

Ground Network (GN) Users' Guide

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Preface

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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 the Wallops Flight Facility (WFF) in Virginia. The GN also includes the Network Control Center (NCC) located at GSFC and the Wallops Orbital Tracking Information System (WOTIS) at WFF.

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:

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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 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 scheduling process.

Section 9 describes baseband data interfaces.

Section 10 describes frequency management considerations.

Section 11 describes link budget parameters.

Appendix A is the acronym list.

Section 2. Ground Network Overview

This section provides an overview of the GN stations and describes general characteristics of their tracking, telemetry, and command functions. *Table 2-1* summarizes general capabilities and *Table 2-2* identifies the command and telemetry capabilities of each station.

To help a flight project select the appropriate GN station(s) on the basis of frequency bands and data rates supported, the following two tables are provided:

- *Table 2-3* – Telemetry support (sorted by frequency band and data rate).
- *Table 2-4* – Command support (sorted by frequency band and data rate).

The last part of this section describes the process for obtaining GN services.

2.1 EPGS (Norway and Alaska)

The Earth Observing System (EOS) Polar Ground Stations (EPGS) project consists of two high-latitude multi-mission ground stations. The Alaska Ground Station (AGS) is located at the Poker Flat Research Range near Fairbanks, Alaska. The Svalbard Ground Station (SGS) is located in Norway on Spitsbergen, the main island in the Svalbard archipelago. Each station supports S-band command and telemetry and X-band telemetry.

Both EPGS stations are automated, and are scheduled and monitored from WFF at Wallops Island, Virginia. Automated scheduling is performed by WOTIS, operated by the Wallops Scheduling Group (WSG).

2.2 WFF Ground Stations (Virginia)

2.2.1 AWOTS

The Automated Wallops Orbital Tracking Station (AWOTS) consists of the following three automated ground stations located at WFF:

- Wallops Ground Station (WGS)
- Low Earth Orbiter-Terminal (LEO-T) – WFF
- Transportable Orbital Tracking System (TOTS) – WFF.

WOTIS performs automated scheduling for all three stations. The characteristics of the three stations are briefly described below.

2.2.1.1 WGS

WGS supports S-band command and telemetry and X-band telemetry.

Table 2-1. GN Overview

Station	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
SGS (Norway)	11.3 m	2025-2120	66	2200-2400 8000-9000	23 35.4	78°N 15°E	1- & 2-Way Dop, Angle
WGS (WFF)	11.3 m	2025-2120	66	2200-2400 8000-9000	23 35	38°N 75°W	1- & 2-Way Dop, Angle
LEO-T (WFF)	5 m	2025-2120	59	2200-2300	17	38°N 75°W	—
TOTS (WFF)	8 m	2025-2120	62	2200-2400	21	38°N 75°W	1- & 2-Way Dop, Angle
MGTAS (WFF)	7.3 m (2)	—	—	1435-1535 1670-1720 2200-2400	11 12.5 15.5	38°N 75°W	1-Way Dop, Range, Angle
SATAN (WFF)	Arrays (3)	147-155	59	136-138	-7.03	38°N 75°W	Range
SCAMP (WFF)	Array	147-155	57	—	—	38°N 75°W	Range (with SATAN)
METEOSAT (WFF)	7.3 m	—	—	1685-1710	12	38°N 75°W	—
18 Foot Mobile System	5.5 m	—	—	1435-1535 1615-1720 2200-2300	9.4 11.6 14.6	Varies	Angle
20 Foot Mobile System	6.1 m	—	—	1435-1535 1615-1720 2200-2400	10.3 12.5 15.5	Varies	Angle
10 Foot Mobile System	3.0 m	—	—	1435-1535 1615-1720 2200-2300	4.1 5.1 8.0	Varies	Angle
8 Foot Mobile System	2.4 m	—	—	1435-1535 1615-1720 2200-2300	3.3 4.5 7.0	Varies	Angle

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

Station	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBWi)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
23 Foot Mobile System	7.0 m	—	—	1435-1535 1615-1720 2200-2400	12.0 13.7 20.0	Varies	Angle
Fixed UHF Command System	Quad Helix (2)	410-450	46	—	—	38°N 76°W	—
Mobile UHF Command System	Single Helix (2)	410-450	43	—	—	Varies	—
RADARs							
ASRF	18.3 m	UHF-Band	69	UHF-Band	—	38°N 76°W	—
Spander	18.3 m	S-Band	67	S-Band	—	38°N 76°W	—
AN/ASR-7	5.3x2.7 m	S-Band	56	S-Band	—	38°N 75°W	—
Marine Pathfinder	3.7x0.15 m	X-Band	43	X-Band	—	38°N 75°W	—
Radar #3	3.66 m	C-Band	60	C-Band	—	38°N 75°W	—
Radar #5	8.84 m	C-Band	65	C-Band	—	38°N 76°W	—
Radar #18	4.88 m	C-Band	60	C-Band	—	38°N 75°W	—
Radar #2	2.38 m	C-Band	60	C-Band	—	Varies	—
Radar #8	2.38 m	C-Band	60	C-Band	—	Varies	—
Radar #10	3.66 m	C-Band	60	C-Band	—	Varies	—
Radar #11	3.66 m	C-Band	60	C-Band	—	Varies	—

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

Station	Antenna Diameter	Transmit Frequency (MHz)	EIRP (dBW)	Receive Frequency (MHz)	G/T (dB/K)	Location	User Tracking
MGS (Antarctica)	10 m	2025-2120	63	2200-2400 8025-8400	21.1 32.5	78°S 193°W	—
ASF (Alaska)	10 m	—	—	2200-2400 8025-8400	21.1 32.5	65°N 148°W	—
	11.3 m	—	—	2200-2400 8000-9000	23 35	65°N 148°W	—
LEO-T (Alaska)	5 m	2025-2120	59.2	2200-2300	17	65°N 147°W	—
TOTS (Alaska)	8 m	2025-2120	62	2200-2400	21	65°N 147°W	1- & 2-Way Dop, Angle
AGS (Alaska)	11.3 m	2025-2120	66	2200-2400 8000-9000	23 36	65°N 147°W	1- & 2-Way Dop, Angle
MILA (Florida)	9 m (2)	2025-2120	63	2200-2300	24	29°N 81°W	1- & 2-Way Dop, Range, Angle
PDL (Florida)	4.3 m	2025-2120	58	2200-2300	11	29°N 81°W	—

Table 2-2. Command and Telemetry Support by Station

Station	Data Type	Band	Carrier or Subcarrier	Maximum Data Rate	Coding
EPGS (SGS and 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	Viterbi and/or R-S
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	110 Mbps	
LEO-T (WFF)	Command	S-band	Carrier	200 kbps	—
			Subcarrier	32 kbps	
	Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
			Subcarrier	1 Mbps	
TOTS (WFF)	Command	S-band	Carrier	200 kbps	—
			Subcarrier	32 kbps	
	Telemetry	S-band	Carrier	5 Mbps	Viterbi and/or R-S
			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*	
SATAN	Command	VHF	Carrier	20 kbps	—
			Subcarrier	2 kbps	
	Telemetry	VHF	Carrier	10 Mbps	Viterbi and/or R-S
			Subcarrier	1.3 Mbps*	

* The data rate of the telemetry subcarrier must be less than $\frac{2}{3}$ the frequency of the subcarrier.

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

Station	Data Type	Band	Carrier or Subcarrier	Maximum Data Rate	Coding
SCAMP	Command	VHF	Carrier	20 kbps	—
			Subcarrier	2 kbps	
METEOSAT	Telemetry	L-band	Carrier	6.6 Mbps	Viterbi and/or R-S
			Subcarrier	1.3 Mbps*	
18 Foot Mobile System	Telemetry	L-band	Carrier	4.0 Mbps	Viterbi and/or R-S
			Subcarrier	1.3 Mbps*	
		S-band	Carrier	4.0 Mbps	Viterbi
			Subcarrier	1.3 Mbps*	
20 Foot, 10 Foot, and 8 Foot Mobile Systems	Telemetry	L-band	Carrier	4.0 Mbps	Viterbi
			Subcarrier	1.3 Mbps*	
		S-band	Carrier	4.0 Mbps	Viterbi
			Subcarrier	1.3 Mbps*	
23 Foot Mobile System	Telemetry	L-band	Carrier	4.0 Mbps	Viterbi and/or R-S
			Subcarrier	1.3 Mbps*	
		S-band	Carrier	4.0 Mbps	Viterbi and/or R-S
			Subcarrier	1.3 Mbps*	
Fixed UHF Command System	Command	UHF band	Carrier	IRIG Standard Tones	—
Mobile UHF Command System	Command	UHF band	Carrier	IRIG Standard Tones	—
MGS	Command	S-band	Carrier	200 kbps	—
			Subcarrier	32 kbps	—
	Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
			Subcarrier	1 Mbps	Viterbi and/or R-S
		X-band	Carrier	110 Mbps	Viterbi and/or R-S

* The data rate of the telemetry subcarrier must be less than $\frac{2}{3}$ the frequency of the subcarrier.

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

Station	Data Type	Band	Carrier or Subcarrier	Maximum Data Rate	Coding
LEO-T (Alaska)	Command	S-band	Carrier	200 kbps	—
			Subcarrier	32 kbps	—
	Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
			Subcarrier	1 Mbps	Viterbi and/or R-S
TOTS (Alaska)	Command	S-band	Carrier	200 kbps	—
			Subcarrier	32 kbps	—
	Telemetry	S-band	Carrier	4 Mbps	Viterbi and/or R-S
			Subcarrier	1 Mbps	Viterbi and/or R-S
ASF	Telemetry	S-band	Carrier	8 Mbps	Viterbi and/or R-S
			Subcarrier	1 Mbps	Viterbi and/or R-S
		X-band	Carrier	110 Mbps	Viterbi and/or R-S
MILA	Command	S-band	Carrier	216 kbps	—
			Subcarrier	8 kbps	—
	Telemetry	S-band	Carrier	10 Mbps	Viterbi and/or R-S
			Subcarrier	2 Mbps	Viterbi and/or R-S
PDL	Command	S-band	Carrier	—	—
			Subcarrier	8 kbps	—
	Telemetry	S-band	Carrier	2 Mbps	Viterbi and/or R-S
			Subcarrier	1.3 Mbps*	Viterbi and/or R-S

* The data rate of the telemetry subcarrier must be less than $\frac{2}{3}$ 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	EPGS (SGS and AGS) WGS MGS LEO-T (WFF) LEO-T (Alaska) ASF
	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	
	5 Mbps	Carrier	Viterbi and/or R-S	TOTS (WFF)
	1 Mbps	Subcarrier	Viterbi and/or R-S	
	4 Mbps	Carrier	Viterbi	18 Foot, 20 Foot, 10 Foot, and 8 Foot Mobile Systems
	1.3 Mbps*	Subcarrier	Viterbi	
	4 Mbps	Carrier	Viterbi and/or R-S	23 Foot Mobile System
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	
	4 Mbps	Carrier	Viterbi and/or R-S	TOTS (Alaska)
	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	EPGS (SGS and AGS)
	110 Mbps	Carrier	Viterbi and/or R-S	WGS MGS ASF
L-band	6.6 Mbps	Carrier	Viterbi and/or R-S	METEOSAT MGTAS
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	
	4 Mbps	Carrier	Viterbi and/or R-S	18 Foot and 23 Foot Mobile Systems
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	
	4 Mbps	Carrier	Viterbi	20 Foot, 10 Foot, and 8 Foot Mobile Systems
	1.3 Mbps*	Subcarrier	Viterbi	
VHF	10 Mbps	Carrier	Viterbi and/or R-S	SATAN (WFF)
	1.3 Mbps*	Subcarrier	Viterbi and/or R-S	
	5 Mbps	Carrier	Viterbi and/or R-S	SATAN (Santiago)
		Subcarrier		

* The data rate of the telemetry subcarrier must be less than $\frac{2}{3}$ 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	
	200 kbps	Carrier	EPGS (SGS/AGS) WGS MGS LEO-T (WFF) TOTS (WFF) LEO-T (Alaska) TOTS (Alaska)
	32 kbps	Subcarrier	
VHF	20 kbps	Carrier	SATAN (WFF) SCAMP
	2 kbps	Subcarrier	
	2 kbps	Carrier	SATAN (Santiago)
	—	Subcarrier	
UHF	IRIG Standard Tones	Carrier	UHF Command Systems (WFF)

2.2.1.2 LEO-T – WFF

The LEO-T station at WFF supports S-band command and telemetry.

2.2.1.3 TOTS – WFF

The TOTS station at WFF supports S-band command and telemetry.

2.2.2 Other WFF Ground Stations

In addition to the AWOTS, the following ground stations are also located at WFF:

- Medium Gain Telemetry Antenna System (MGTAS)
- Satellite Automatic Tracking Antenna (SATAN)
- Small Command Antenna on a Medium Pedestal (SCAMP)
- Meteorological Satellite (METEOSAT).
- 18 Foot, 20 Foot, 10 Foot, 8 Foot, and 23 Foot Mobile Systems.
- UHF Command Systems
- Radar Systems

These stations support tracking and data acquisition for NASA-approved missions, as well as range safety operations for high-inclination launches from the Kennedy Space Center (KSC), including the Space Shuttle. The characteristics of the stations are briefly described below.

2.2.2.1 MGTAS

MGTAS supports only telemetry at S- and L-band. WOTIS provides automated scheduling.

2.2.2.2 SATAN

SATAN has three VHF antenna arrays: one for transmit and two for receive. It supports VHF command and telemetry. The user, WSG, and ground station personnel schedule the station via e-mail and telephone.

2.2.2.3 SCAMP

SCAMP supports only VHF commanding. When used with the receive portion of SATAN, SCAMP can support range tracking. The user, WSG, and ground station personnel schedule the station via e-mail and telephone.

2.2.2.4 METEOSAT

METEOSAT supports only L-band telemetry. The user, WSG, and ground station personnel schedule the station via e-mail and telephone.

2.2.2.5 Mobile Systems

The 18 Foot, 20 Foot, 10 Foot, 8 Foot, and 23 Foot Mobile Systems support L-band and S-band telemetry. The user, WSG, and mobile system personnel schedule each mobile system via e-mail and telephone.

2.2.2.6 UHF Command Systems

The Fixed UHF Command System and Mobile UHF Command System support the transmission of specific flight termination commands (arm/destroy/terminate) and other types of commands, such as, control of events and guidance. The user and WFF Range and Mission Management Office schedule each mobile system via e-mail and telephone.

2.2.2.7 Radar Systems

The seven Fixed Radar Systems and four Mobile Radar Systems provide tracking services. The user and WFF Radar coordinator schedule each mobile system via e-mail and telephone.

2.3 McMurdo Ground Station (MGS) (Antarctica)

McMurdo Ground Station (MGS) is located at McMurdo Station in Antarctica. It supports S-band command and telemetry and X-band telemetry. WOTIS provides automated scheduling.

2.4 Alaska Ground Stations

The Alaska GN stations are located in two separate areas: Poker Flat Research Range and the Alaska Synthetic Aperture Radar (SAR) Facility (ASF) in Fairbanks.

2.4.1 Poker Flat Research Range

In addition to the AGS discussed in Section 2.1 above, the Poker Flat Research Range contains two other ground stations: LEO-T – Alaska and TOTS – Alaska. These stations are located 30 miles northeast of Fairbanks. The characteristics of the two stations are briefly described below.

2.4.1.1 LEO-T – Alaska

The LEO-T station in Alaska supports S-band command and telemetry. WOTIS provides automated scheduling.

2.4.1.2 TOTS – Alaska

The TOTS station in Alaska supports S-band command and telemetry. The user, WSG, and ground station personnel perform scheduling via e-mail and telephone.

2.4.2 Alaska SAR Facility (ASF)

The ASF in Fairbanks consists of two receive-only ground stations – one has a 10-meter antenna, the other an 11.3-meter antenna. Both support only telemetry at S- and X-band. Scheduling is not automated; the user and ASF personnel interact via telephone.

2.5 Florida Ground Stations

There are two GN stations in Florida: Merritt Island Launch Area (MILA) and Ponce De Leon (PDL). They primarily support Space Shuttle launches and landings. MILA and PDL support S-band command and telemetry. The NCC, located at the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, schedules both stations.

2.6 Analysis, Test, and Simulation Support

The Missions Services Program Office performs analysis, testing, and simulation which 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 Missions Services Program Office preliminary funding and manpower requirements. The results of such analyses will enable an early assessment of the project's compatibility with the GN, and other analyses or information pertaining to other GN elements.

2.6.1 Network Loading Analysis

To ensure that sufficient GN resources are available to meet commitments to current and future users, the Missions Services Program Office provides a representative to each user flight project as early as possible during mission planning to assist in the definition of user flight project needs for Missions Services Program Office services. Typical information needed are 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.

2.6.2 RF Link Margin and Coverage Analysis

Information exchange 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.

2.6.3 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 posttest 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 Missions Services Program Office readiness-for-launch criteria.

2.6.4 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. In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines. Guidelines for this support appear in the STDN Test and Simulation Support Plan, 530-NOP-STDN/TS.

2.6.5 Orbit Support Analysis

Prelaunch 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.

2.8 Obtaining Ground Network Services

For all GN stations, flight projects should request GN support through NASA/GSFC, Code 451, Customer Commitment Office.

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).

The general characteristics of the station are as follows:

- Location: 78° 13' 49" N
15° 23' 34" 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 WFF using WOTIS (see Section 8.2).
- 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 SGS.

3.2 S-Band Telemetry

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

Table 3-1. SGS 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 SGS.

3.4 Tracking Services

3.4.1 Doppler Tracking

The SGS 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. SGS 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)

3.4.2 Antenna Autotracking Angle Data

The SGS 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 [o] in Section 1.3, above.)

3.5 Baseband Data Interfaces

The SGS 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 9.2, 9.3, and 9.4, respectively). 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 (see Section 9.5).

Table 3-3. SGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 9000 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. SGS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{\text{transmit}} \times [240/221] - f_{\text{received}}) + f_{\text{bias}}$

Section 4. Wallops Flight Facility (WFF) Ground Stations

This section describes the GN stations located at WFF: AWOTS and the other stations.

AWOTS consists of the following ground stations:

- WGS (Section 4.1)
- LEO-T – WFF (Section 4.2)
- TOTS – WFF (Section 4.3)

The other GN stations located at WFF are the following:

- MGTAS (Section 4.4)
- SATAN (Section 4.5)
- SCAMP (Section 4.6)
- METEOSAT (Section 4.7)
- Mobile Systems (Sections 4.8 – 4.12)
- UHF Command Systems (Section 4.13)
- Fixed And Mobile Radar Systems (Section 4.14)

4.1 WGS

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

- Location: 37° 55' 30" N
75° 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 WFF using WOTIS (see Section 8.2).
- 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 through 4.1.3 describe S-band and X-band performance characteristics. Sections 4.1.4 and 4.1.5 describe the tracking services and baseband data interfaces, respectively.

4.1.1 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 dBW _i
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

4.1.2 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	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-L : 100 bps - 8 Mbps Bi ϕ -L : 100 bps - 4 Mbps
Carrier Data Format	NRZ-L or Bi ϕ -L
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L or Bi ϕ -S
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

4.1.3 X-Band Telemetry

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

4.1.4 Tracking Services

4.1.4.1 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	8000 – 9000 MHz
G/T	≥ 35 dB/K
System Noise Temperature	150 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	QPSK or UQPSK
Data Rate	6 – 110 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

4.1.4.2 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 [o] in Section 1.3, above.)

4.1.5 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 Sections 9.2, 9.3, and 9.4, respectively). 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 (see Section 9.5).

Table 4-4. WGS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{\text{transmit}} \times [240/221] - f_{\text{received}}) + f_{\text{bias}}$

4.2 LEO-T – WFF

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

- Location: 37° 55' N
75° 28' 25" W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 4-2 is a photograph of the LEO-T antenna.
- Automatically scheduled by WFF using WOTIS.
- 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)

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 Sections 9.2, 9.3, and 9.4, respectively). 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 TOTS – WFF

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

- Location: 37° 55' 11" N
75° 28' 25" W
- One 8-meter antenna for simultaneously transmitting and receiving at S-band. Figure 4-3 is a photograph of the TOTS antenna.
- Automatically scheduled by WFF using WOTIS (see Section 8.2).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 4.3.1 and 4.3.2 describe S-band performance characteristics. Sections 4.3.3 and 4.3.4 describe the tracking services and baseband data interfaces, respectively.

