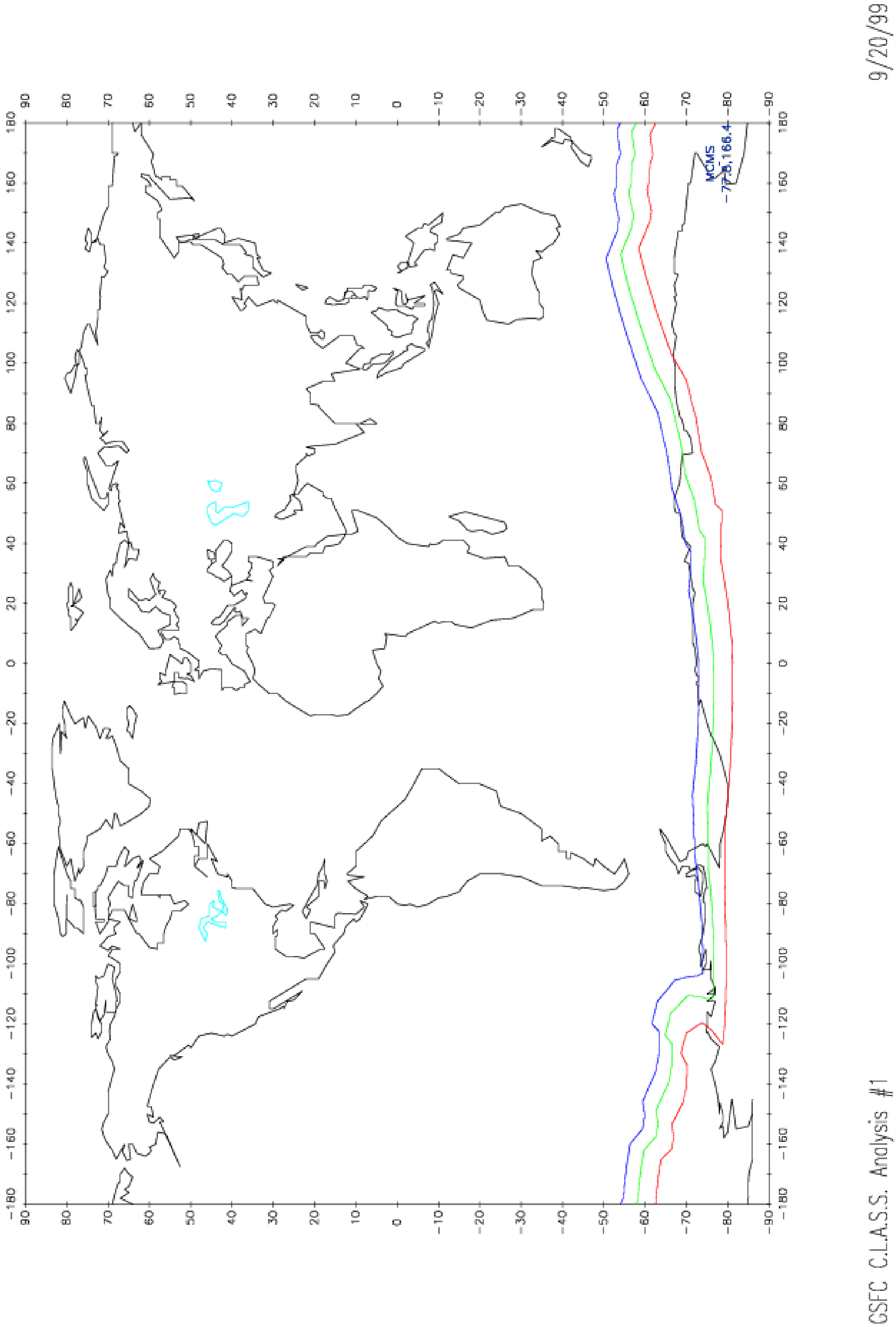

Figure 14-3. MGS Line-Of-Sight Coverage

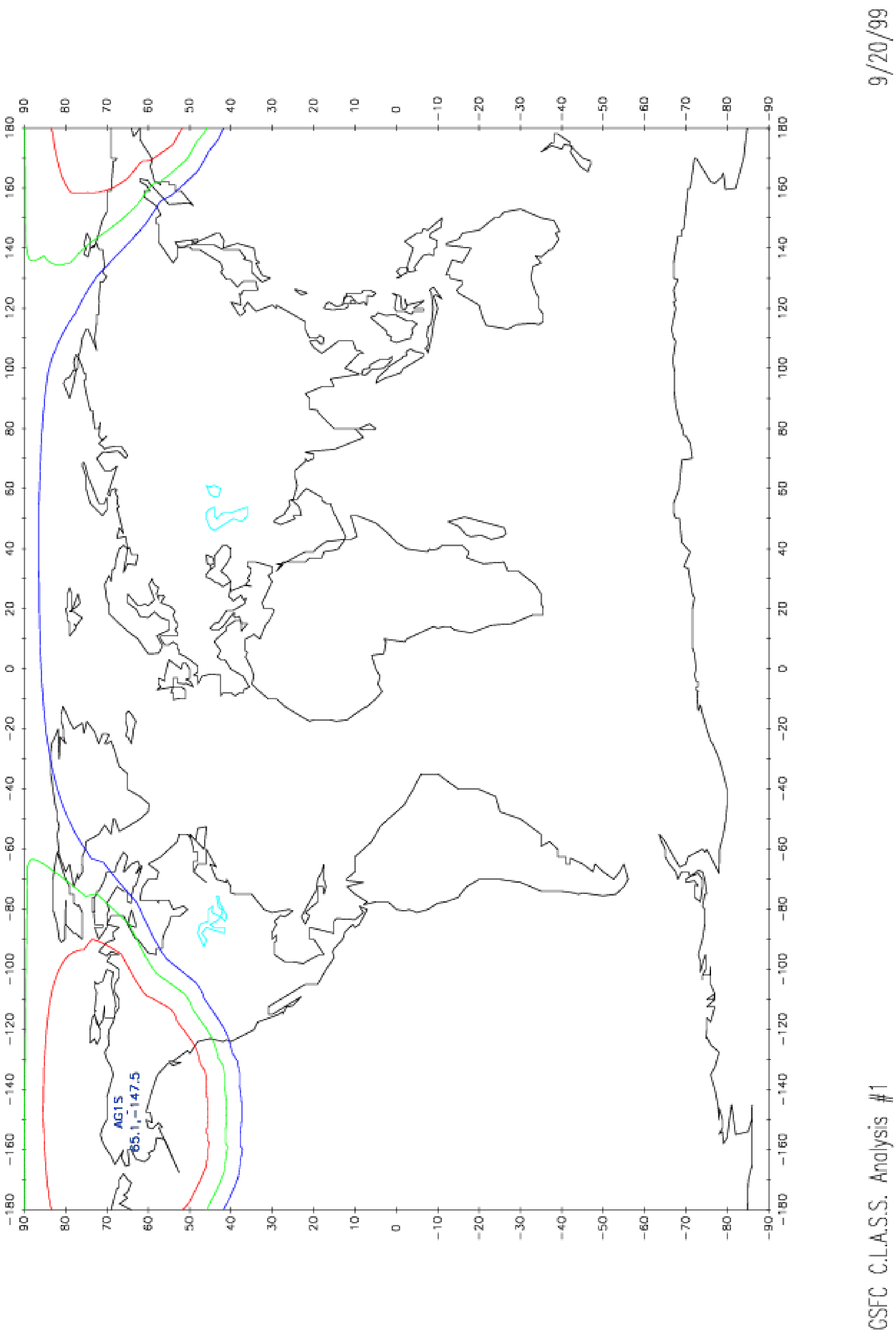

Figure 14-4. AGS/ASF Line-Of-Sight Coverage

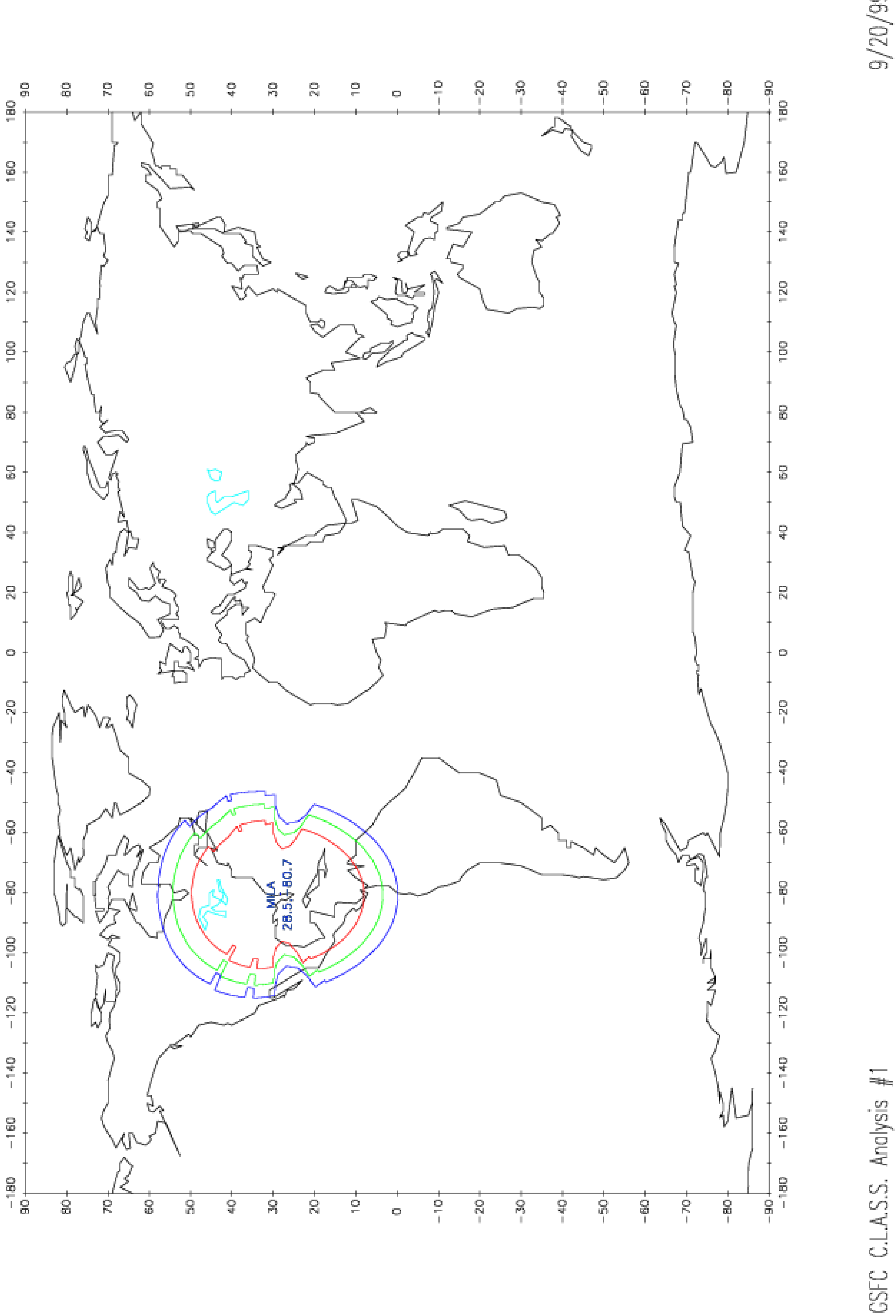

Figure 14-5. MILA Line-Of-Sight Coverage

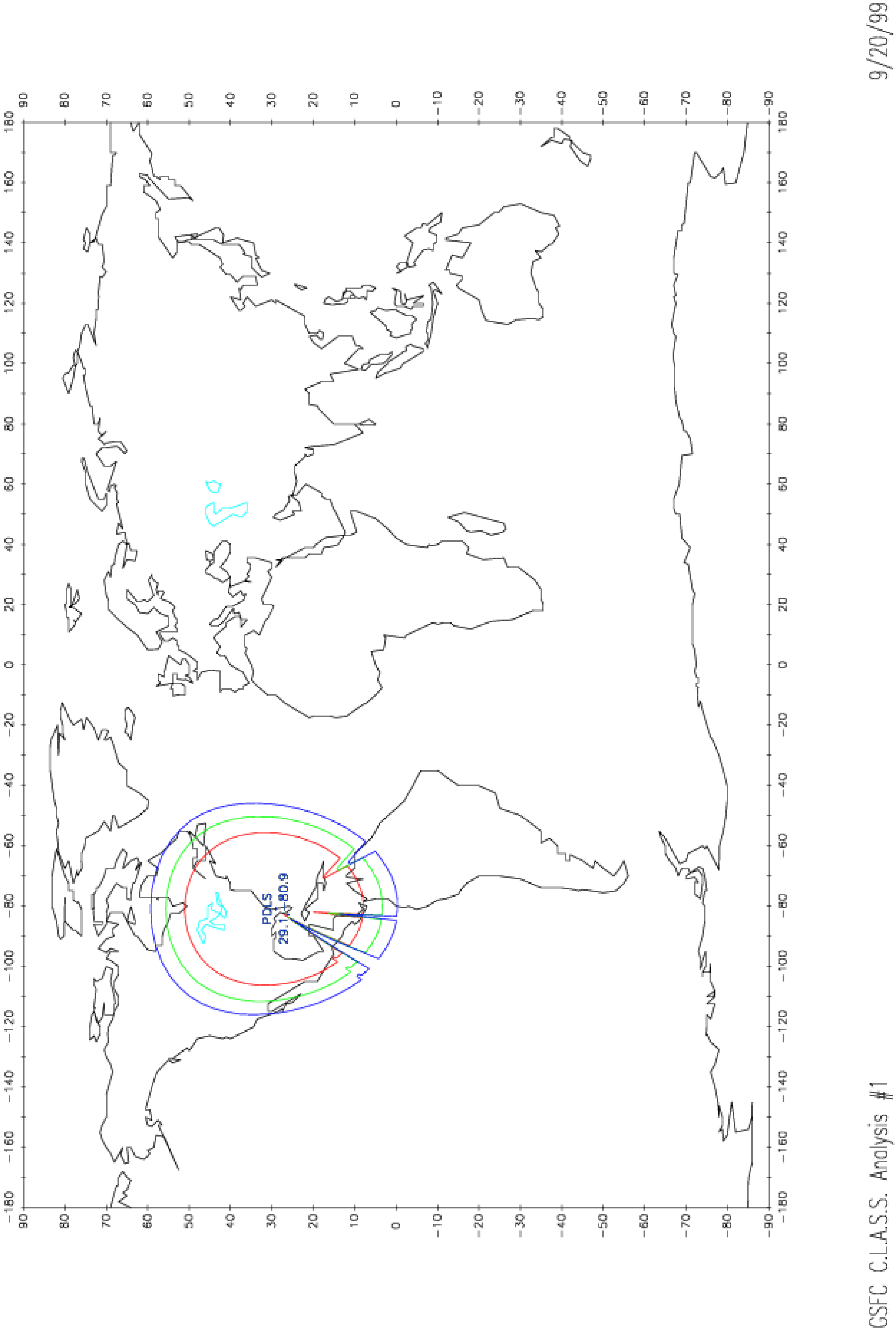

Figure 14-6. PDL Line-Of-Sight Coverage

Appendix A. Acronyms

ACE	Advanced Composition Explorer
AGS	Alaska Ground Station
AWOTS	Automated Wallops Orbital Tracking Station Project
AXAF	Chandra Advanced X-ray Astrophysics Facility
CADU	Channel Access Data Unit
CCSDS	Consultative Committee for Space Data Systems
CDH	Command Delivery Header
CLASS	Communications Link Analysis and Simulation System