4.3.1 S-Band Command

Table 4-7 identifies the S-band command characteristics of the TOTS – WFF.

4.3.2 S-Band Telemetry

Table 4-8 identifies the S-band telemetry characteristics of the TOTS – WFF station.



Figure 4-3. TOTS – WFF Antenna

Table 4-7. TOTS – WFF S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 62 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	1.27°
Antenna Gain	42.1 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 4-8. TOTS – WFF S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21 dB/K
System Noise Temperature	150 K
Polarization	RHC or LHC
Antenna Beamwidth	1.14°
Antenna Gain	42.8 dBi
Carrier Modulation	PM, BPSK, FM, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	Uncoded: 5 Mbps Rate-½ coded: 2.5 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)

4.3.3 Tracking Services

4.3.3.1 Doppler Tracking

The TOTS – WFF station 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 TOTS – WFF S-band uplink signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 4-9*.

4.3.3.2 Antenna Autotracking Angle Data

TOTS – WFF 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 [o] in Section 1.3, above.)

Table 4-9. TOTS – WFF Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{\text{transmit}} \times [240/221] - f_{\text{received}}) + f_{\text{bias}}$

4.3.4 Baseband Data Interfaces

The TOTS – 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 Sections 9.2, 9.3, and 9.4, respectively). TOTS – WFF currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

4.4 MGTAS

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

- Location: 37° 55' N
75° 28' W
- Two 7.3-meter L- and S-band receive-only antennas. Figure 4-4 is a photograph of the MGTAS antennas.
- Automatically scheduled by WFF using WOTIS.
- Tracking services: 1-way Doppler, ranging, and antenna autotracking angle.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 4.4.1 through 4.4.3 describe the L- and S-band receive-only performance characteristics. Sections 4.4.4 and 4.4.5 describe the tracking services and baseband data interfaces, respectively.

4.4.1 L1-Band Telemetry

Table 4-10 identifies the L1-band telemetry characteristics of the MGTAS station (the two L1-band systems are functionally identical).



Figure 4-4. MGTAS Antennas

Table 4-10. MGTAS L1-Band Telemetry Characteristics

Characteristic	Value
Frequency	1435 – 1535 MHz
G/T	≥ 11.0 dB/K
System Noise Temperature	446 K
Polarization	RHC or LHC
Antenna Beamwidth	1.69°
Antenna Gain	37.5 dBi
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	≤ 6.6 Mbps
Carrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Decoding	Viterbi (Rate- $\frac{1}{2}$) and/or Reed-Solomon (CCSDS)

4.4.2 L2-Band Telemetry

Table 4-11 identifies the L2-band telemetry characteristics of MGTAS (the two L2-Band systems are functionally identical).

4.4.3 S-Band Telemetry

Table 4-12 identifies the S-band telemetry characteristics of MGTAS (the two S-Band systems are functionally identical).

4.4.4 Tracking Services

4.4.4.1 Doppler Tracking

MGTAS generates 1-way Doppler tracking data derived from the S-band downlink carrier. Doppler tracking characteristics are shown in *Table 4-13*.

4.4.4.2 Range Tracking

Range tracking characteristics are shown in *Table 4-14*.

4.4.4.3 Antenna Autotracking Angle Data

MGTAS 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 [o] in Section 1.3, above.)

4.4.5 Baseband Data Interfaces

The MGTAS station can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 9.2 and 9.4, respectively). MGTAS currently has a T-1 (1.544 Mbps) communications link with GSFC to support command, low-rate telemetry, and ground station control and monitor.

Table 4-11. MGTAS L2-Band Telemetry Characteristics

Characteristic	Value
Frequency	1670 – 1720 MHz
G/T	≥ 12.5 dB/K
System Noise Temperature	510 K
Polarization	RHC or LHC
Antenna Beamwidth	1.69°
Antenna Gain	39.6 dBi
Carrier Modulation	PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	≤ 6.6 Mbps
Carrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Decoding	Viterbi (Rate- $\frac{1}{2}$) and/or Reed-Solomon (CCSDS)

Table 4-12. MGTAS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 15.5 dB/K
System Noise Temperature	446 K
Polarization	RHC or LHC
Antenna Beamwidth	1.28°
Antenna Gain	42.0 dBi
Carrier Modulation	PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	≤ 6.6 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-½) and/or Reed-Solomon (CCSDS)

Table 4-13. MGTAS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 seconds
Output Equation	$1000 (f_{\text{transmit}} \times [240/221] - f_{\text{received}}) + f_{\text{bias}}$

Table 4-14. MGTAS Range Tracking Characteristics

Characteristic	Value
Operating Modes	2-way coherent and non-coherent
Modulation Index	Carrier: 0.2 – 1.5 radians (peak) Subcarrier (1.7 MHz): 0.3 – 1.2 radians (peak)
Major Tone Frequencies	500 kHz, 100 kHz, and 20 kHz
Minor Tone Frequencies	100 kHz, 20 kHz, and 4 kHz on carrier or 1.7-MHz subcarrier 800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz tone
C_{received}/N	≥ 10 dB
Tone Power/ N_0	> 15 dB-Hz
Accuracy	1.0 m
Unambiguous Range	$\leq 644,000$ km

4.5 SATAN

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

- Location: 37° 55' N
75° 28' W
- One transmit array and two receive array antennas for simultaneously transmitting and receiving at VHF. Figure 4-5 is a photograph of the SATAN antennas.
- Manually scheduled by WSG.
- Tracking service: Ranging.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 4.5.1 and 4.5.2 describe VHF performance characteristics. Sections 4.5.3 and 4.5.4 describe the tracking services and baseband data interfaces, respectively.

4.5.1 VHF Command

Table 4-15 identifies the VHF command characteristics of the SATAN station.

4.5.2 VHF Telemetry

Table 4-16 identifies the VHF telemetry characteristics of the SATAN station.



Figure 4-5. SATAN Antennas

Table 4-15. SATAN VHF Command Characteristics

Characteristic	Value
Frequency	147 – 155 MHz
EIRP	≥ 59 dBWi
Polarization	RHC or LHC
Antenna Beamwidth	13°
Antenna Gain	19 dBi
Output Power	10 kW
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 3 radians (peak) FM: 1 MHz deviation
Carrier Data Rate	100 bps – 20 kbps
Subcarrier Frequency	8 kHz or 16 kHz
Subcarrier Modulation	FSK or PSK
Subcarrier Data Rate	1 kbps – 2 kbps
Data Format	NRZ-L or Biφ-L

Table 4-16. SATAN VHF Telemetry Characteristics

Characteristic	Value
Frequency	136 – 138 MHz
G/T	≥ -7.03 dB/K
System Noise Temperature	800 K
Polarization	RHC or LHC
Antenna Beamwidth	12.5°
Antenna Gain	22 dBi
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	≤ 10 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate- ¹ / ₂ or Rate- ¹ / ₃) and/or Reed-Solomon (CCSDS)

4.5.3 Tracking Services

SATAN supports only range tracking service.

4.5.3.1 Range Tracking

Range tracking characteristics are shown in *Table 4-17*.

4.5.4 Baseband Data Interfaces

The SATAN station can send and receive baseband data in either of the following formats: IP and 4800-bit blocks encapsulated in IP packets (see Sections 9.2 and 9.4, respectively). MGTAS currently has a T-1 (1.544 Mbps) communications link with GSFC to support low-rate telemetry.

Table 4-17. SATAN Range Tracking Characteristics

Characteristic	Value
Operating Mode	2-way coherent
PM Modulation Index	0.2 – 1.5 radians (peak) on carrier/715-kHz subcarrier
Minor Tone Frequencies	4 kHz on carrier 800 Hz, 160 Hz, 40 Hz, and 10 Hz on 4-kHz tone
C_{received}/N	≥ 15 dB

The user does not send command data directly to SATAN. Instead, SATAN maintains a database of user commands. Using telephone or e-mail, a user requests specific commands from the database, which SATAN then transmits to the user.

4.6 SCAMP

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

- Location: 37° 55' N
75° 28' W
- One VHF transmit-only antenna array. Figure 4-6 is a photograph of the SCAMP antenna.
- Manually scheduled by WSG.
- Tracking services: Ranging (with SATAN receive system).
- Baseband data interface: None (uses a command database).

Section 4.6.1 describes the VHF transmit-only performance characteristics. Sections 4.6.2 and 4.6.3 describe the tracking services and baseband data interface, respectively.

4.6.1 VHF Command

Table 4-18 identifies the VHF command characteristics of the SCAMP station.

4.6.2 Tracking Services

SCAMP supports range tracking only when used with the receive portion of the SATAN station.

4.6.2.1 Range Tracking

Range tracking characteristics are shown in *Table 4-19*.



Figure 4-6. SCAMP Antenna

Table 4-18. SCAMP VHF Command Characteristics

Characteristic	Value
Frequency	147 – 155 MHz
EIRP	≥ 57 dBW _i
Polarization	RHC or LHC
Antenna Beamwidth	20°
Antenna Gain	17 dBi
Output Power	10 kW
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 3 radians (peak) FM: 1 MHz deviation
Carrier Data Rate	100 bps – 20 kbps
Subcarrier Frequency	8 kHz or 16 kHz
Subcarrier Modulation	FSK or PSK
Subcarrier Data Rate	1 kbps – 2 kbps
Data Format	NRZ-L or Biφ-L

Table 4-19. SCAMP Range Tracking Characteristics

Characteristic	Value
Operating Mode	Coherent (when operating with <i>SATAN</i> receiver)
PM Modulation Index	0.2 – 1.5 radians (peak) on carrier
Major Tone Frequency	20 kHz

4.6.3 Baseband Data Interfaces

SCAMP is a transmit-only station, but the user does not send command data directly to the station. Instead, SCAMP maintains a database of user commands. Using telephone or e-mail, a user requests specific commands from the database, which SCAMP then transmits to the user.

4.7 METEOSAT

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

- Location: 37° 55' N
75° 28' W
- One 7.3-meter L-band receive-only antenna. Figure 4-7 is a photograph of the METEOSAT antenna.
- Manually scheduled by WSG.
- Tracking services: None.
- Baseband data interface: None (data is sent via telephone).

Section 4.7.1 describes the L-band receive-only performance characteristics, and Section 4.7.2 describes the baseband data interface.

4.7.1 L-Band Telemetry

Table 4-20 identifies the L-band telemetry characteristics of the METEOSAT station.

4.7.2 Baseband Data Interfaces

METEOSAT records received baseband data on computer disk. The recorded data is sent via commercial telephone lines. METEOSAT does not use the NASCOM or NASA Integrated Services Network (NISN) data circuits described in section 9.



Figure 4-7. METEOSAT Antenna

Table 4-20. METEOSAT L-Band Telemetry Characteristics

Characteristic	Value
Frequency	1685 – 1710 MHz
G/T	≥ 12 dB/K
System Noise Temperature	500 K
Polarization	RHC or LHC
Antenna Beamwidth	1.7°
Antenna Gain	39 dBi
Carrier Modulation	PM, FM, or AM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Carrier Data Rate	≤ 6.6 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2 or Rate-1/3) and/or Reed-Solomon (CCSDS)

4.8 18 Foot Mobile System

The general characteristics of the WFF 18 Foot Mobile System are as follows:

- Location: Varies
- One 5.5-meter L- and S-band receive-only antenna. Figure 4-8 is a photograph of the 18 Foot antenna.
- Manually scheduled by WSG.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Mail.

Sections 4.8.1, 4.8.2, and 4.8.3 describe L-band and S-band performance characteristics. Sections 4.8.4 and 4.8.5 describe the tracking services and baseband data interfaces, respectively.

4.8.1 L1-Band Telemetry

Table 4-21 identifies the L1-band telemetry characteristics of the 18 Foot Mobile System.

4.8.2 L2-Band Telemetry

Table 4-22 identifies the L2-band telemetry characteristics of the 18 Foot Mobile System.

4.8.3 S-Band Telemetry

Table 4-23 identifies the S-band telemetry characteristics of the 18 Foot Mobile System.

4.8.4 Tracking Services

4.8.4.1 Antenna Autotracking Angle Data

The 18 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

4.8.5 Baseband Data Interfaces

The 18 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 9.5).



Figure 4-8. 18 Foot Mobile System Antenna

Table 4-21. 18 Foot Mobile System L1-Band Telemetry Characteristics

Characteristic	Value
Frequency	1435 – 1535 MHz
G/T	≥ 9.4 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	2.25°
Antenna Gain	34.9 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon (CCSDS)

Table 4-22. 18 Foot Mobile System L2-Band Telemetry Characteristics

Characteristic	Value
Frequency	1615 – 1720 MHz
G/T	≥ 11.6 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	2.25°
Antenna Gain	37.1 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon (CCSDS)

Table 4-23. 18 Foot Mobile System S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 14.6 dB/K (at 45° elevation angle)
System Noise Temperature	310 K
Polarization	RHC or LHC
Antenna Beamwidth	1.7°
Antenna Gain	39.5 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 1.4 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2)

4.9 20 Foot Mobile System

The general characteristics of the WFF 20 Foot Mobile System are as follows:

- Location: Varies
- One 6.1-meter L- and S-band receive-only antenna. Figure 4-9 is a photograph of the 20 Foot antenna.
- Manually scheduled by WSG.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Mail.

Sections 4.9.1, 4.9.2, and 4.9.3 describe L-band and S-band performance characteristics. Sections 4.9.4 and 4.9.5 describe the tracking services and baseband data interfaces, respectively.

4.9.1 L1-Band Telemetry

Table 4-24 identifies the L1-band telemetry characteristics of the 20 Foot Mobile System.

4.9.2 L2-Band Telemetry

Table 4-25 identifies the L2-band telemetry characteristics of the 20 Foot Mobile System.

4.9.3 S-Band Telemetry

Table 4-26 identifies the S-band telemetry characteristics of the 20 Foot Mobile System.

4.9.4 Tracking Services

4.9.4.1 Antenna Autotracking Angle Data

The 20 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

4.9.5 Baseband Data Interfaces

The 20 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 9.5).



Figure 4-9. 20 Foot Mobile System Antenna

Table 4-24. 20 Foot Mobile System L1-Band Telemetry Characteristics

Characteristic	Value
Frequency	1435 – 1535 MHz
G/T	≥ 10.3 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	2.03°
Antenna Gain	35.8 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-½)

Table 4-25. 20 Foot Mobile System L2-Band Telemetry Characteristics

Characteristic	Value
Frequency	1615 – 1720 MHz
G/T	≥ 12.5 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	2.03°
Antenna Gain	38.0 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-½)

Table 4-26. 20 Foot Mobile System S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 15.5 dB/K (at 45° elevation angle)
System Noise Temperature	316 K
Polarization	RHC or LHC
Antenna Beamwidth	1.53°
Antenna Gain	40.5 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2)

4.10 10 Foot Mobile System

The general characteristics of the WFF 10 Foot Mobile System are as follows:

- Location: Varies
- One 3.0-meter L- and S-band receive-only antenna. Figure 4-10 is a photograph of the 10 Foot antenna.
- Manually scheduled by WSG.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Mail.

Sections 4.10.1, 4.10.2, and 4.10.3 describe L-band and S-band performance characteristics. Sections 4.10.4 and 4.10.5 describe the tracking services and baseband data interfaces, respectively.

4.10.1 L1-Band Telemetry

Table 4-27 identifies the L1-band telemetry characteristics of the 10 Foot Mobile System.

4.10.2 L2-Band Telemetry

Table 4-28 identifies the L2-band telemetry characteristics of the 10 Foot Mobile System.

4.10.3 S-Band Telemetry

Table 4-29 identifies the S-band telemetry characteristics of the 10 Foot Mobile System.

4.10.4 Tracking Services

4.10.4.1 Antenna Autotracking Angle Data

The 10 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

4.10.5 Baseband Data Interfaces

The 10 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 9.5).



Figure 4-10. 10 Foot Mobile System Antenna

Table 4-27. 10 Foot Mobile System L1-Band Telemetry Characteristics

Characteristic	Value
Frequency	1435 – 1535 MHz
G/T	≥ 4.1 (at 45° elevation angle)
System Noise Temperature	435 K
Polarization	RHC or LHC
Antenna Beamwidth	4.5°
Antenna Gain	30.5 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2)

Table 4-28. 10 Foot Mobile System L2-Band Telemetry Characteristics

Characteristic	Value
Frequency	1615 – 1720 MHz
G/T	≥ 5.1 (at 45° elevation angle)
System Noise Temperature	435 K
Polarization	RHC or LHC
Antenna Beamwidth	4.1°
Antenna Gain	31.5 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-½)

Table 4-29. 10 Foot Mobile System S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 8.0 dB/K (at 45° elevation angle)
System Noise Temperature	435 K
Polarization	RHC or LHC
Antenna Beamwidth	3.1°
Antenna Gain	34.4 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2)

4.11 8 Foot Mobile System

The general characteristics of the WFF 8 Foot Mobile System are as follows:

- Location: Varies
- One 2.4-meter L- and S-band receive-only antenna. Figure 4-11 is a photograph of the 8 Foot antenna.
- Manually scheduled by WSG.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Mail.
- Sections 4.11.1, 4.11.2, and 4.11.3 describe L-band and S-band performance characteristics. Sections 4.11.4 and 4.11.5 describe the tracking services and baseband data interfaces, respectively.

4.11.1 L1-Band Telemetry

Table 4-30 identifies the L1-band telemetry characteristics of the 8 Foot Mobile System.

4.11.2 L2-Band Telemetry

Table 4-31 identifies the L2-band telemetry characteristics of the 8 Foot Mobile System.

4.11.3 S-Band Telemetry

Table 4-32 identifies the S-band telemetry characteristics of the 8 Foot Mobile System.

4.11.4 Tracking Services

4.11.4.1 Antenna Autotracking Angle Data

The 8 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

4.11.5 Baseband Data Interfaces

The 8 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 9.5).



Figure 4-11. 8 Foot Mobile System Antenna

Table 4-30. 8 Foot Mobile System L1-Band Telemetry Characteristics

Characteristic	Value
Frequency	1435 – 1535 MHz
G/T	≥ 3.3 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	5.1°
Antenna Gain	28.8 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-½)

Table 4-31. 8 Foot Mobile System L2-Band Telemetry Characteristics

Characteristic	Value
Frequency	1615 – 1720 MHz
G/T	≥ 4.5 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	5.1°
Antenna Gain	30.0 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-½)

Table 4-32. 8 Foot Mobile System S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2300 MHz
G/T	≥ 7.0 dB/K (at 45° elevation angle)
System Noise Temperature	350 K
Polarization	RHC or LHC
Antenna Beamwidth	3.9°
Antenna Gain	32.5 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Decoding	Viterbi (Rate-1/2)

4.12 23 Foot Mobile System

The general characteristics of the WFF 23 Foot Mobile System are as follows:

- Location: Varies
- One 7.0-meter L- and S-band receive-only antenna. Figure 4-12 is a photograph of the 23 Foot antenna.
- Manually scheduled by WSG.
- Tracking Services: Antenna autotracking angle.
- Baseband data interface: Mail.
- Sections 4.12.1, 4.12.2, and 4.12.3 describe L-band and S-band performance characteristics. Sections 4.12.4 and 4.12.5 describe the tracking services and baseband data interfaces, respectively.

4.12.1 L1-Band Telemetry

Table 4-33 identifies the L1-band telemetry characteristics of the 23 Foot Mobile System.

4.12.2 L2-Band Telemetry

Table 4-34 identifies the L2-band telemetry characteristics of the 23 Foot Mobile System.

4.12.3 S-Band Telemetry

Table 4-35 identifies the S-band telemetry characteristics of the 23 Foot Mobile System.

4.12.4 Tracking Services

4.12.4.1 Antenna Autotracking Angle Data

The 23 Foot Mobile System can record the angle of its ground antenna as it autotracks the user. This data is provided to the user as UTDF messages. (See Table 4-1 of Reference [o] in section 1.3, above.)

4.12.5 Baseband Data Interfaces

The 23 Foot Mobile System has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 9.5).



Figure 4-12. 23 Foot Mobile System Antenna

Table 4-33. 23 Foot Mobile System L1-Band Telemetry Characteristics

Characteristic	Value
Frequency	1435 – 1535 MHz
G/T	≥ 12.0 dB/K (at 45° elevation angle)
System Noise Temperature	398 K
Polarization	RHC or LHC
Antenna Beamwidth	1.97°
Antenna Gain	38 (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Bi ϕ -L, M, or S
Decoding	Viterbi (Rate- $\frac{1}{2}$)

Table 4-34. 23 Foot Mobile System L2-Band Telemetry Characteristics

Characteristic	Value
Frequency	1615 – 1720 MHz
G/T	≥ 13.7 dB/K (at 45° elevation angle)
System Noise Temperature	240 K
Polarization	RHC or LHC
Antenna Beamwidth	1.70°
Antenna Gain	37.5 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon (CCSDS)

Table 4-35. 23 Foot Mobile System S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 20.0 dB/K (at 45° elevation angle)
System Noise Temperature	153 K
Polarization	RHC or LHC
Antenna Beamwidth	1.38°
Antenna Gain	40.55 dBi (at 45° elevation angle)
Carrier Modulation	BPSK, PM, AM, or FM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Main Carrier Data Rate	≤ 4.0 Mbps
Main Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Ratio of Subcarrier Frequency to Subcarrier Data Rate	> 1.5
Subcarrier Modulation	BPSK
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi (Rate-1/2) and/or Reed-Solomon (CCSDS)

4.13 UHF Command Systems

This section describes UHF Command Systems located at WFF:

- Fixed UHF Command System (Section 4.13.1)
- Mobile UHF Command Systems (Section 4.13.2)

4.13.1 Fixed UHF Command System

The general characteristics of the Fixed UHF Command System at WFF are as follows:

- Location: 37° 51' 59" N
75° 30' 18" W
- Two Orbit quad-helix UHF transmit-only antennas.
- Scheduling: WFF Range and Mission Management Office
- Tracking Services: None
- Baseband command interfaces: Refer to 4.13.1.2

Section 4.13.1.1 describes the command characteristics of the Fixed UHF Command System. Section 4.13.1.2 describes the baseband command interfaces.



Figure 4-13. Fixed UHF Command System Antennas

4.13.1.1 UHF Command

Table 4-36 identifies the command characteristics of the Fixed UHF Command System.

4.13.1.2 Baseband Command Interfaces

The fixed command system located at WFF is remotely controlled from the WFF Range Safety Officer (RSO) console at the WFF Range Control Center (RCC) via a Time Division Multiple Access (TDMA) system. The TDMA consist of encoders near the RSO console and decoders near the UHF command transmitters area. These encoders and decoders are connected with twisted pair communication lines.

Table 4-36. Fixed UHF Command System Characteristics

Characteristic	Value
Frequency	410 – 450 MHz
EIRP	≥ 76 dBm
Polarization	LHC
Antenna Beamwidth	20°
Antenna Gain	18 dB
Output Power	1000 W
Carrier Modulation	FM IRIG Standard Tones (1-20)

4.13.2 Mobile UHF Command System

The general characteristics of the Mobile UHF Command System at WFF are as follows:

- Location: Varies
- Two Taco single-helix UHF transmit-only antennas.
- Scheduling: WFF Range and Mission Management Office
- Tracking Services: None
- Baseband command interfaces: Refer to 4.13.2.2

Section 4.13.2.1 describes the command characteristics of the Mobile UHF Command System. Section 4.13.2.2 describes the baseband command interfaces.



Figure 4-14. Mobile UHF Command System Antennas

4.13.2.1 UHF Command

Table 4-37 identifies the command characteristics of the Mobile UHF Command System.

4.13.2.2 Baseband Command Interfaces

These systems can be standalone or remotely controlled. In the standalone mode a Range Safety representative has to initiate the command locally. In the remotely controlled mode the command system receives commands from the Range Safety Officer (RSO) console at the WFF RCC or from another mobile command system. The Mobile UHF Command system receives the commands via a Time Division Multiple Access (TDMA) system. The TDMA consist of encoders near the RSO console or in the additional mobile command system and decoders in the mobile command transmitters area. These encoders and decoders are connected with modems and standard telephone communications lines.

Table 4-37. Mobile UHF Command System Characteristics

Characteristic	Value
Frequency	410 – 450 MHz
EIRP	≥ 73 dBm
Polarization	LHC
Antenna Beamwidth	27 degrees
Antenna Gain	15 dB
Output Power	1000 W
Carrier Modulation	FM IRIG Standard Tones (1-20)

4.14 Fixed And Mobile Radar Systems

This section describes the seven fixed radar systems and the four mobile radar systems located at WFF:

- Fixed ASRF Radar System (Section 4.14.1)
- Fixed Spandar Radar System (Section 4.14.2)
- Fixed AN/ASR-7 Radar System (Section 4.14.3)
- Fixed Marine Pathfinder Radar System (Section 4.14.4)
- Fixed Radar #3 Radar System (Section 4.14.5)
- Fixed Radar #5 Radar System (Section 4.14.6)
- Fixed Radar #18 Radar System (Section 4.14.7)
- Mobile Radar #2 Radar System (Section 4.14.8)
- Mobile Radar #8 Radar System (Section 4.14.9)
- Mobile Radar #10 Radar System (Section 4.14.10)
- Mobile Radar #11 Radar System (Section 4.14.11)

4.14.1 Fixed ASRF Radar System

The general characteristics of the ASRF Radar System at WFF are as follows:

- Location: 37° 51' 20" N
 75° 30' 44" W
- One 18.3-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Data processed into photos, graphs, and/or text.

Section 4.14.1.1 describes the tracking services.

4.14.1.1 Tracking Services

Table 4-38 identifies the ASRF Radar System characteristics.

4.14.2 Fixed Spandar Radar System

The general characteristics of the Spandar Radar System at WFF are as follows:

- Location: 37° 51' 17" N
 75° 30' 47" W
- One 18.3-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Data processed into photos, graphs, and/or text.

Section 4.14.2.1 describes the tracking services.

4.14.2.1 Tracking Services

Table 4-39 identifies the Spandar Radar System characteristics.

Table 4-38. ASRF Radar Characteristics

Characteristic	Value
Wave Length Band	(UHF-band)
Peak Power Output	8 MW
Pulse Rate Frequency	320 – 960 pps
Beamwidth	2.9°
Antenna Size	18.29 m
Antenna Gain	36 dB
Maximum Range	800 nm
1-m ² Skin Track	1480 km
Range Precision	204 yards
Angle Precision	2.0 Mils
Slew Rate	AZ: 8 deg/sec EL: 8 deg/sec

Table 4-39. Spandar Radar Characteristics

Characteristic	Value
Wave Length Band	(S-band)
Peak Power Output	5 MW
Pulse Rate Frequency	160, 310, 640, 960 pps
Beamwidth	0.39°
Antenna Size	18.29 m
Antenna Gain	52.8 dB
Maximum Range	480,000 km
1-m ² Skin Track	2200 km
Range Precision	5 m
Angle Precision	1.0 Mils
Slew Rate	AZ: 15 deg/sec EL: 15 deg/sec

4.14.3 Fixed AN/ASR-7 Radar System

The general characteristics of the AN/ASR-7 Radar System at WFF are as follows:

- Location: 37° 55' 58" N
75° 28' 19" W
- One 5.33×2.74-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Real-time data for WFF Range Safety only.

Section 4.14.3.1 describes the tracking services.

4.14.3.1 Tracking Services

Table 4-40 identifies the AN/ASR-7 Radar System characteristics.

4.14.4 Fixed Marine Pathfinder Radar System

The general characteristics of the Marine Pathfinder Radar System at WFF are as follows:

- Location: 37° 50' 27" N
75° 28' 51" W
- One 3.67×0.15-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Real-time data for WFF Range Safety only.

Section 4.14.4.1 describes the tracking services.

4.14.4.1 Tracking Services

Table 4-41 identifies the Marine Pathfinder Radar System characteristics.

Table 4-40. AN/ASR-7 Radar Characteristics

Characteristic	Value
Wave Length Band	(S-band)
Peak Power Output	425 kW
Pulse Rate Frequency	713, 1200, others pps
Beamwidth	1.5 degrees
Antenna Size	5.33×2.74 m
Antenna Gain	34 dB
Maximum Range	110 km
1-m ² Skin Track	75 (A/C) km
Range Precision	±1%
Angle Precision	2 ¼ degrees
Slew Rate	N/A

Table 4-41. Marine Pathfinder Radar Characteristics

Characteristic	Value
Wave Length Band	(X-band)
Peak Power Output	20 kW
Pulse Rate Frequency	900, 1800, 3600 pps
Beamwidth	0.9 degrees
Antenna Size	3.67×0.15 m
Antenna Gain	32 dB
Maximum Range	125 km
1-m ² Skin Track	8 nm
Range Precision	0.3% or 4 yards whichever is greater
Angle Precision	0.3 degrees
Slew Rate	AZ: 20 RPM EL: N/A

4.14.5 Fixed RADAR #3 Radar System

The general characteristics of the Fixed RADAR #3 – RIR-716 Radar System at WFF are as follows:

- Location: 37° 50' 29" N
 75° 29' 06" W
- One 3.66-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.14.5.1 and 4.14.5.2 describe the tracking services and baseband data interfaces, respectively.

4.14.5.1 Tracking Services

Table 4-42 identifies the RADAR #3 Radar System characteristics.

4.14.5.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

4.14.6 Fixed RADAR #5 Radar System

The general characteristics of the Fixed RADAR #5 – RIR-706 Radar System at WFF are as follows:

- Location: 37° 51' 37" N
 75° 30' 33" W
- One 8.84-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.14.6.1 and 4.14.6.2 describe the tracking services and baseband data interfaces, respectively.

4.14.6.1 Tracking Services

Table 4-43 identifies the RADAR #5 Radar System characteristics.

Table 4-42. RADAR #3 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	1 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	1.23°
Antenna Size	3.66 m
Antenna Gain	43 dB
Maximum Range	60,000 km
1-m ² Skin Track	350 km
Range Precision	10 m
Angle Precision	0.2 Mils
Slew Rate	AZ: 30 deg/sec EL: 30 deg/sec

Table 4-43. RADAR #5 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	3 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	0.39°
Antenna Size	8.84 m
Antenna Gain	51 dB
Maximum Range	60,000 km
1-m ² Skin Track	1300 km
Range Precision	10 m
Angle Precision	0.1 Mils
Slew Rate	AZ: 20 deg/sec EL: 20 deg/sec

4.14.6.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

4.14.7 Fixed RADAR #18 Radar System

The general characteristics of the Fixed RADAR #18 – RIR-778C Radar System at WFF are as follows:

- Location: 37° 56' 39" N
 75° 27' 51" W
- One 4.88-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.14.7.1 and 4.14.7.2 describe the tracking services and baseband data interfaces, respectively.

4.14.7.1 Tracking Services

Table 4-44 identifies the RADAR #18 Radar System characteristics.

4.14.7.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

4.14.8 Mobile RADAR #2 Radar System

The general characteristics of the Mobile RADAR #2 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 2.38-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.14.8.1 and 4.14.8.2 describe the tracking services and baseband data interfaces, respectively.

Table 4-44. RADAR #18 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	1 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	0.71°
Antenna Size	4.88 m
Antenna Gain	46 dB
Maximum Range	60,000 km
1-m ² Skin Track	435,000 km
Range Precision	10 m
Angle Precision	0.15 Mils
Slew Rate	AZ: 25 deg/sec EL: 20 deg/sec

4.14.8.1 Tracking Services

Table 4-45 identifies the RADAR #2 Radar System characteristics.

4.14.8.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

Table 4-45. RADAR #2 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	1 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	3°
Antenna Size	2.38 m
Antenna Gain	38 dB
Maximum Range	60,000 km
1-m ² Skin Track	220 km
Range Precision	10 m
Angle Precision	0.24 Mils
Slew Rate	AZ: 40 deg/sec EL: 40 deg/sec

4.14.9 Mobile RADAR #8 Radar System

The general characteristics of the Mobile RADAR #8 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 2.38-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Data Processing: Hardcopy plots of tracking versus time.

Sections 4.14.9.1 and 4.14.9.2 describe the tracking services and baseband data interfaces, respectively.

4.14.9.1 Tracking Services

Table 4-46 identifies the RADAR #8 Radar System characteristics.

4.14.9.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

Table 4-46. RADAR #8 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	1 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	3°
Antenna Size	2.38 m
Antenna Gain	38 dB
Maximum Range	60,000 km
1-m ² Skin Track	220 km
Range Precision	10 m
Angle Precision	0.24 Mils
Slew Rate	AZ: 40 deg/sec EL: 40 deg/sec

4.14.10 Mobile RADAR #10 Radar System

The general characteristics of the Mobile RADAR #10 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 3.66-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Baseband data interfaces: Hardcopy plots of tracking versus time.

Sections 4.14.10.1 and 4.14.10.2 describe the tracking services and baseband data interfaces, respectively.

4.14.10.1 Tracking Services

Table 4-47 identifies the RADAR #10 Radar System characteristics.

4.14.10.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

4.14.11 Mobile RADAR #11 Radar System

The general characteristics of the Mobile RADAR #11 – RIR-778C Radar System at WFF are as follows:

- Location: Varies
- One 3.66-meter RADAR antenna
- Scheduling directly coordinated with WFF Range Personnel (see Section 8.5).
- Tracking services: RADAR
- Baseband data interfaces: Hardcopy plots of tracking versus time.

Sections 4.14.11.1 and 4.14.11.2 describe the tracking services and baseband data interfaces, respectively.

4.14.11.1 Tracking Services

Table 4-48 identifies the RADAR #11 Radar System characteristics.

4.14.11.2 Baseband Data Interfaces

Tracking data is recorded on 9-track tape and on a PC hard drive for back-up. WFF personnel will process the data according to user requests. WFF can provide real-time plots of the data.

Table 4-47. RADAR #10 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	1 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	1.1°
Antenna Size	3.66 m
Antenna Gain	43 dB
Maximum Range	60,000 km
1-m ² Skin Track	425 km
Range Precision	10 m
Angle Precision	0.2 Mils
Slew Rate	AZ: 30 deg/sec EL: 30 deg/sec

Table 4-48. RADAR #11 Radar Characteristics

Characteristic	Value
Wave Length Band	(C-band)
Peak Power Output	1 MW
Pulse Rate Frequency	160, 320, 640 pps
Beamwidth	1.1°
Antenna Size	3.66 m
Antenna Gain	43 dB
Maximum Range	60,000 km
1-m ² Skin Track	425 km
Range Precision	10 m
Angle Precision	0.2 Mils
Slew Rate	AZ: 30 deg/sec EL: 30 deg/sec

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 WFF using WOTIS.
- Tracking services: None.
- Baseband data interfaces: IP, 4800-bit blocks encapsulated in IP packets, and mail (also uses TDRS relay, which supports serial clock and data and other interfaces).

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

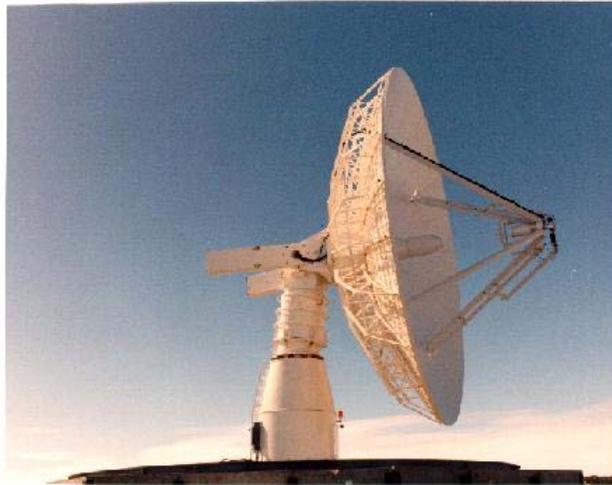


Figure 5-1. MGS Antenna

5.1 S-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 Sections 9.2 and 9.4, respectively). 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 (see Section 9.5).

In addition to the baseband data options described above, MGS can relay high-rate X-band telemetry data through a Tracking and Data Relay Satellite (TDRS). MGS data is rate-buffered through the TDRS at 105 Mbps or less. At the White Sands ground station, where the TDRS relay ends, the raw data is sent to the user in one of the following formats: IP, serial clock and data, or 4800-bit blocks encapsulated in IP packets.

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: $\pm 90^\circ$
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 Bi ϕ -L, M, or S

Table 5-2. MGS S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21.1 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 Bi ϕ -L: 100 bps – 4 Mbps
Carrier Data Format	NRZ-L or Bi ϕ -L
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; Bi ϕ -L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

Table 5-3. MGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 32.5 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 – 110 Mbps UQPSK: 10 – 23 Mbps 75 – 90 Mbps
Data Format	NRZ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

Section 6. Alaska Ground Stations

This section describes the five GN stations in Alaska:

- ASF: 10-m antenna (Section 6.1)
- ASF: 11.3-m antenna (Section 6.2)
- LEO-T – Alaska (Section 6.3)
- TOTS – Alaska (Section 6.4)
- AGS (Section 6.5)

6.1 ASF: 10-m Antenna

The general characteristics of the 10-m ASF ground station in Alaska are as follows:

- Location: 64° 51' 36" N
147° 50' 50" W
- One 10-meter antenna for simultaneously receiving S- and X-band. Figure 6-1 is a photograph of the 10-meter antenna.
- Scheduling directly coordinated by ASF personnel.
- Tracking services: None.
- Baseband data interface: Mail.

Sections 6.1.1 and 6.1.2 describe the S- and X-band receive-only performance characteristics, and Section 6.1.3 describes the baseband data interface.

6.1.1 S-Band Telemetry

Table 6-1 identifies the S-band telemetry characteristics of the 10-m ASF station.

6.1.2 X-Band Telemetry

Table 6-2 identifies the X-band telemetry characteristics of the 10-m ASF station.

6.1.3 Baseband Data Interfaces

The 10-m ASF station has no IP or point-to-point data line interfaces with NISN. The station tape records telemetry data and mails it to the user (see Section 9.5).



Figure 6-1. ASF 10-m Antenna

Table 6-1. 10-m ASF S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21.1 dB/K
System Noise Temperature	245 K
Polarization	RHC or LHC
Antenna Beamwidth	0.91°
Antenna Gain	45 dBi
Carrier Modulation	PM, BPSK, FM, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ-L: 100 bps – 8 Mbps Bi ϕ -L: 100 bps – 4 Mbps
Carrier Data Format	NRZ-L or Bi ϕ -L
Subcarrier Frequency	≤ 4 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L or Bi ϕ -L
Decoding	Viterbi (Rate- $\frac{1}{2}$) and/or Reed-Solomon (CCSDS)

Table 6-2. 10-m ASF X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 8400 MHz
G/T	≥ 32.5 dB/K
System Noise Temperature	225 K
Polarization	RHC or LHC
Antenna Beamwidth	0.26°
Antenna Gain	56 dBi
Modulation	QPSK or UQPSK
Data Rate	QPSK: 6 – 110 Mbps UQPSK: 10 – 23 Mbps 75 – 90 Mbps
Data Format	NRZ-L
Decoding	Viterbi (Rate-½) and/or Reed-Solomon (CCSDS)

6.2 ASF: 11.3-m Antenna

The general characteristics of the 11.3-m ASF ground station in Alaska are as follows:

- Location: 64° 51' 31" N
147° 51' 27" W
- One 11.3-meter receive-only antenna for S- and X-band. Figure 6-2 is a photograph of the ASF 11.3-m antenna.
- Scheduling directly coordinated by ASF personnel.
- Tracking services: None.
- Baseband data interface: Mail.

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

6.2.1 S-Band Telemetry

Table 6-3 identifies the S-band telemetry characteristics of the 11.3-m ASF station.



Figure 6-2. ASF 11.3-m Antenna

Table 6-3. 11.3-m ASF 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, BPSK, FM, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ-L: 100 bps – 8 Mbps Bi ϕ -L: 100 bps – 4 Mbps
Carrier Data Format	NRZ-L or Bi ϕ -L
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L or Bi ϕ -L
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

6.2.2 X-Band Telemetry

Table 6-4 identifies the X-band telemetry characteristics of the 11.3-m ASF station.

6.2.3 Baseband Data Interfaces

The 11.3-m ASF station has no IP or point-to-point data line interfaces with NISN. The station tape records the telemetry data and mails it to the user (see Section 9.5)

Table 6-4. 11.3-m ASF X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 9000 MHz
G/T	≥ 35 dB/K
System Noise Temperature	150 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	QPSK or UQPSK
Data Rate	QPSK: 6 – 110 Mbps UQPSK: 10 – 23 Mbps 75 – 90 Mbps
Data Format	NRZ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS)

6.3 LEO-T – Alaska

The general characteristics of the LEO-T ground station in Alaska are as follows:

- Location: 65° 07' N
147° 27' W
- One 5-meter antenna for simultaneously transmitting and receiving at S-band. Figure 6-3 is a photograph of the LEO-T antenna.
- Automatically scheduled by WFF using WOTIS (see Section 8.2).
- Tracking services: None.
- Baseband data interface: IP.