CLTU	Command Link Transmission Unit
CSR	Customer Service Representative
DCN	Document Change Notice
Dop	Doppler
DSN	Deep Space Network
DS-T	Deep Space Terminal
EIRP	Effective Isotropic Radiated Power
EOS	Earth Observing System
EPGS	EOS Polar Ground Stations
ESC	Exploration and Space Communications Projects Division
FCC	Federal Communications Commission
GB	Gigabytes
GN	Ground Network
GN PAO	GN Performance Analyst Office
GNPO	Ground Networks Project Office
GNSO	Ground Network Scheduling Operator
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
IP	Internet Protocol
IPDU	Internet Protocol Data Unit
IRAC	Interdepartment Radio Advisory Committee
ITU	International Telecommunications Union
KSC	Kennedy Space Center
LEO-T	Low Earth Orbiter-Terminal
Mbps	Megabits per second

MBps	Megabytes per second
METEOSAT	Meteorological Satellite
MGS	McMurdo Ground Station
MGTAS	Medium Gain Telemetry Antenna System
MILA	Merritt Island Launch Annex
MOC	Mission Operations Center
MSP	Mission Services Program (former GSFC Code 450 title)
MTRS	McMurdo TDRS Relay System
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NCC COMM	Network Control Center Communications
NCCDS	Network Control Center Data System (at WSC)
NISN	NASA Integrated Services Network
NOM	Network Operations Manager
NPD	NASA Policy Directive
NSF	National Science Foundation
NTIA	National Telecommunications and Information Agency
PAO	Performance Analyst Office
PDL	Ponce De Leon
POC	Point of Contact
PTP	Programmable Telemetry Processor
RCC	Range Control Center
RF	Radio Frequency
R-S	Reed-Solomon
RSM	Range Support Manager
RSO	Range Safety Officer
RTP	Real-time Transmission Protocol
SAFS	Standard Autonomous File Server
SCP	Space Communications Program (GSFC Code 450)
SFCG	Space Frequency Coordination Group
SFDU	Standard Formatted Data Unit
SGS	Svalbard Ground Station
SMM	STDN Mission Manager
STDN	Spaceflight Tracking and Data Network
TCP	Transmission Control Protocol
TD	Test Director
TDMA	Time Division Multiple Access