Sections 6.3.1 and 6.3.2 describe S-band performance characteristics, and Section 6.3.3 describes the baseband data interface.

6.3.1 S-Band Command

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

6.3.2 S-Band Telemetry

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

6.3.3 Baseband Data Interfaces

The LEO-T – Alaska station can send and receive baseband data in the IP format only (see Section 9.2). 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 6-3. 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)

6.4 TOTS – Alaska

The general characteristics of the TOTS ground station in Alaska are as follows:

- Location: 65° 07' 02" N
147° 27' 33" W
- One 8-meter antenna for simultaneously transmitting and receiving at S-band. Figure 6-4 is a photograph of the TOTS antenna.
- Automatically scheduled by WFF using WOTIS (see Section 8.2).
- Tracking services: 1- & 2-way Doppler and antenna autotracking angle.
- Baseband data interfaces: IP, serial clock and data, and 4800-bit blocks encapsulated in IP packets.

Sections 6.4.1 and 6.4.2 describe S-band performance characteristics. Sections 6.4.3 and 6.4.4 describe the tracking services and baseband data interfaces, respectively.



Figure 6-4. TOTS - Alaska Antenna

6.4.1 S-Band Command

Table 6-7 identifies the S-band command characteristics of the TOTS – Alaska station.

6.4.2 S-Band Telemetry

Table 6-8 identifies the S-band telemetry characteristics of the TOTS – Alaska station.

Table 6-7. TOTS – Alaska S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 62 dBW _i
Polarization	RHC or LHC
Antenna Beamwidth	1.27°
Antenna Gain	42.1 dBi
Output Power	200 W
Carrier Modulation	PM, FM, or PSK
Modulation Index	PM: 0 – 1.5 radians (peak) FM: 50 kHz – 50 MHz 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

6.4.3 Tracking Services

6.4.3.1 Doppler Tracking

The TOTS – Alaska station 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 TOTS – Alaska S-band up-link signal with a frequency ratio of 240/221. Doppler tracking characteristics are shown in *Table 6-9*.

6.4.3.2 Antenna Autotracking Angle Data

TOTS – Alaska 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 [o] in Section 1.3, above.)

Table 6-8. TOTS – Alaska S-Band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 21 dB/K
System Noise Temperature	150 K
Polarization	RHC or LHC
Antenna Beamwidth	1.14°
Antenna Gain	42.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Carrier Data Rate	≤ 4 Mbps
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)

6.4.4 Baseband Data Interfaces

The TOTS – Alaska 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 Sections 9.2, 9.3, and 9.4, respectively). 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.

Table 6-9. TOTS – Alaska Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.25 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{\text{transmit}} \times [240/221] - f_{\text{received}}) + f_{\text{bias}}$

6.5 AGS

This section describes the EOS Polar Ground Station located near Fairbanks, Alaska, known as the Alaska Ground Station (AGS).

The general characteristics of the station are as follows:

- Location: 65° 07' 00" N
147° 27' 42" W
- One 11.3-meter antenna for simultaneously transmitting at S-band while receiving at S- and X-band. Figure 6-5 is a photograph of the AGS antenna.
- Automatically scheduled by WFF using WOTIS (see Section 8.2).
- 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 6.5.1 through 6.5.3 describe S- and X-band performance characteristics. Sections 6.5.4 and 6.5.5 describe the tracking services and baseband data interfaces, respectively.

6.5.1 S-Band Command

Table 6-10 identifies the S-band command characteristics of the AGS.

6.5.2 S-Band Telemetry

Table 6-11 identifies the S-band telemetry characteristics of the AGS.

6.5.3 X-Band Telemetry

Table 6-12 identifies the X-band telemetry characteristics of the AGS.



Figure 6-5. AGS Antenna

Table 6-10. AGS S-Band Command Characteristics

Characteristic	Value
Frequency	2025 – 2120 MHz
EIRP	≥ 66 dBW _i
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 6-11. 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)

6.5.4 Tracking Services

6.5.4.1 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 6-13*.

6.5.4.2 Antenna Autotracking 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 [o] in Section 1.3, above.)

Table 6-12. AGS X-Band Telemetry Characteristics

Characteristic	Value
Frequency	8000 – 9000 MHz
G/T	≥ 36 dB/K (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

6.5.5 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 Sections 9.2, 9.3, and 9.4, respectively). 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 (see Section 9.5).

Table 6-13. AGS Doppler Tracking Characteristics

Characteristic	Value
Counter Resolution	0.001 cycles
Doppler Frequency Shift	≤ 0.23 MHz
Doppler Bias Frequency	0.24 MHz
Drift ($\Delta f/f$)	4×10^{-11} at 0.1 seconds
Accuracy	0.01 Hz
Output Equation	$1000 (f_{\text{transmit}} \times [240/221] - f_{\text{received}}) + f_{\text{bias}}$

Section 7. Florida Ground Stations

This section describes the two GN stations in Florida:

- MILA (Section 7.1)
- PDL (Section 7.2)

7.1 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 Spaceflight Tracking and Data Network (STDN).

The general characteristics of the station are as follows:

- Location (each antenna):
28° 30' 29.4" N
80° 41' 33.9" W

28° 30' 29.4" N
80° 41' 36.2" W
- Two 9-meter antennas for simultaneously transmitting and receiving at S-band. Figure 7-1 is a photograph of the MILA Ground Station.

(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: 407-867-3515.)
- Scheduled by the NCC at GSFC (see Section 8.4).
- Tracking services: 1- & 2-way Doppler, ranging, and antenna autotracking angle.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 7.1.1 and 7.1.2 describe the S-band performance characteristics. Sections 7.1.3 and 7.1.4 describe the tracking services and baseband data interfaces, respectively.

7.1.1 S-Band Command

Table 7-1 identifies the S-band command characteristics of MILA.

7.1.2 S-Band Telemetry

Table 7-2 identifies the S-band telemetry characteristics of MILA.



Figure 7-1. MILA Ground Station

Table 7-1. 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; Bi ϕ -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; Bi ϕ -L, M, or S

7.1.3 Tracking Services

7.1.3.1 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 7-3*.

7.1.3.2 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 7-4*.

Table 7-2. 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) and/or STS-TDRS mode Viterbi decoders (Rate- ¹ / ₃)

Table 7-3. MILA Doppler Tracking Characteristics

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

Table 7-4. 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	$\leq 644,000$ km (one-way)

7.1.3.3 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 [o] in Section 1.3, above.)

7.1.4 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 9.2 and 9.4, respectively). MILA currently has a T-1 (1.544 Mbps) communications link with the NCC to support command, low-rate telemetry, and ground station control and monitor.

7.2 PDL

This section describes the PDL ground station in Florida. Like MILA, PDL is a part of the STDN. 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: 29° 4' 00" N
80° 54' 47" W
- One 4.3-meter antenna for simultaneously transmitting and receiving at S-band. Figure 7-2 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: 407-867-3515.)

- Scheduled by the NCC at GSFC (see Section 8.4).
- Tracking services: None.
- Baseband data interfaces: IP and 4800-bit blocks encapsulated in IP packets.

Sections 7.2.1 and 7.2.2 describe the S-band performance characteristics, and Section 7.2.3 describes the baseband data interfaces.

7.2.1 S-Band Command

Table 7-5 identifies the S-band command characteristics of PDL.

7.2.2 S-Band Telemetry

Table 7-6 identifies the S-band telemetry characteristics of the PDL.

7.2.3 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 9.2 and 9.4, respectively). The station currently has a T-1 (1.544 Mbps) communications link with the NCC to support command, low-rate telemetry, and ground station control and monitor.



Figure 7-2. PDL Ground Station

Table 7-5. PDL 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 Bi ϕ -L, M, or S

Table 7-6. PDL 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) and/or STS-TDRS Mode Viterbi decoders (Rate- ¹ / ₃)

Section 8. Scheduling

8.1 Introduction

This section describes the following options for scheduling support:

- Automated Scheduling
- Manual Scheduling
- NCC Scheduling
- Direct Scheduling

Table 8-1 identifies the scheduling options offered by each GN station; an “X” means that capability is available.

8.2 Automated Scheduling

WOTIS provides automated scheduling and information dissemination for many of the GN stations. WOTIS is operated by WSG, located at WFF.

WOTIS ensures that GN support is properly accomplished and that its customers get as much quality telemetry and command support as possible. Using WOTIS, WSG can automatically track a customer’s status from the time a support request is submitted to the time the data is satisfactorily in the hands of the customer.

WOTIS is composed of the following three elements, depicted in Figure 8-1:

a. **Wallops Information System Access (WISAC)**

All incoming and outgoing scheduling files pass through WISAC via FTP or e-mail. Some file reformatting is done at WISAC, if necessary. WISAC uses UNIX scripting; therefore, all functions are handled automatically. Each user is assigned a mailbox on WISAC.

b. **Wallops Orbital Tracking Resource Scheduler (WOTRS)**

WOTRS is the core scheduling system. WOTRS uses de-conflict algorithms to simultaneously schedule multiple users. Input to WOTRS is in the form of either a generic request file (see Section 8.2.1) or a specific request file (see Section 8.2.2). The output is the “official” schedules that are sent to the GN stations, users, and WISDB via WISAC.

c. **Wallops Information System Database (WISDB)**

WISDB is the central database that tracks every support throughout its life. WOTRS uses the “official” schedules to determine what is scheduled at any given time at all GN stations that use WOTIS. Spacecraft pass results from the GN stations flow into WISDB via WISAC. WISDB then provides pass reports to the users.

Table 8-1. GN Scheduling Options

Station	WOTIS Scheduling		WSG Manual Scheduling	NCC Scheduling	Direct Scheduling
	Generic	Specific			
SGS	X	X			
WGS	X	X			
LEO-T – WFF	X	X			
TOTS – WFF	X	X			
MGTAS	X	X			
SATAN			X		
SCAMP			X		
METEOSAT			X		
Mobile Systems			X		
UHF Command Systems					X
Radar Systems					X
MGS	X	X			
ASF: 10-m					X
ASF: 11.3-m					X
LEO-T – Alaska	X	X			
TOTS – Alaska			X		
AGS	X	X			
MILA				X	
PDL				X	

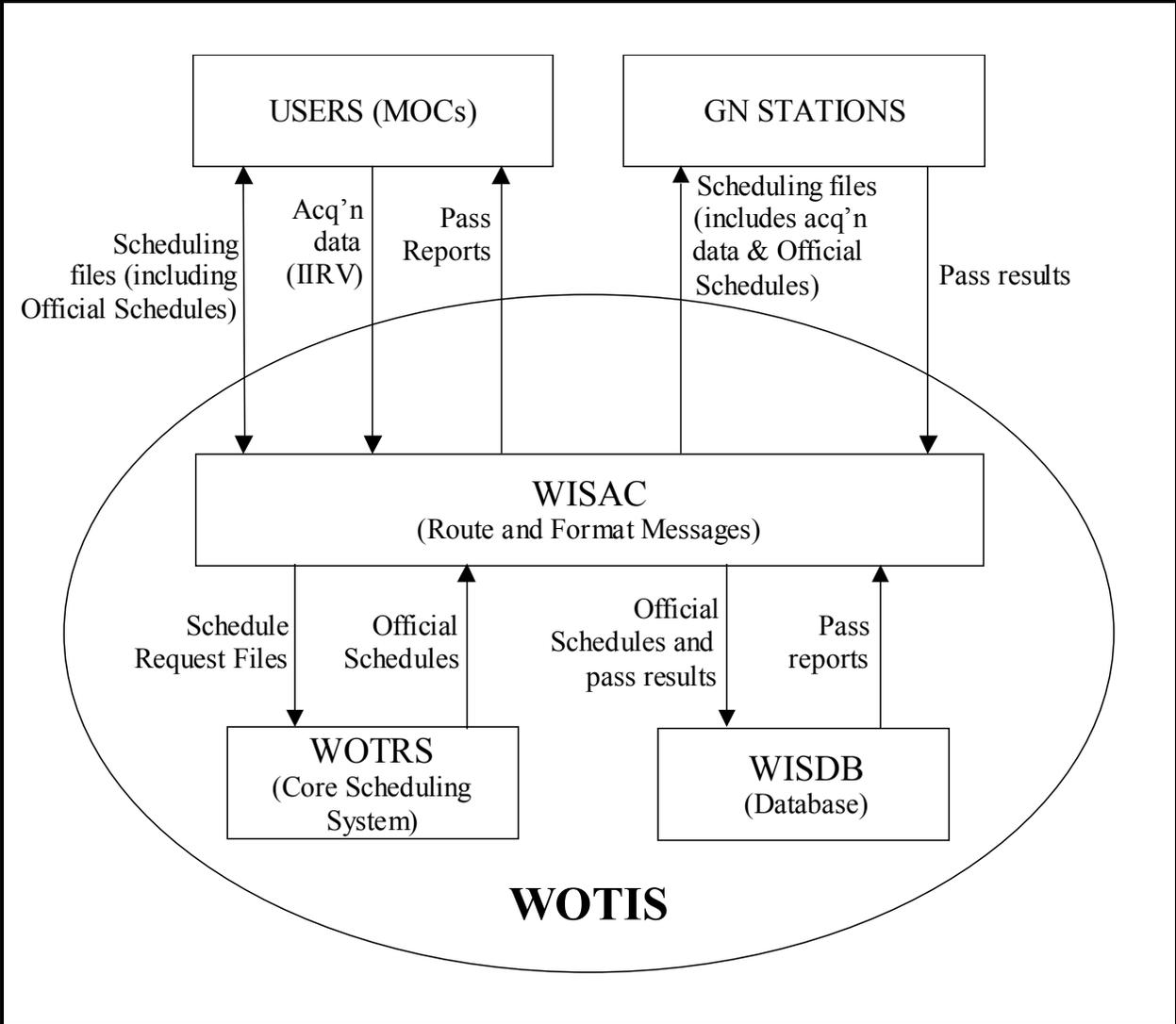


Figure 8-1. WOTIS Functional Diagram

8.2.1 Generic Scheduling

With generic scheduling, the MOC sends its *generic* scheduling requirements to WOTIS. WOTIS uses an algorithm to automatically select the optimum support periods and GN stations. Generic scheduling is also known as rule-based scheduling.

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.

Table 8-2 presents a typical generic scheduling timeline.

8.2.2 Specific Scheduling

If a mission chooses to use specific scheduling, the MOC requests the *specific* GN station and the *specific* start and end times of the pass. The MOC submits the schedule every week. Table 8-3 provides an example of specific scheduling. (WSG prefers generic scheduling because it optimizes the use of shared GN resources.)

8.2.3 WOTIS Scheduling During WFF Emergency Evacuations

If an emergency hurricane evacuation or other unplanned evacuation event occurs at WFF and the WOTIS network is shut down, all scheduling files, such as the Master File in Table 8-2, will not be sent automatically. Each MOC (user) will need to directly send 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 (user) until the WOTIS network is re-stored. However, post-pass results files are not mission critical.

If a minor evacuation event causes WSG personnel to leave WOTIS unattended, but with the WOTIS network still running, automated scheduling files, such as the Master File, will still be processed and sent to the ground stations. However, if the MOC (User) requires any additions, deletions, or other final changes to the Master file when WSG personnel are not available, the MOC will need to directly contact the ground station by telephone.

Table 8-2. Generic Scheduling Timeline

Time	Message	Source → Destination	Notes
2 – 3 weeks before target	Strawman Schedule file	WOTIS → MOC (via FTP)	Preliminary schedule Contains initial supports at GN station in accordance with agreed-upon scheduling rules Generated weekly
2 – 3 weeks before target	Update to Strawman Schedule file (optional)	MOC → WOTIS (via FTP)	Not needed if Strawman Schedule is correct Deletes supports not needed by MOC MOC may adjust times and activity codes MOC may request a new support
1 week before target	Official Schedule file	WOTIS → MOC	Sent if MOC requires Final operations schedule Contains supports that will be sent to GN station Generated on Tuesday
Daily, as needed	Master file (GN station Official Schedule)	WOTIS → GN station (via FTP)	Weekly and/or daily schedule Covers 1 week Generated on Thursday/Friday Contains ephemeris

8.3 Manual Scheduling

With manual scheduling, WSG personnel perform the scheduling without automated support from WOTIS. SATAN, SCAMP, METEOSAT, the Mobile Systems, and TOTS in Alaska use manual scheduling exclusively. The process is as follows:

- a. MOC and WSG agree on the schedule via e-mail and telephone.
- b. WSG e-mails the schedule to the GN station operators.
- c. GN station operators manually configure the equipment for the scheduled pass.

Table 8-3. Specific Scheduling Timeline

Time	Message	Source → Destination	Notes
3 weeks before target week	Strawman Request file	MOC → WOTIS	Begins the scheduling process MOC's best-guess estimate of mission support needs for the target week Covers 1 week, with 1 day of overlap on each end
2½ weeks before first day of target week	Forecast Schedule file	WOTIS → MOC	Preliminary schedule Sent on Thursday Covers 1 week, with 1 day of overlap on each end
1 to 2 weeks before target week	Confirmed Schedule (optional)	MOC → WOTIS	Eliminates unnecessary support from the Forecast Schedule Covers 1 week, with 1 day of overlap on each end If the Forecast Schedule provides insufficient mission support, MOC and WOTIS operators negotiate via voice and/or e-mail
> 4 hours before beginning of target day	Daily Official Schedule file	WOTIS → MOC	Covers 48 hours: the target day and the following day (for overlap) Sent every day no later than 2000Z First support period starts after 0000Z Updates the database at WOTIS Automatically and immediately updates information at the GN station sites
> 4 hours before beginning of target day	Master Official Schedule file	WOTIS → GN station WOTIS → MOC	Support period is automatically added to the GN station schedule (without operator intervention) Covers at least 24 hours, often several days to a week
< 4 hours before beginning of target day	Schedule changes (optional)	MOC → GN station	Additions and modifications to the master official schedule Voice communications between the MOC and the GN station operators Confirmed via e-mail

8.4 NCC Scheduling

The NCC is responsible for scheduling all STDN resources, including the GN stations at MILA and PDL. Scheduling activities consist of Parameter Control, Forecast Scheduling, and Active Scheduling. Each of these activities is discussed below.

8.4.1 Parameter Control

The NCC's Parameter Control (PC) is responsible for the Network Operation Forecast and the scheduling of all pre-mission test and launch support. PC is also responsible for distributing the STDN Telemetry/Command and Tracking Priority List and other schedule-related documentation.

8.4.1.1 Network Operation Forecast Message

PC predicts network activities. Each week, PC generates the Network Operation Forecast message that contains predicted network activities for six months. If a customer wants to project tentative activities on the Network Operation Forecast, they should contact PC in the NCC.

8.4.1.2 Scheduling Pre-Mission Test and Launch Support

PC 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 PC with the relevant technical details, including schedule requirements, supporting stations, and support requirements. PC coordinates the pre-mission test GN activities for a flight project. PC identifies and resolves resource conflicts pre-mission tests may have with activities already on STDN schedules.

b. Scheduling Launch Support

When scheduling launch support, the NOM, in conjunction with the user, provides PC with the following:

- (1) Launch schedule requirements (at least 5 days before launch).
- (2) GN stations required by the mission during launch.
- (3) Launch support requirements.

PC schedules launch support three times: 5 days before launch, 2 days before launch, and 1 day before launch.

8.4.1.3 Telemetry/Command and Tracking Priority List

The primary method for conflict resolution is negotiation between users and resources. If there is an impasse or insufficient time for negotiations, PC uses the Telemetry/Command and Tracking Priority List to resolve the conflict.

8.4.2 Forecast Scheduling

Every Monday, the NCC's Ground Network Scheduling Operator (GNSO) compiles all of the user schedule requests for the forecast week beginning 14 days from the current day (Monday). The GNSO uses this compilation to produce the Forecast Schedule. After the GNSO transmits it to the users, the Forecast Schedule becomes active and the Active Scheduling period begins. There are two types of user schedule requests: Generic Schedule Requests, and Specific Telemetry/Command Schedule Requests.

a. Generic Schedule Requests

A Generic Schedule Request contains *generic requirements* that define the GN support the user needs. With these requirements, the GNSO determines the specific GN station(s) and frequency of GN support. Requirement parameters include the vehicle name, support mode, percent of coverage required, number of passes per day or week, minimum and maximum gap between passes, minimum station antenna elevation angle, and apogee and perigee support.

b. Specific Telemetry/Command Schedule Requests

A Specific Telemetry/Command Schedule Request states the *specific* time periods that *specific* GN stations are required.

Reference [j] in Section 1.3 describes the format of these Schedule Requests.

8.4.3 Active Scheduling

The Active Scheduling period begins when the GNSO transmits the Forecast Schedule (described in Section 9.4.2), and ends when the forecast period begins. The Active Scheduling period lasts between 5 and 12 days.

a. Schedule Support Request Update Form

During or after the Active Scheduling period, the user can request a change to the active Forecast Schedule by sending a Schedule Support Request Update Form to the GNSO. There are three types of Update Forms: the Change Form, Deletion Form, and Addition Form. The GNSO decides whether the NCC can accept the changes in the Update Form, using the NCC Network Operations Schedule to help make the decision.

The user submits the Update Form by fax or by hand. The GNSO retains copies of the original Update Forms. If the GNSO receives the Update Form within four hours of the start of the pass or during the pass, the GNSO classifies that Update Form as a real-time change.

b. Network Operations Schedules: Weekly and Daily

The GNSO transmits the *Weekly* Network Operations Schedule to the users and all STDN facilities before 12-noon local time every Thursday. He/she transmits the *Daily* Network Operation Schedule to the users and all STDN facilities between 12 noon and 8 PM local time, approximately 24 hours before the start of the schedule day.

8.5 Direct Scheduling

Direct Scheduling is the term used when the user coordinates scheduling directly with the GN station operators; the WSG, WOTIS, and the NCC are not involved. The two ASF stations, WFF UHF Command Systems, and WFF Radar Systems use this kind of scheduling exclusively.

For the WFF Radar Systems, the first step for scheduling range assets is to contact the Suborbital Projects and Operations Directorate, Code 800 at 757-824-1332. Code 800 will assign a Range Support Manager (RSM) to the user/customer. The RSM will help the user with all scheduling activities. Reference [w] describes range scheduling and other WFF Radar Systems details.

Section 9. Baseband Data Interfaces

9.1 Introduction

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

- a. NISN IP Network
- b. Serial Clock and Data
- c. 4800-Bit Block Encapsulated in IP Packets
- d. Mail Delivery of Recorded Data

Table 9-1 summarizes the baseband data interfaces available at each station; an “X” means that capability is offered.

9.2 NISN IP Network

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

a. Open and Closed Networks

The NISN IP Network uses both open and closed NASA IP networks. “Open” and “closed” are relative – both are secure. 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. TCP/IP and UDP/IP

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

Figure 9-1 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 9-1, the Internet Protocol Data Unit (IPDU) packet encapsulates the Channel Access Data Unit (CADU) packet. For UDP/IP, the layering is identical to Figure 9-1, except the TCP layer is replaced by a UDP layer.

c. Packets and Layers

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 Reference [p] in Section 1.3 for more information on *CADUs* and *CLTUs*.) For commands, the *CADU* layer in Figure 9-1 is replaced by a *CLTU* layer.

Table 9-1. Baseband Data Interface Options

Station	NISN IP Network	Serial Clock and Data	4800-Bit Blocks Encapsulated in IP Packets	Mail Delivery
SGS	X	X	X	X
WGS	X	X	X	X
LEO-T – WFF	X	X	X	
TOTS – WFF	X	X	X	
MGTAS	X		X	
SATAN*	X		X	
SCAMP*				
METEOSAT**				
Mobile Systems				X
Radar Systems				X
MGS	X	X (via MTRS and White Sands)	X	X
ASF: 10-m				X
ASF: 11.3-m				X
LEO-T – Alaska	X			
TOTS – Alaska	X	X	X	
AGS	X	X	X	X
MILA	X		X	
PDL	X		X	

* Users conduct SATAN and SCAMP transmissions by requesting commands via telephone or e-mail with the GN station directly.

** METEOSAT records received data onto computer disks, then sends it via telephone. METEOSAT does not use NASCOM or NISN data circuits.

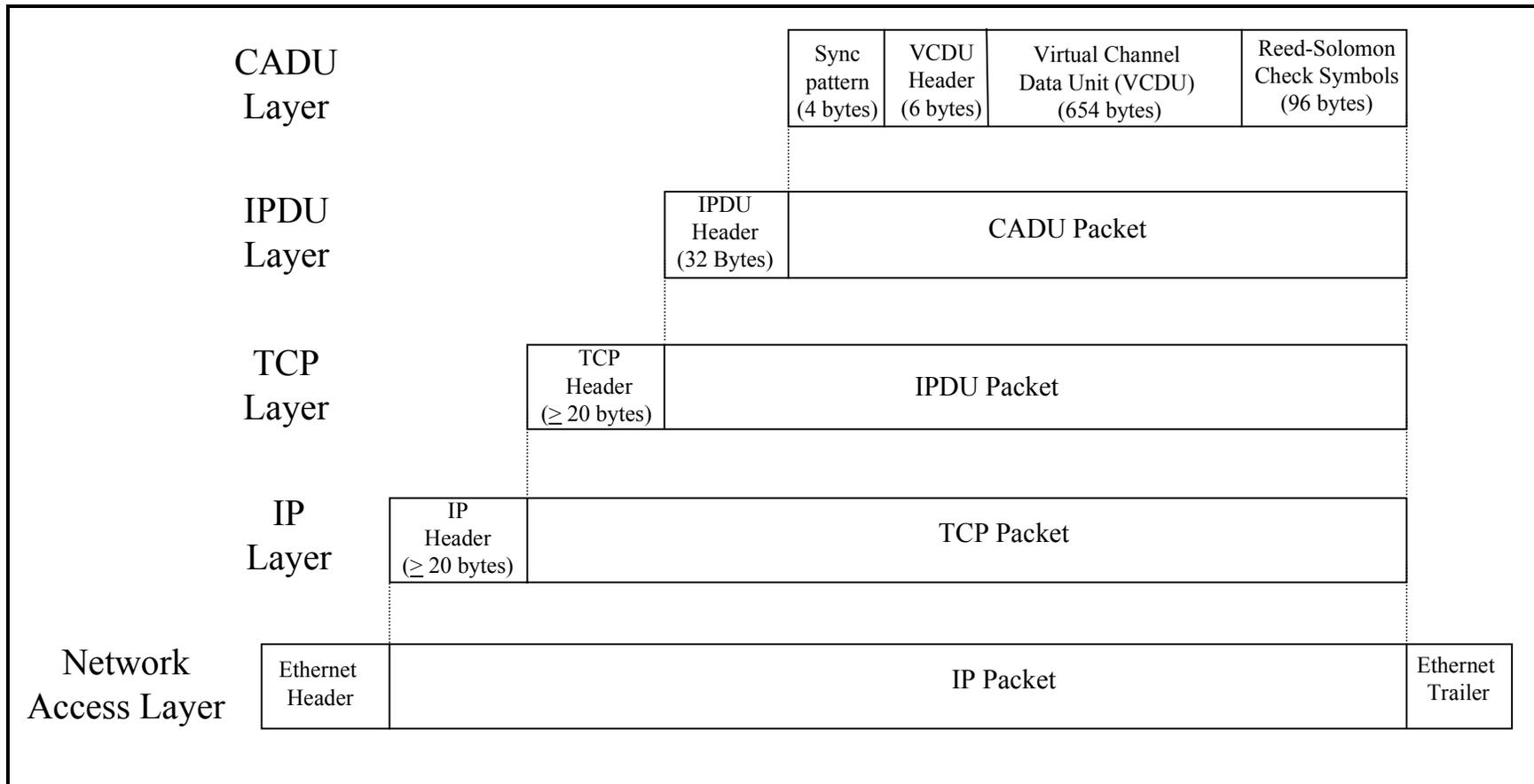


Figure 9-1. NISN IP Network Layers*

- * 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 *IPDU* packet is a NASA protocol (see Reference [q] for a detailed description). 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. Reference [r] fully describes the TCP, IP, and Network Access Layers of an IP network.

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.

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 (Reference [g] describes the PTP in detail). 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 PTP's.

9.2.1 **Command Data (Real-Time)**

The MOC sends real-time command data to the GN station via the NISN IP 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.

9.2.2 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.

9.3 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.

9.4 4800-Bit Block Encapsulated in IP Packets

NASA is currently converting its remaining 4800-bit block point-to-point serial circuits to an IP-based network. The new NISN IP Network, however, will remain backward compatible with MOCs and other facilities that support only NASCOM 4800-bit-block serial clock and data transport. GN stations will provide legacy support to users who require the 4800-bit-block service by providing conversion devices that encapsulate 4800-bit blocks in UDP/IP datagrams. At GSFC, conversion devices will de-encapsulate the 4800-bit blocks and send them to the user over serial data circuits. Sections 9.4.1 through 9.4.5 describe this 4800-bit block format, depicted in Figure 9-2.

9.4.1 Network Header

The first 48 bits in the 4800-bit block contain the NASCOM synchronization code, routing, and block-accounting information, as described below:

a. Bits 1-24 (NASCOM Synchronization Code)

A fixed, 24-bit code (627627_{16}).

b. Bits 25-32 (Source)

An 8-bit, NASCOM-assigned code that identifies the sender by geographic location.

c. Bits 33-40 (Destination)

An 8-bit, NASCOM-assigned code that identifies the geographic destination (one or multiple destinations).

d. Bits 41-43 (Block Sequence Number)

A 3-bit code that identifies the block's location in a sequence of blocks. This enables the destination system to place each block in its proper order.

e. Bits 44-48 (Format Code)

A 5-bit code that identifies the type of data in the Data Field: telemetry, real-time commands, tracking data, or non-real-time commands.

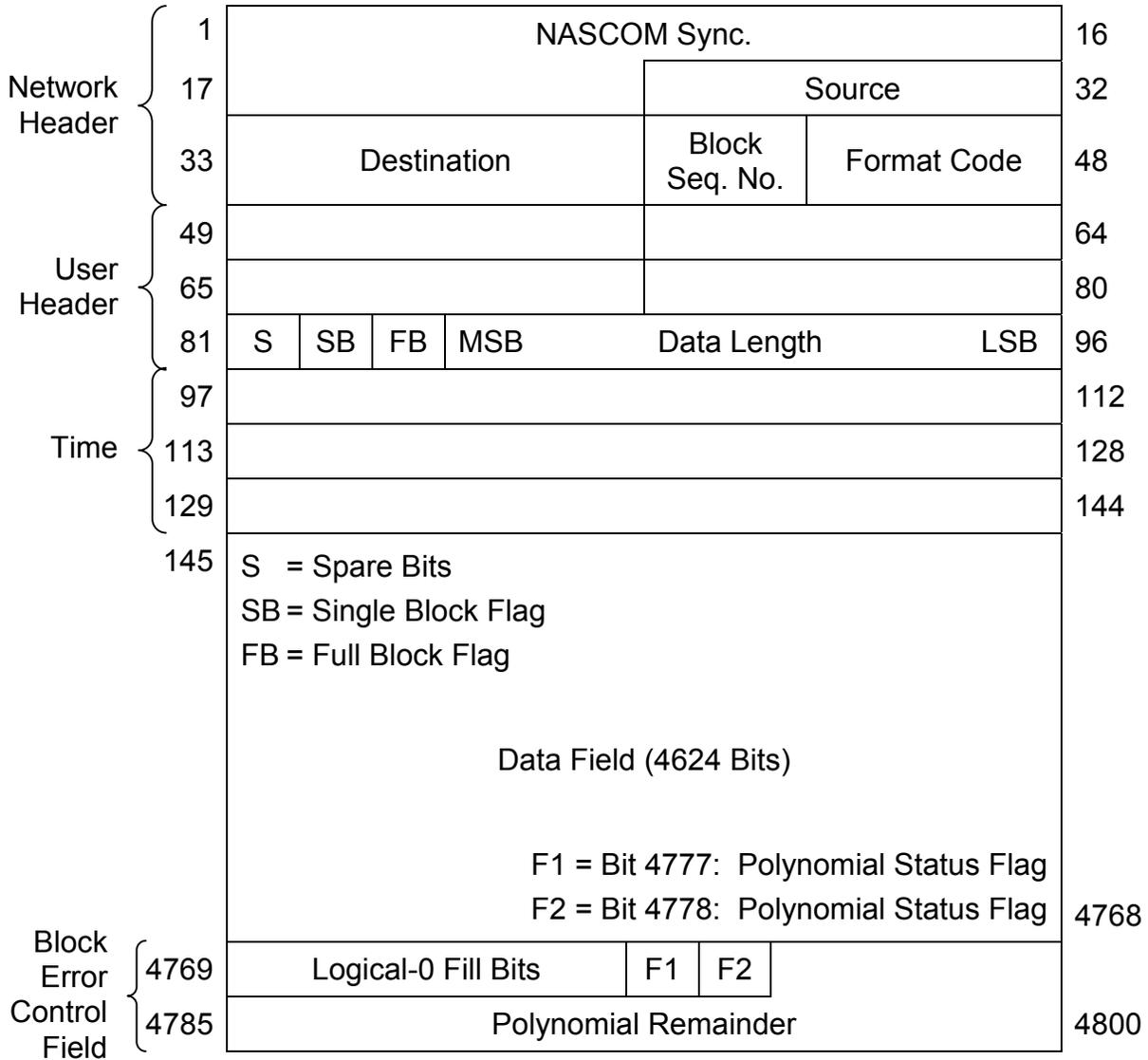


Figure 9-2. NASCOM 4800-Bit Block Format

9.4.2 User Header

A 48-bit field that contains sender-supplied information that the destination system requires to route and process the data.

9.4.3 Time

A 48-bit code that provides the Universal Time Code (UTC) in NASA Parallel Binary-4 (PB-4) format, with the parity bits set to logical 0.

9.4.4 Data Field

A 4624-bit field that contains the user data. If the user data is less than 4624 bits, fill bits are inserted after the real data.

9.4.5 Block Error Control Field

A 32-bit field that enables error detection, as described below:

a. Bits 4769-4776 (Spares)

The sender inserts logical 0 bits in this 8-bit field.

b. Bit 4777 (Polynomial Status Flag)

A 1-bit field that indicates whether the block passed (logical 0) or failed (logical 1) the sender's polynomial check.

c. Bit 4778 (Polynomial Status Flag)

A 1-bit field that indicates whether the block passed (logical 0) or failed (logical 1) the destination system's polynomial check.

d. Bits 4779-4800 (Polynomial Remainder)

The sender generates this 22-bit polynomial code.

9.5 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 9-2* identifies the recording capabilities at each GN station; an "X" means that capability is available. *Table 9-3* lists the capabilities of each digital tape recorder.

Table 9-2. GN Recording Capabilities

Station	Magnetic <u>Disk</u> Recording	Magnetic <u>Tape</u> Recording				
		Ampex DIS260I	Ampex DCSRi 170	VLDS	Sony	Analog Recorders
SGS		X		X		
WGS				X	X	
LEO-T – WFF	X					
TOTS – WFF				X		
MGTAS				X		X
SATAN						X
METEOSAT	X					
Radar Systems	X					X
MGS			X	X		
ASF: 10-m			X		X	
ASF: 11.3-m			X		X	
LEO-T – Alaska	X					
TOTS – Alaska				X		
AGS		X		X		
MILA				X		
PDL				X		

Table 9-3. 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
Metrum VLDS	S-VHS	32 Mbps	Any	10 GB
Sony	D2	160 Mbps	Any	160 GB

Section 10. Frequency Management

10.1 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.

10.2 Determining Frequency Spectrum Requirements

10.2.1 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 10-1 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 10-1. GN Primary Frequency Allocations

Band	Direction	Frequencies
S-band	Earth-to-space	2025 – 2110 MHz
S-band	Space-to-earth	2200 – 2290 MHz
X-band	Space-to-earth	8025 – 8400 MHz

Table 10-2 and *Table 10-3* 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 10.2.3).

10.2.2 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 10-2. 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 10-2 and Table 10-3.

10.2.3 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 10-4*.

Table 10-3. 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.

10.2.4 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 10-5* summarizes these limits.

Table 10-4. 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 Recommendation ITU-R SA.1273

Table 10-5. 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
		$5^\circ < \theta < 25^\circ$	$25 \leq \theta \leq 90$	
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 Recommendation ITU-R SA.1273

International Radio Regulations: Article S21 (Table S21-4)

10.3 Obtaining Frequency Spectrum Authorization

10.3.1 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 [m] provides detailed instructions for obtaining frequency spectrum authorization in compliance with Reference [l].

10.3.2 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 Mission Services 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 [m] in Section 1.3.
2. Ensure interference-free operations between user vehicles and the GN, in accordance with Chapter 4 of Reference [m].
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 [n] 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 G of Reference [m] describes the four-stage review process.

10.3.3 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 10.3.2 above). Each project must designate a point-of-contact for working with the Spectrum Management Office.

10.4 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 10-1 depicts the SFCG 17-2R1 mask recommendation for suppressed carrier modulation systems with data rates greater than or equal to 2 Mbps. See reference [u] for additional information on the SFCG recommendations.

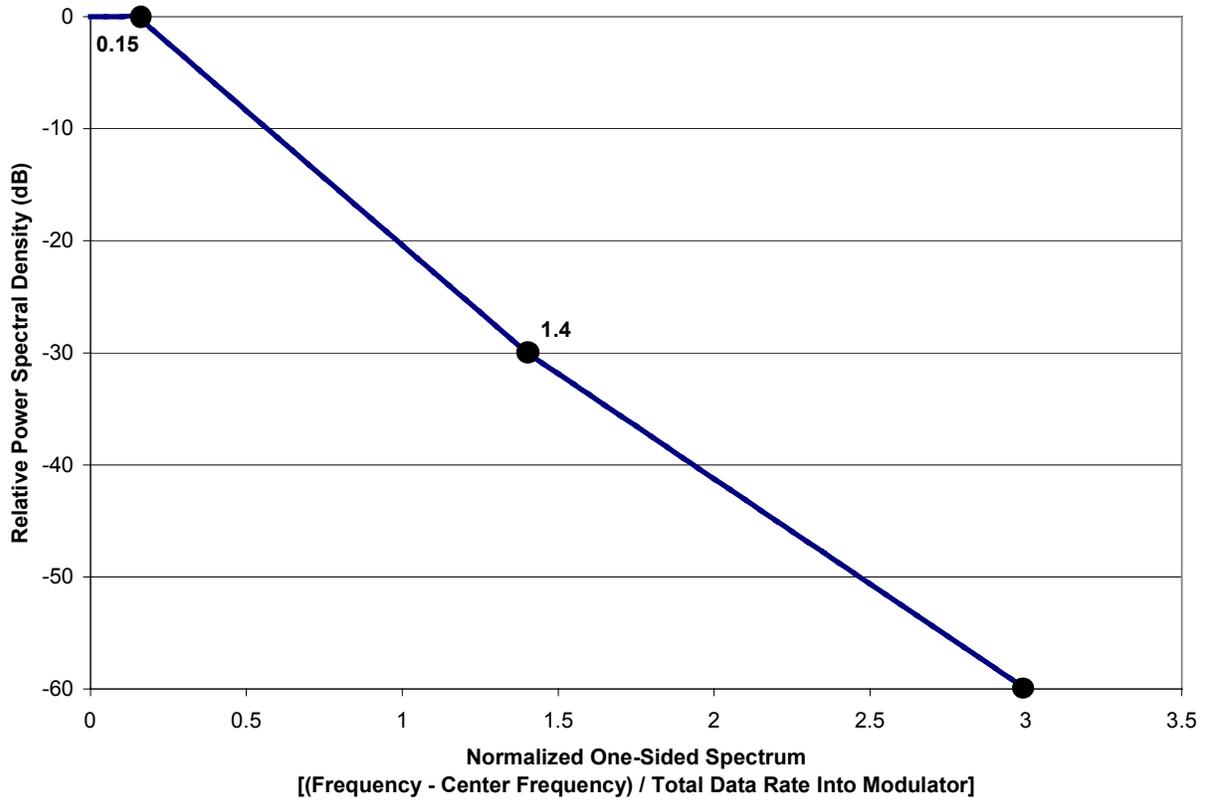


Figure 10-1. SFCG Spectral Limit Recommendation

Section 11. 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 Mission Services 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.