TDRS	Tracking and Data Relay Satellite
TFDH	Telemetry Frame Delivery Header
TOTS	Transportable Orbital Tracking System
UDP	User Datagram Protocol
US	United States
UTC	Universal Time, Coordinated
UTDF	Universal Tracking Data Format
WFF	Wallops Flight Facility
WGS	Wallops Ground Station
WISAC	Wallops Information System Access
WISDB	Wallops Information System Database
WOTIS	Wallops Orbital Tracking Information System
WOTRS	Wallops Orbital Tracking Resource Scheduler
WRC	World Radiocommunication Conferences
WSC	White Sands Complex
WSCOS	White Sands Complex Operations Supervisor

Appendix B.
Ground Network New Project Questionnaire

General

1. Planned launch date? _______
2. Project Duration? __________
3. Passes required per day; launch early orbit phase? _________on orbit phase? _________
4. Data dumps required over any specific location? _______
5. Is the orbit Near Earth, Elliptical, or Geo-stationary? __________
6. Can the requirements of this spacecraft be compared with another spacecraft supported by the GN? _______
7. Do you presently plan to put any project or mission unique equipment on site? ________

Scheduling Requirements

1. Will this spacecraft require specific views or are spacecraft requirements flexible enough for generic scheduling? _______
2. Are there certain times of day commanding will be required? ___________
3. What are your minimum view periods for a pass? _________

Telemetry

1. Number of downlinks ______ (provide the following for each link, including X-Band, as applicable)
2. Frequency? ________
3. Subcarrier? ________
4. Modulation Type? (PM/FM/BPSK/QPSK/Etc.,)? ________
5. Modulation Index/Deviation/Carrier Suppression? ________
6. Coherent/Non-coherent downlink? _______
7. CCSDS? ________
8. CCSDS Version? ________
9. Symbol Rate? ________
10. Data rate? ________
11. PCM Coding (NRZ-L, M, S/Bi0L, M, S)? _______

12. Frame Sync Pattern? _________
13. Convolutional Encoded ½ rate? ___________
14. Station performing Viterbi Decoding? _________
15. Data Randomized? _________
16. Station de-randomization function enable? _________
17. Reed-Solomon encoded? _________
18. Station perform Reed-Solomon decoding? __________
19. Code word length? __________
20. R/S Interleave? __________
21. R/S Offset? __________
22. Encrypted? _________
23. CCSDS CRC checking? __________
24. Station perform CRC check? __________
25. CCSDS Virtual Channel Processing? __________
26. Virtual Channel Recording? __________
27. Virtual Channel Real-Time to project? __________
28. Virtual Channel post pass to project? __________
29. Data Latency requirement? ________
30. Project on the closed or Open IONet? _________
31. Type of socket connection TCP/IP or UDP/IP? __________
32. Do you plan to use the SAFS? ________
33. Spacecraft transmit antenna gain? _________
34. Transmitter output power? __________
35. Tone ranging? Major range tone? ARC? Mod Index?
36. Is real-time status information required? _______
37. Any post pass summaries or reports required?
38. On site data retention requirements? ____________

Command

1. Uplink Frequency? _______
2. Sub-carrier frequency for command? _______
3. Modulation (PM, FM)? _________
4. Modulation index/Deviation/Carrier suppression? ________
5. Modulation coding (NRZ-L, M, S/Bi0L, M, S)? _________
6. Command uplink data rate? _________
7. Data format? _________
8. Encryption/encoding? __________
9. Does the site need to insert an Idle pattern? __________
10. If site inserts the idle pattern- What Pattern? Pattern length? __________
11. Type of socket connection TCP/IP or UDP/IP? _________
12. Header needed for socket_______
13. Minimum acceptable spacecraft receive power?
14. Receive Antenna Gain?
15. Tone ranging/ Major range tone?

Tracking and Acquisition Data

1. Where will the acquisition data for both launch and routine operations be generated? _________
2. Do you require tracking data? ___________
3. Is tracking sent to FDF or the project or both? _________
4. Is real time tracking data required or will post pass FTP suffice? ________
5. Can you accept UTDF format? _________
6. What sample rate is required? __________