11.1 S-band Atmospheric and Rain Attenuation Constants

Atmospheric and rain attenuation constants were developed for S-band (2200 MHz - 2300 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 11-1 lists the S-band rain attenuation constants for the GN stations that have S-band capabilities.

11.2 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 11-2 lists the X-band rain attenuation constants for the GN stations that have X-band capabilities.

11.3 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 Mission Services 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 11.3.1 and 11.3.2 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 11.3.1 and 11.3.2 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 11.3.1 and 11.3.2, 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 [u] and [v].

11.3.1 X-Band Implementation Loss Examples

Table 11-3 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 (but not identical) equipment that will be implemented for ICESat (reference [s]). 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.

11.3.2 S-Band Implementation Loss Examples

Table 11-4 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 11-5 lists the signal characteristics for a typical LEO spacecraft's S-Band transmitter for the following two scenarios:

- (1) Suppressed carrier modulation with rate $\frac{1}{2}$ convolutional coding
- (2) PM with a residual carrier with rate $\frac{1}{2}$ 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 rate $\frac{1}{2}$ 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 11-4* and *Table 11-5* characteristics yielded the implementation losses listed in *Table 11-6*:

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

11.4 X-band G/T Measurement Data

Table 11-7 lists the SGS X-band G/T data which was measured during tests performed in August 1998.

Actual G/T measurement data is not available for other GN ground stations, however, as it becomes available, this document will be updated.

11.5 Ground Station Line-Of-Sight Coverage

Figures 11-1 through 11-15 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, except for Figures 11-3, 11-5, and 11-10, which use a uniform 5° mask. Line-of-sight coverage analyses for specific mission orbit parameters can be performed by the Mission Services Program Office.

Table 11-1. S-Band Rain Attenuation Constants (5° elevation angle)

Ground Station	Rain Attenuation for 99% Availability (dB)	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
TOTS (WFF)	0.01	0.06
MGTAS (WFF)	0.01	0.06
SATAN (WFF)	0.01	0.06
SCAMP (WFF)	0.01	0.06
METEOSAT (WFF)	0.01	0.06
MGS (Antarctica)	0.0	0.0
ASF (Alaska)	0.0	0.02
LEO-T (Alaska)	0.0	0.01
TOTS (Alaska)	0.0	0.01
AGS (Alaska)	0.0	0.01
MILA (Florida)	0.05	0.23
PDL (Florida)	0.04	0.16

Table 11-2. X-Band Rain Attenuation Constants (5° elevation angle)

Ground Station	Rain Attenuation for 99% (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
ASF (Alaska), 10-m	0.06	0.76
ASF (Alaska), 11.3-m	0.06	0.76
AGS (Alaska)	0.0	0.24

Table 11-3. 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 11-4. 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 11-5. 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

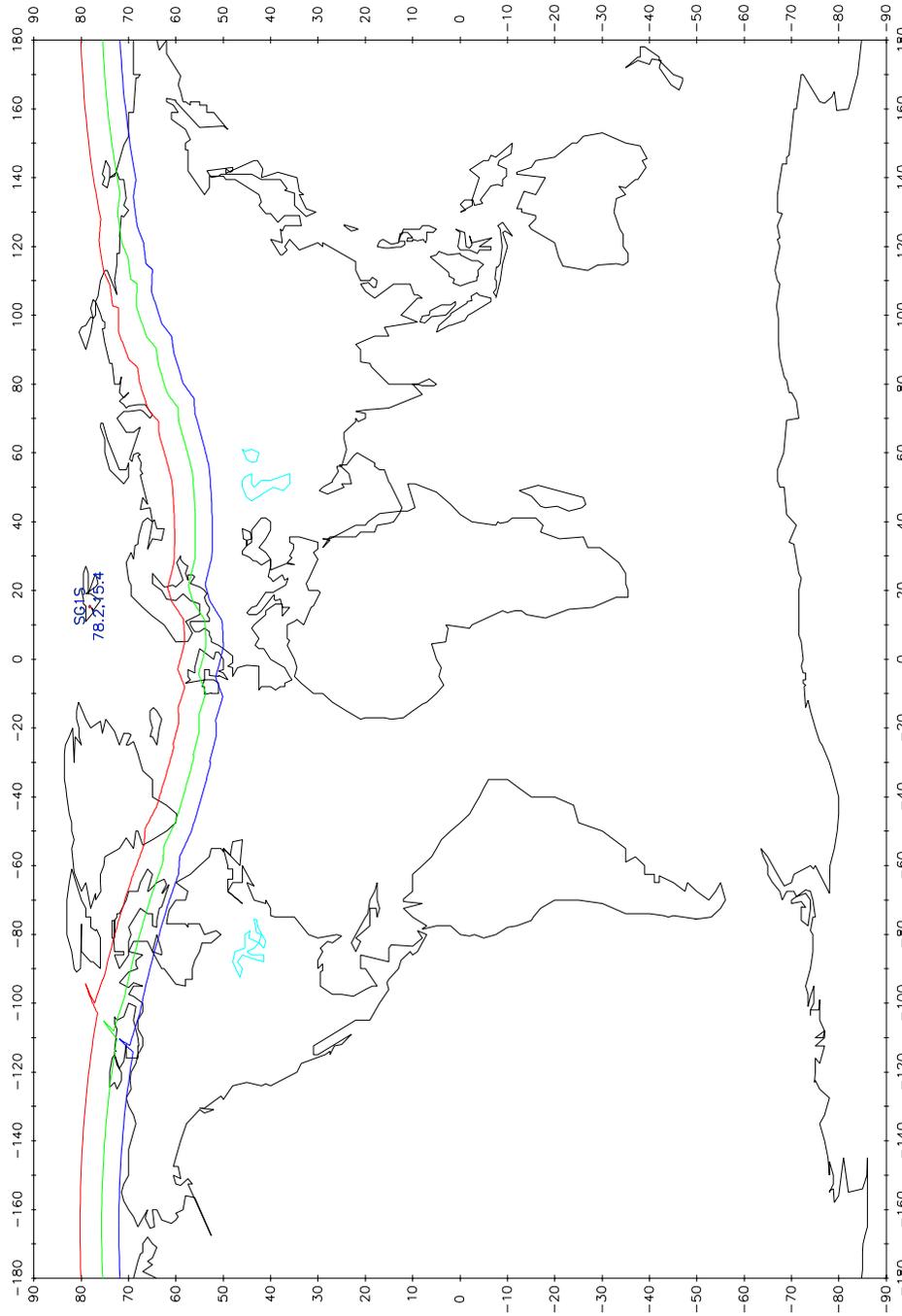
(1) Parameter not simulated, but impact on implementation loss determined via analysis techniques

Table 11-6. 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 1/2 coding)	1.9 dB
BPSK (rate 1/2 coding)	1.9 dB
QPSK (rate 1/2 coding)	2.3 dB

Table 11-7. SGS X-band G/T Measurement Data

X-band Channel	Frequency (MHz)	Elevation $\cong 13^\circ$ (SUN)		Elevation $\cong 56^\circ$ (Cass-A star)	
		RHC (dB/K)	LHC (dB/K)	RHC (dB/K)	LHC (dB/K)
1	8140	35.9	35.8	33.7	34.8
2	8140	34.9	34.8	32.8	33.9
3	8140	36.0	35.9	34.3	34.5
4	8140	35.9	35.9	35.1	34.7
1	8240	36.5	36.3	35.3	35.4
2	8240	36.5	36.3	35.4	35.9
3	8240	36.4	36.3	35.2	36.3
4	8240	36.5	36.3	35.1	35.5
1	8340	36.2	36.2	35.5	35.3
2	8340	36.2	36.2	35.5	34.8
3	8340	36.2	36.2	34.7	33.4
4	8340	36.2	36.2	35.4	35.7

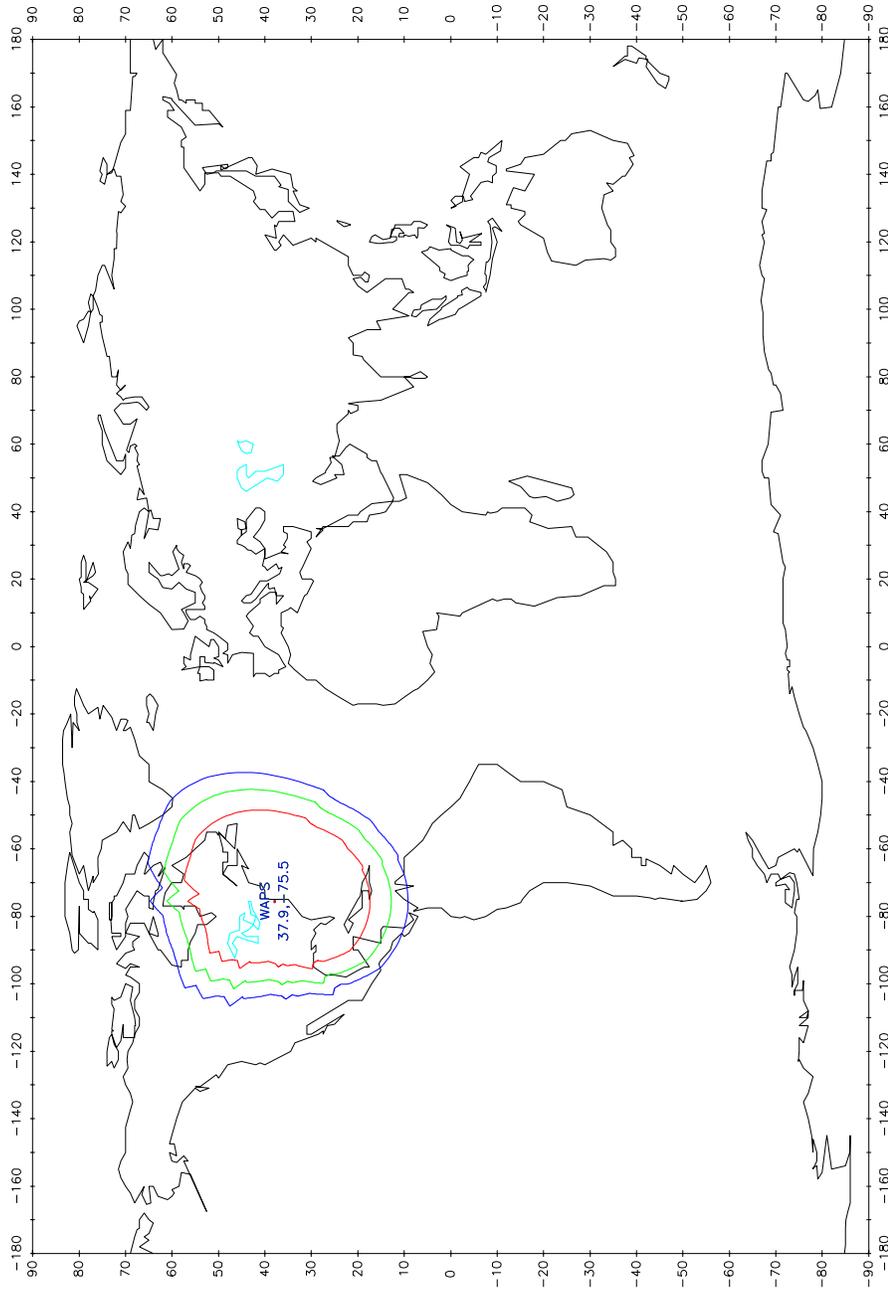


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-1. SGS Line-Of-Sight Coverage

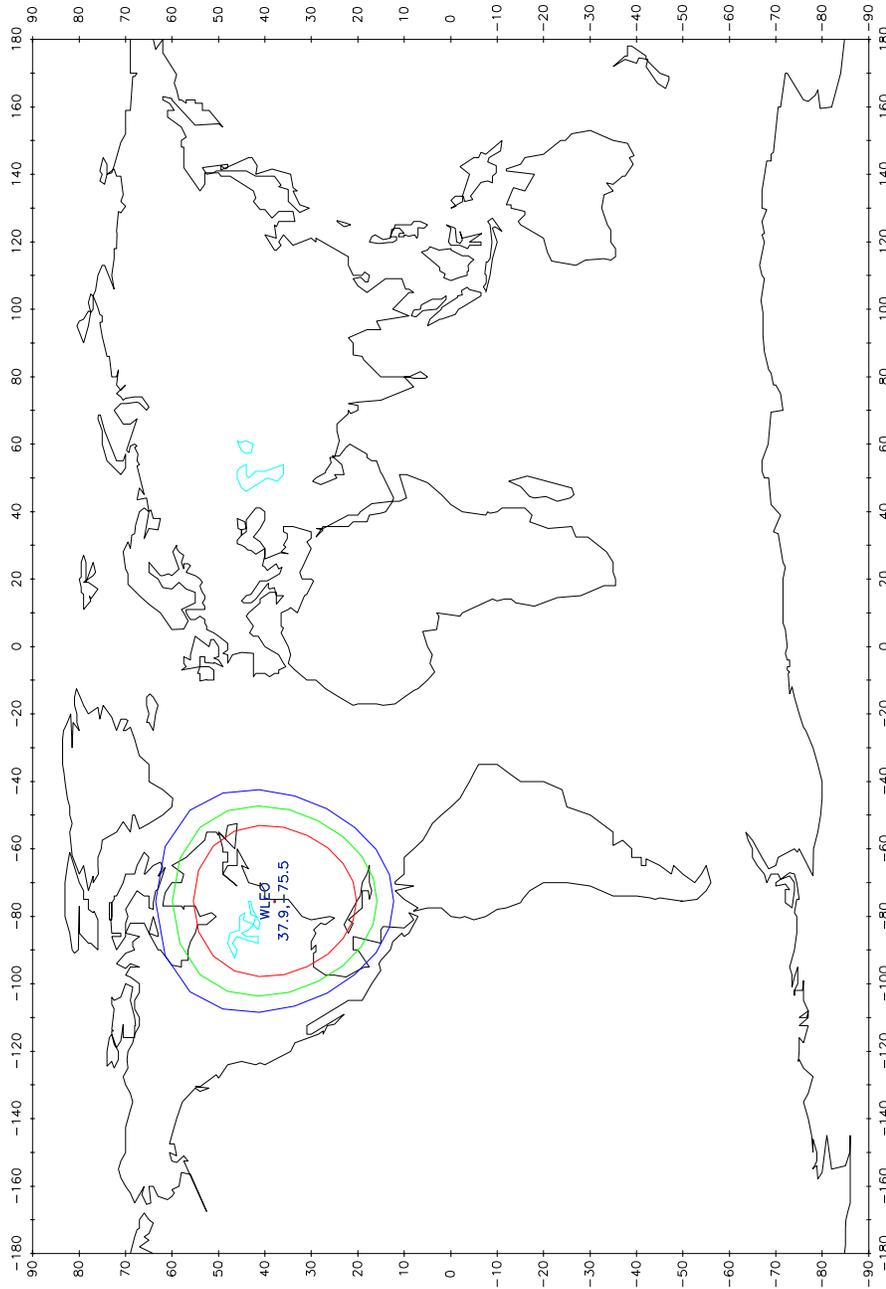


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-2. WGS Line-Of-Sight Coverage

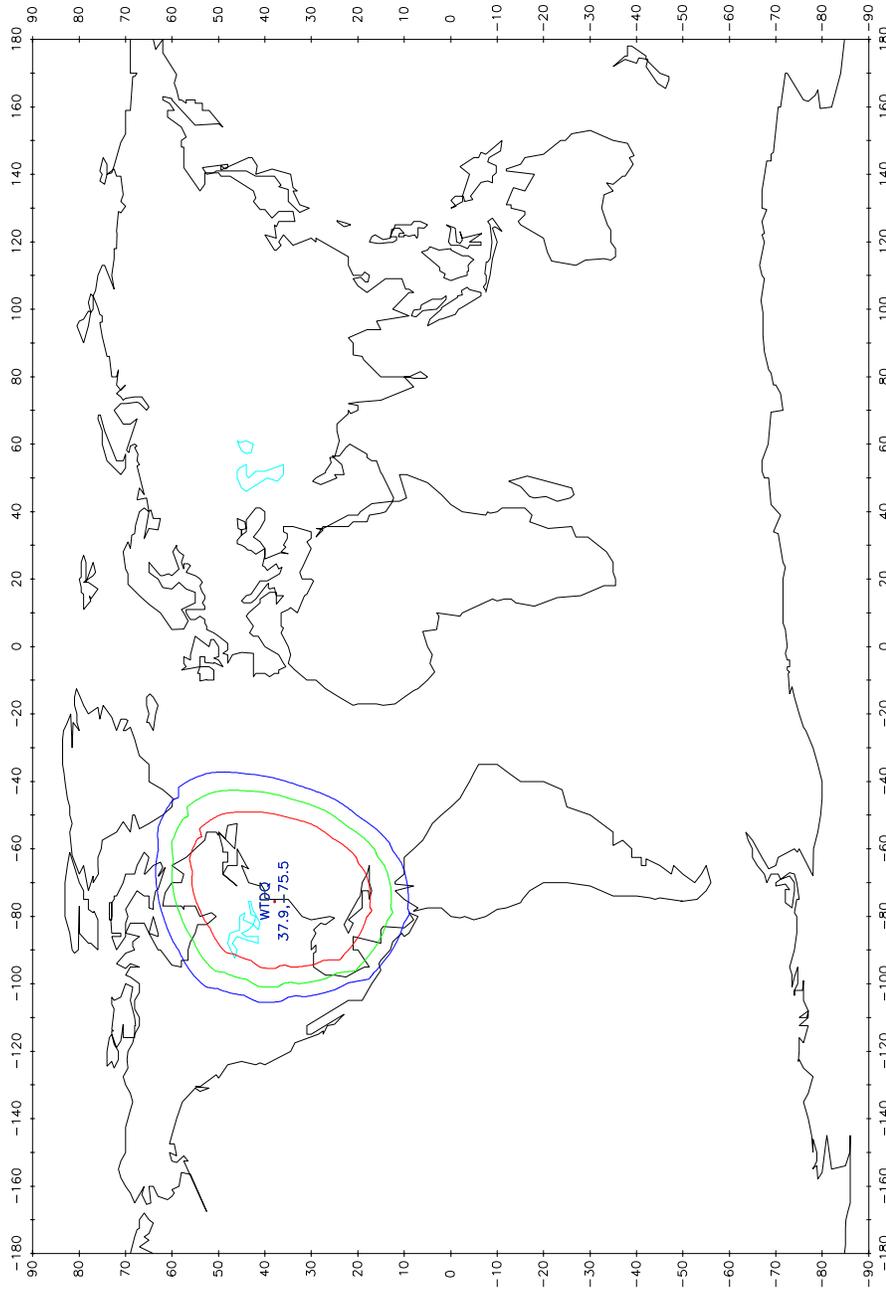


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-3. LEO-T (WFF) Line-Of-Sight Coverage

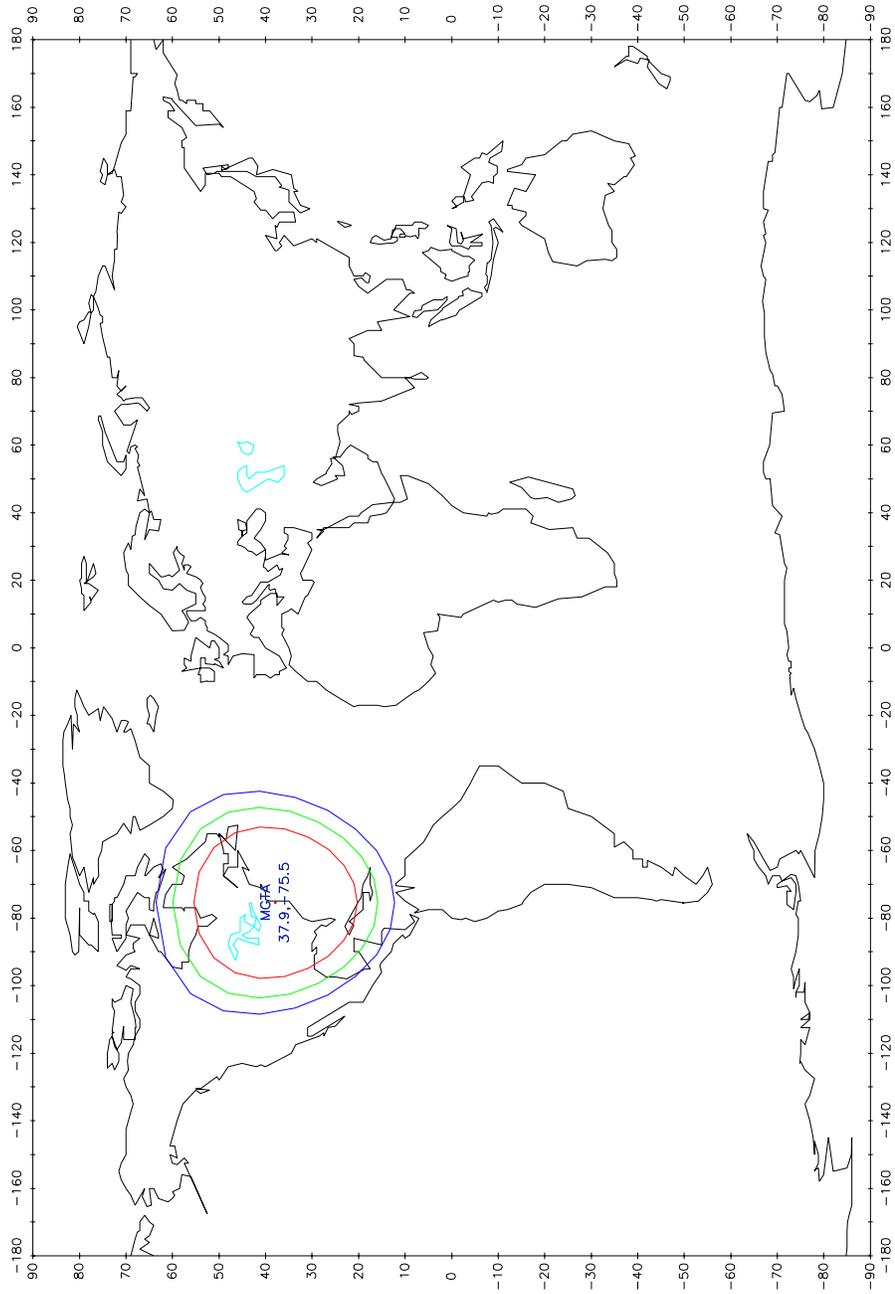


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-4. TOTS (WFF) Line-Of-Sight Coverage

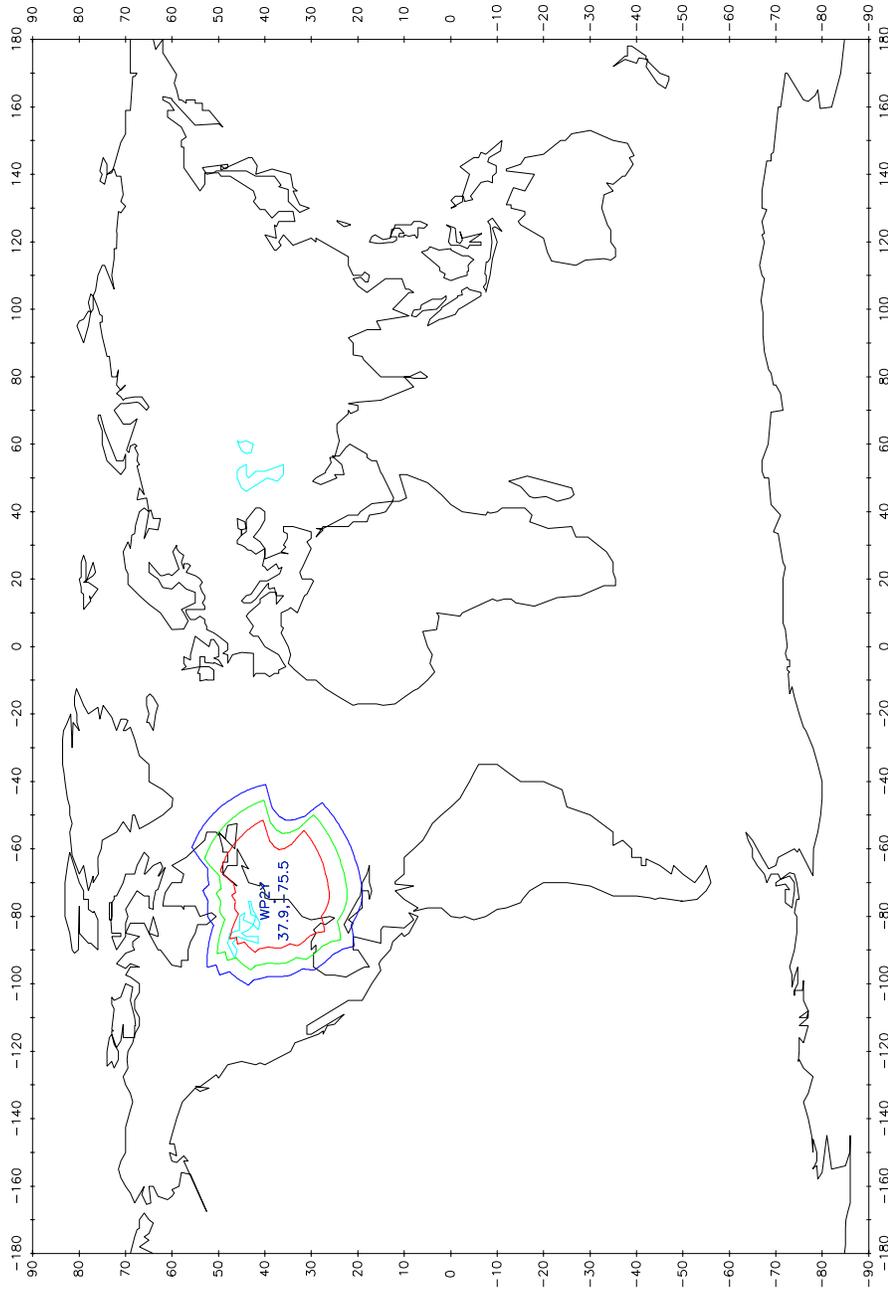


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-5. MGTAS Line-Of-Sight Coverage

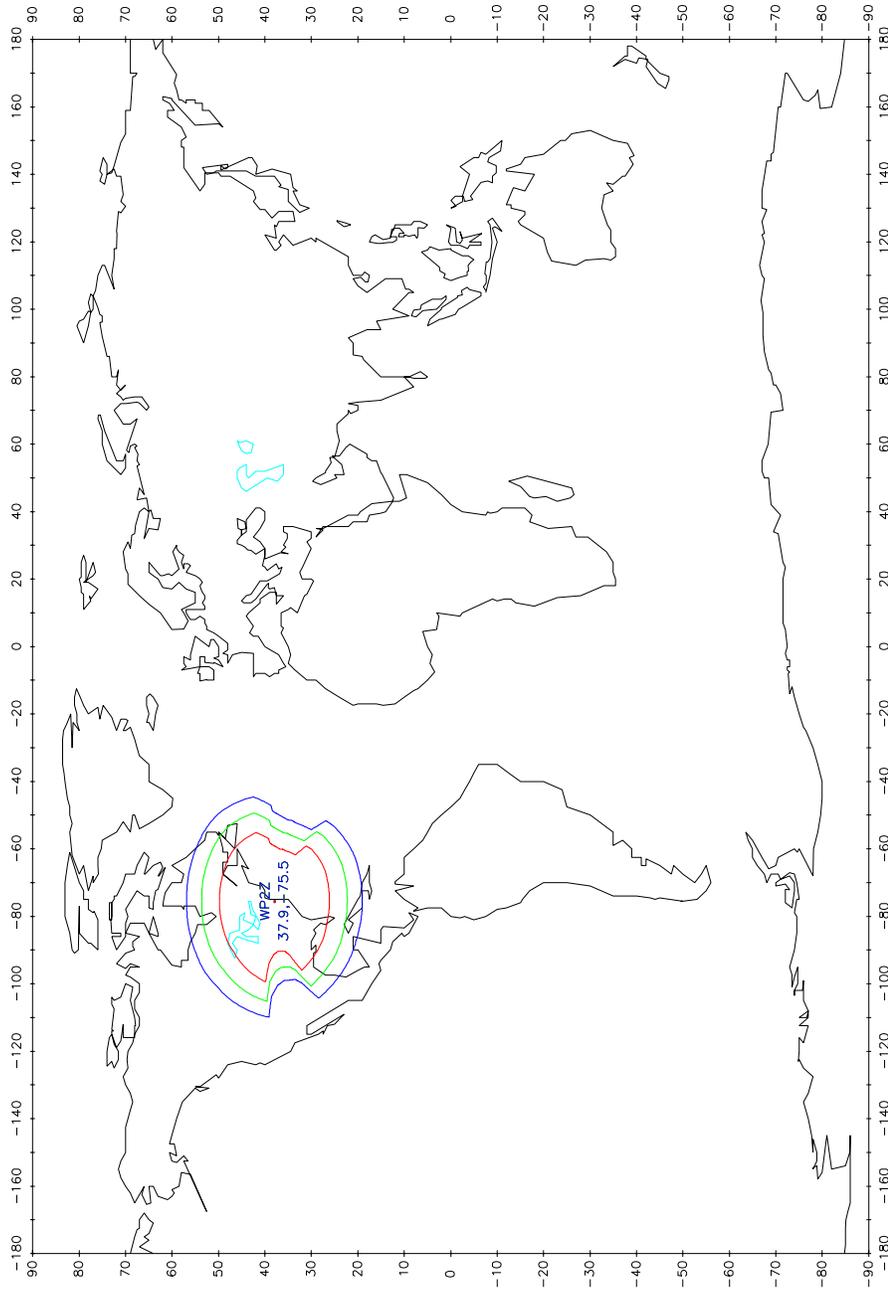


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-6. SATAN Line-Of-Sight Coverage

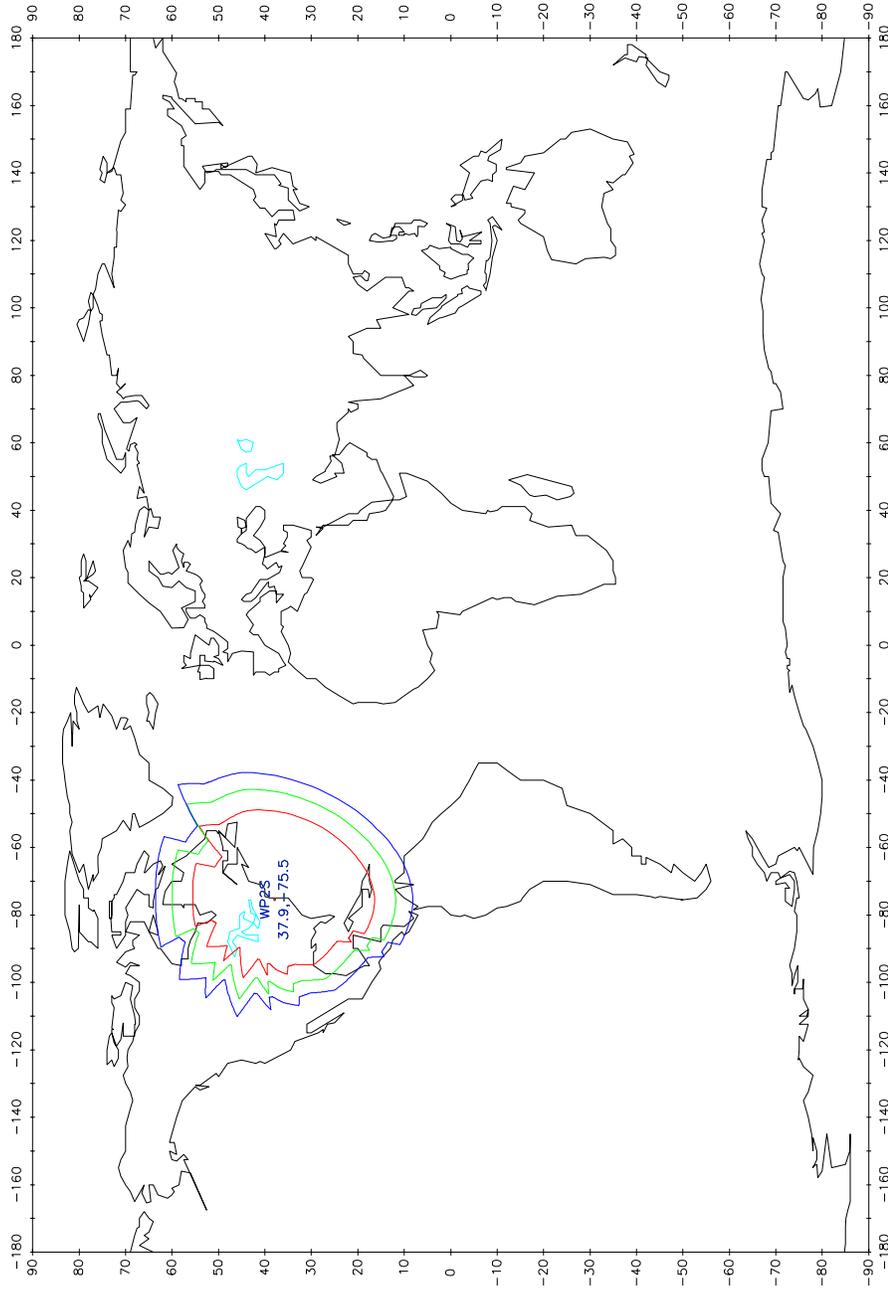


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-7. SCAMP Line-Of-Sight Coverage

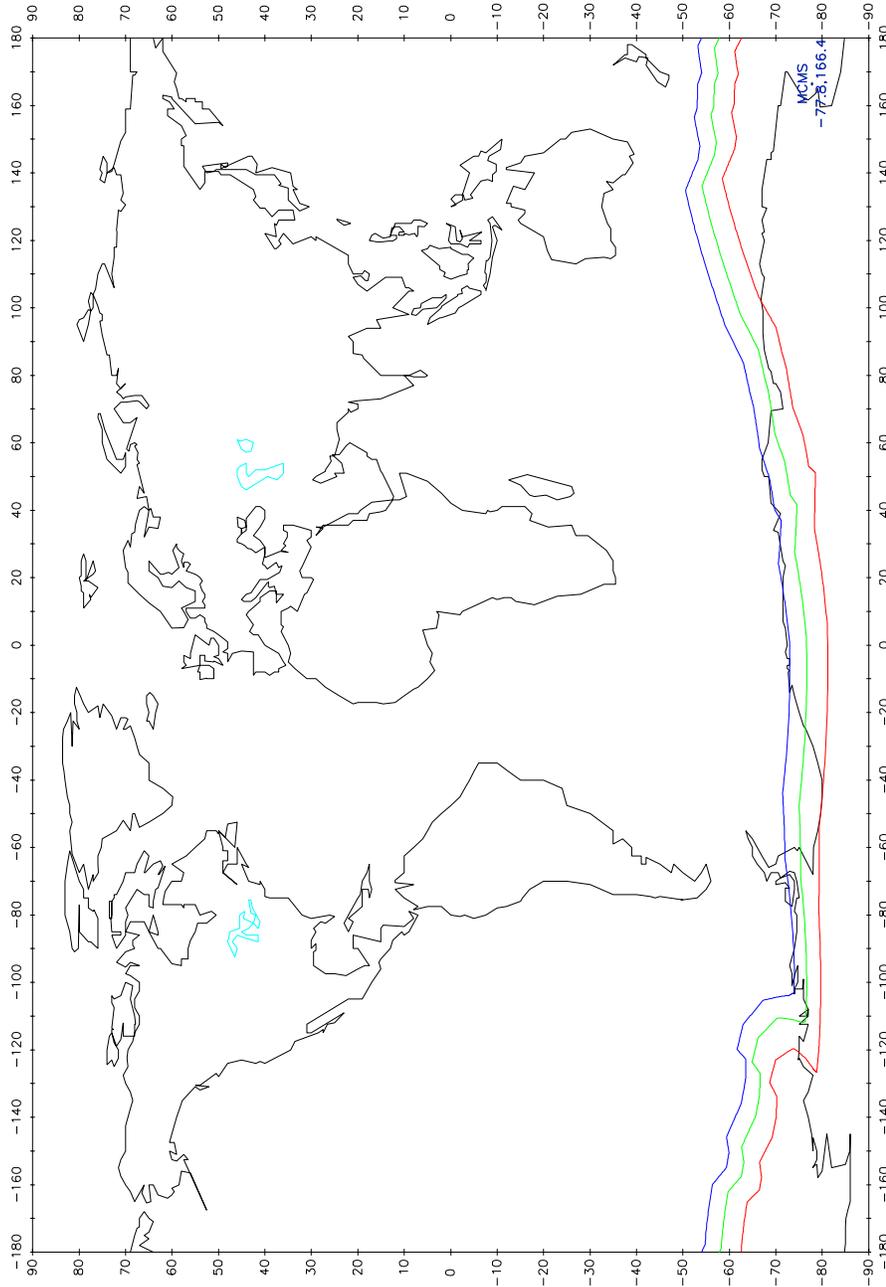


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-8. METEOSAT Line-Of-Sight Coverage

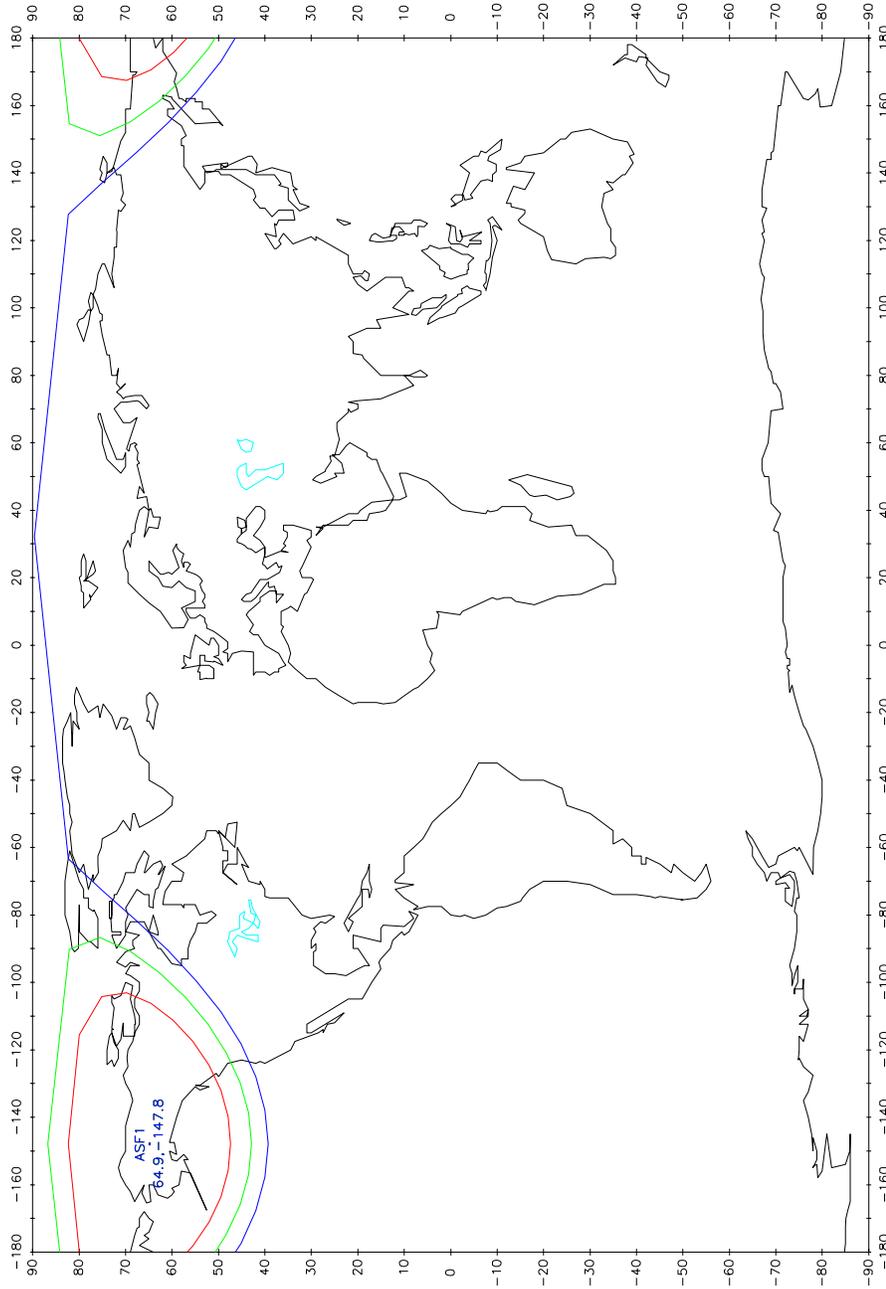


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-9. MGS Line-Of-Sight Coverage

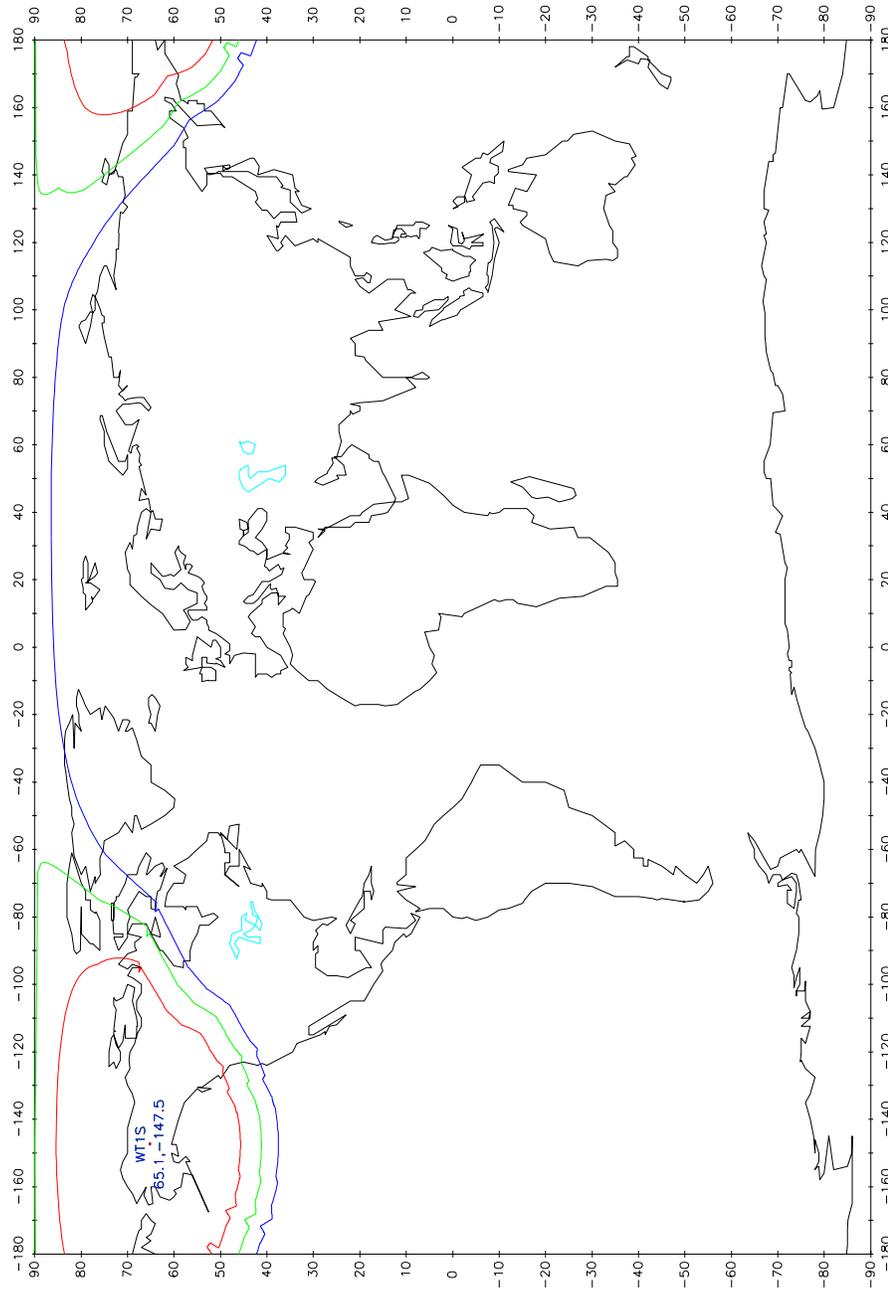


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-10. ASF Line-Of-Sight Coverage

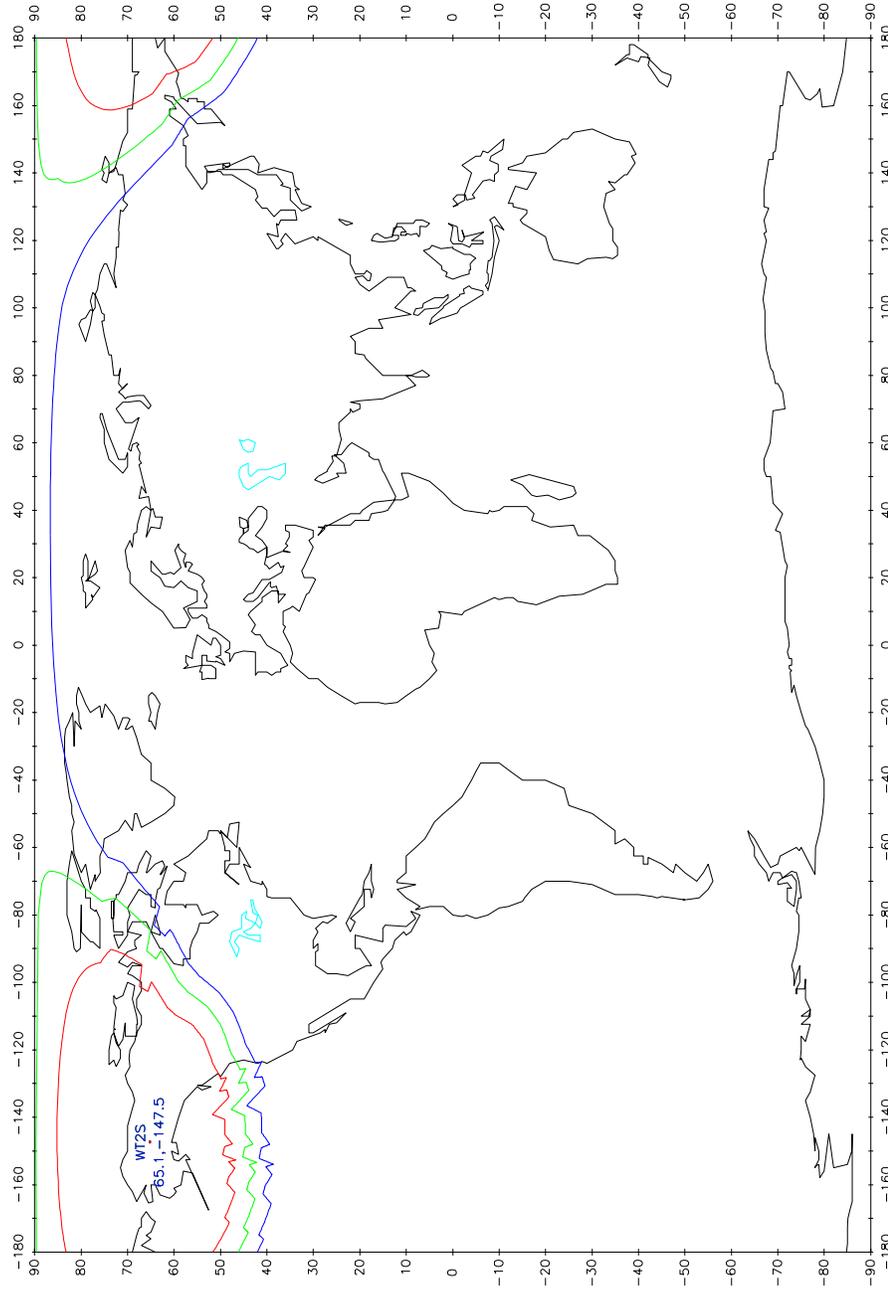


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

GSFC C.L.A.S.S. Analysis #1

9/20/99

Figure 11-11. LEO-T (Alaska) Line-Of-Sight Coverage

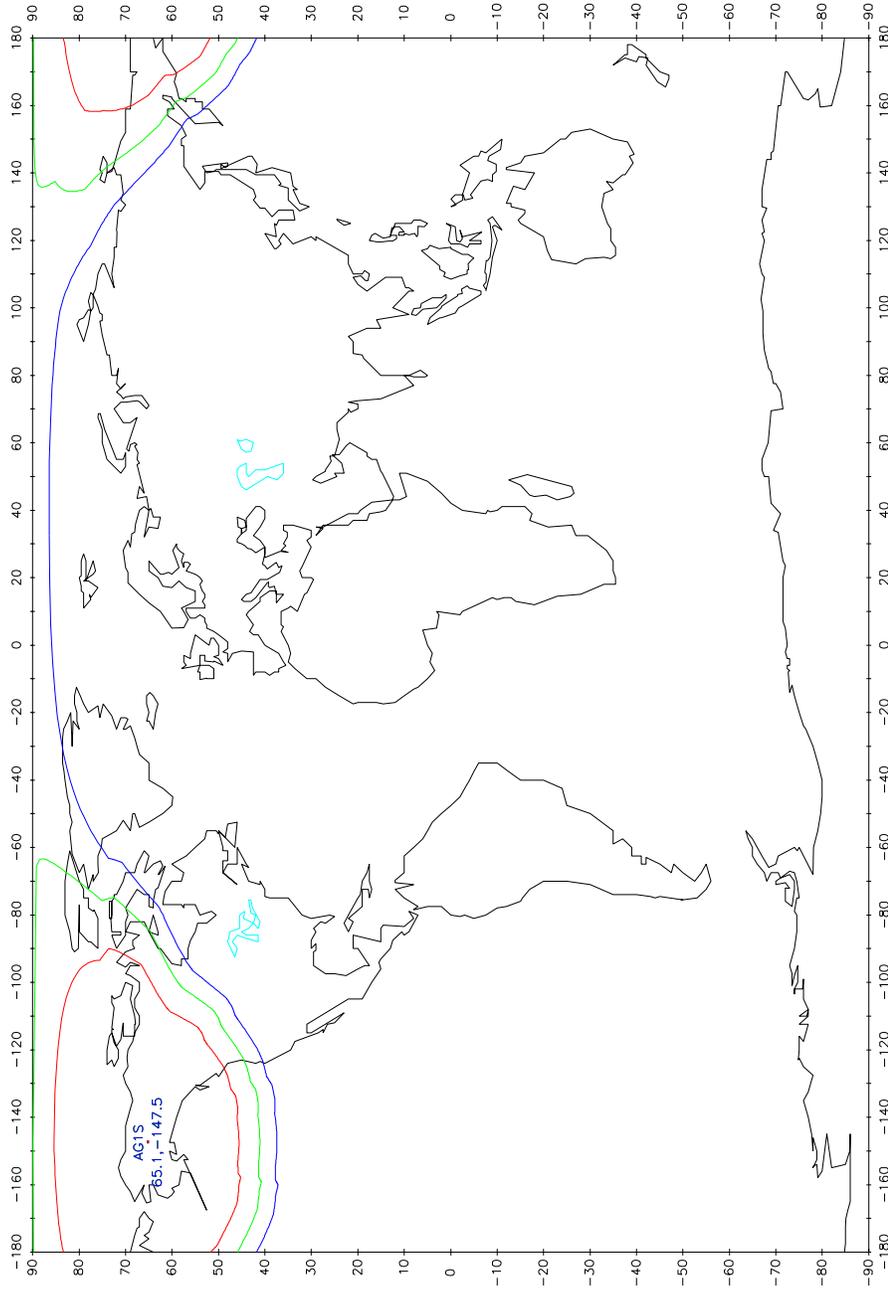


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

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Figure 11-12. TOTS (Alaska) Line-Of-Sight Coverage

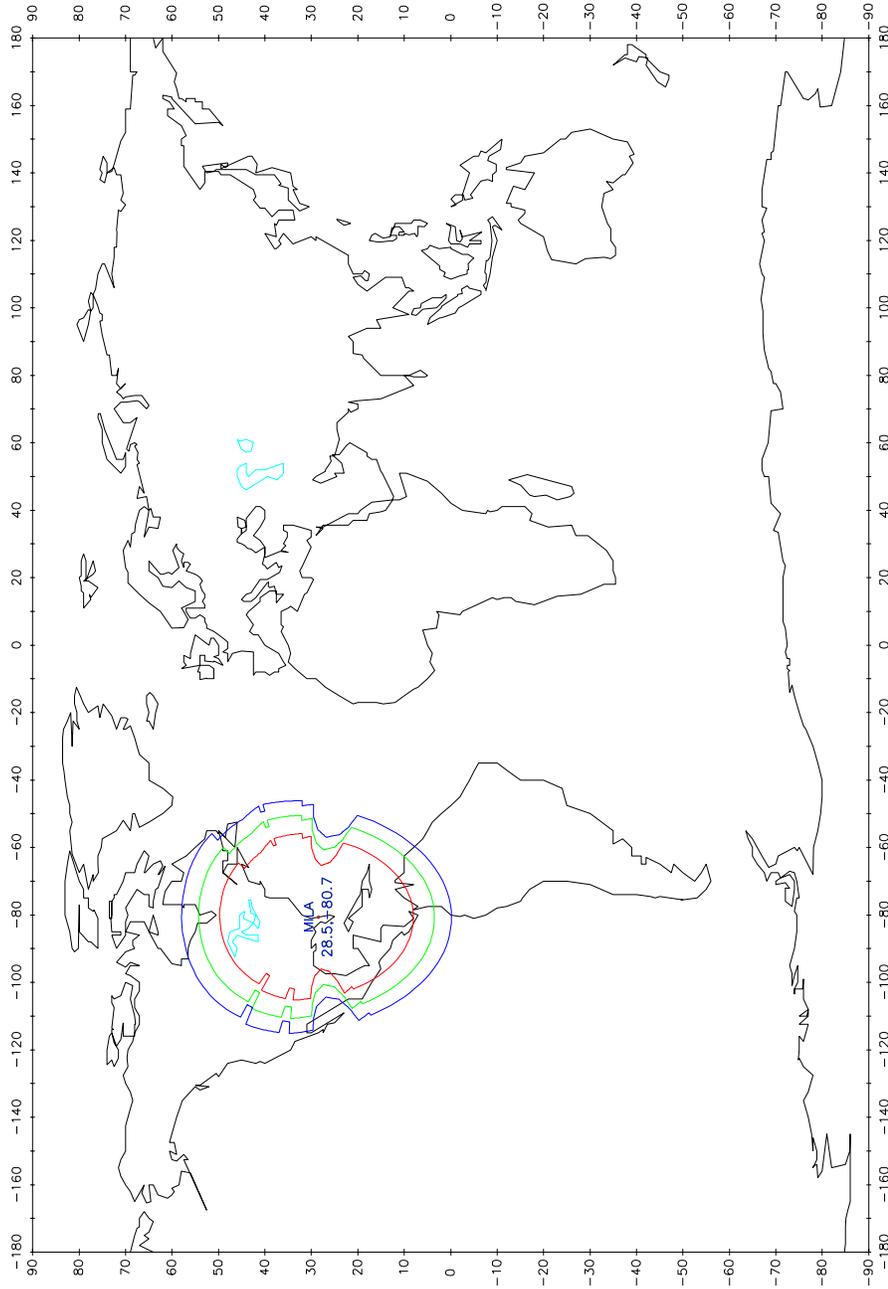


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

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Figure 11-13. AGS Line-Of-Sight Coverage

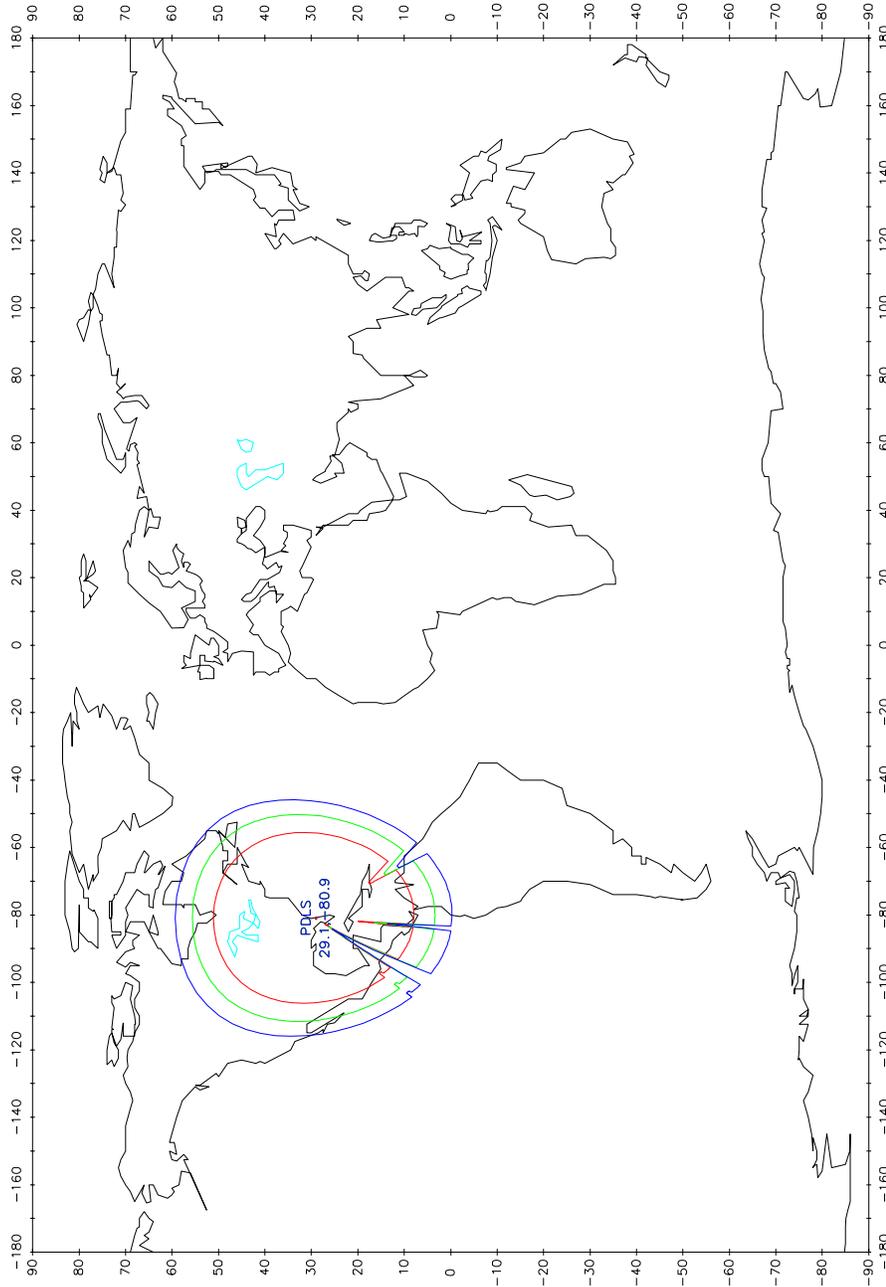


solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

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Figure 11-14. MILA Line-Of-Sight Coverage



solid line = 1000 km altitude
 light dotted line = 750 km altitude
 dark dotted line = 500 km altitude

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Figure 11-15. PDL Line-Of-Sight Coverage

Appendix A. Acronyms

ACE	Advanced Composition Explorer
AGS	Alaska Ground Station
ASF	Alaska SAR Facility
AWOTS	Automated Wallops Orbital Tracking Station
AXAF	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
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
FCC	Federal Communications Commission
GB	Gigabytes
GN	Ground Network
GNPO	Ground Networks Project Office
GNSC	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
METEOSAT	Meteorological Satellite
MGS	McMurdo Ground Station
MGTAS	Medium Gain Telemetry Antenna System
MILA	Merritt Island Launch Area
MOC	Mission Operations Center
Mbps	Megabits per second
MBps	Megabytes per second
MTRS	McMurdo TDRS Relay System
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NCC	Network Control Center
NISN	NASA Integrated Services Network
N&MS	Networks and Missions Services
NOM	Network Operations Manager
NPD	NASA Policy Directive
NSF	National Science Foundation
NTIA	National Telecommunications and Information Agency
PC	Parameter Control
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

SAR	Synthetic Aperture Radar
SATAN	Satellite Automatic Tracking Antenna
SCAMP	Small Command Antenna on a Medium Pedestal
SFCG	Space Frequency Coordination Group
SFDU	Standard Formatted Data Unit
SGS	Svalbard Ground Station
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
UTDF	Universal Tracking Data Format
WFF	Wallops Flight Facility
WGS	Wallops Ground Station
WOTIS	Wallops Orbital Tracking Information System
WRC	World Radiocommunication Conferences
WSG	Wallops Scheduling Group