INTERFACE REQUIREMENTS DOCUMENT (IRD)

FOR

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) PREPARATORY PROJECT (NPP)

MISSION SYSTEM TO DIRECT BROADCAST USERS INTERFACE

December 3, 2001

CHECK THE NPP WEBSITE AT http://jointmission.gsfc.nasa.gov TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

INTEGRATED PROGRAM OFFICE
SILVER SPRING, MARYLAND

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NPP MISSION SYSTEM TO DIRECT BROADCAST USERS INTERFACE

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CHANGE RECORD PAGE

DOCUMENT TITLE: IRD for NPP Mission System to Direct Broadcast Users Interface

DOCUMENT DATE: December 3, 2001

ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
Original	01/07/2002	All pages affected	Approved by CCR 429-01-02-029R1
CH-01	02/07/2002	Pages iii, iv, 1-2, 1-3, 4-1, 4-2, 4-4, and page C-1	Approved by CCR 429-02-02-038R1
CH-02	12/13/2002	Pages iii, iv, 1-1, 2-1, 2-2, and page D-1	Approved by CCR 429-02-02-052

EOS 420-CM-05 (4/92)

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DOCUMENT TITLE:
IRD for NPP Mission System to Direct Broadcast Users Interface

RELEASE DATE:
December 3, 2001

LIST OF AFFECTED PAGES

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EOS 420-CM-04 (4/92)

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1.0 INTRODUCTION

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) is a joint developmental mission being formulated by National Aeronautics and Space Administration (NASA) and the NPOESS Integrated Program Office (IPO). The NPP mission provides remotely sensed land and atmospheric data that supports research into long-term change in the global climate. It is planned to provide a transition from the current National Aeronautics and Space Administration (NASA) Earth Observation System (EOS), Department of Defense (DoD) Defense Meteorological Satellite Program (DMSP), and National Oceanic and Atmospheric Administration (NOAA) Polar-orbiting Operational Environmental Satellite (POES) program to the future converged NPOESS System. The NPP Mission will provide early flight opportunity for the NPOESS Visible-Infrared Imager Radiometer Suite (VIIRS), Cross-Track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), and Ozone Mapping and Profiler Suite (OMPS) instruments. The NPP Mission will also accommodate a Flight of Opportunity for the Clouds and the Earth's Radiant Energy System (CERES) Flight Model 5 (FM-5) instrument. NPP is a joint mission of NASA, the DoD, and the Department of Commerce (DoC). CH-02 CH-02

The NPP system contains six mission segments that, in combination with external entities, maintain all required functionality to meet the mission objectives from launch to data archive. These segments are:

- Space Segment
- Command, Control and Communications Segment
- Interface Data Processing Segment
- Science Data Segment
- Archive and Distribution Segment
- Launch Support Segment

The NPP Mission also interfaces with external program elements such as the Direct Broadcast Users. A more complete description of the NPP Mission can be found in the NPP Mission System and Operations Concept (reference document 1, Section 1.4)

1.1 PURPOSE AND OBJECTIVE

This Interface Requirements Document (IRD) describes the technical interface between the NPP Mission System and the Direct Broadcast Users.

1.2 SCOPE

The provisions of this document apply to the development and operation of the interface between NPP Mission System and the Direct Broadcast Users.

This document contains interface requirements derived from the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) Mission Requirements Specification.

1.3 DOCUMENT ORGANIZATION

This document is comprised of 5 Sections and 3 Appendices.

Section 1 introduces the IRD.

Section 2 describes the specific system and segment functions that the interface supports and contains brief descriptions of the SS and the Direct Broadcast Users, including the interfacing elements of each segment.

Section 3 describes the data flows between the SS and the Direct Broadcast Users and thereby provides a context for understanding the formal interface requirements presented in the next section.

Section 4 provides the functional and performance requirements that must be met by the interface in supporting each data flow.

Section 5 contains information regarding the Interface Control Documents that will be developed for the interface between the SS and the Direct Broadcast Users, including ICD name, responsible organization, and schedule.

Appendix A provides an example link budget of the HRD link.

Appendix B lists issues, TBDs/TBRs in the IRD and describes plans to resolve them.

Appendix C provides a Requirements Traceability Matrix.

Appendix D contains an Abbreviations and Acronym List.

1.4 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this IRD to the extent specified herein. Any conflict between the interface requirements presented in these documents or any conflict between the provisions of these documents and the contents of this IRD should be presented to the reviewers of this IRD for resolution.

a. Consultative Committee for Space Data Systems (CCSDS) Recommendations for Advanced Orbiting Systems - Networks and Data Links: Architectural Specification, (CCSDS 701.0-B). | CH-01

b. Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telemetry Channel Coding, (CCSDS 101.0-B). | CH-01

c. National Telecommunications and Information Administration (NTIA) "Manual of Regulations and Procedures for Federal Radio Frequency Management". | CH-01

1.5 REFERENCE DOCUMENTS

The following reference documents are listed for the convenience of the user. These documents do not form a part of this IRD and are not controlled by their reference herein.

a. NPP Mission Requirements Specification, (GSFC 429-99-02-03) | CH-01

b. NPP Mission System and Operations Concept, (GSFC 429-99-02-02) | CH-01

c. NPP System Interface Control Plan, (GSFC 429-00-02-08)

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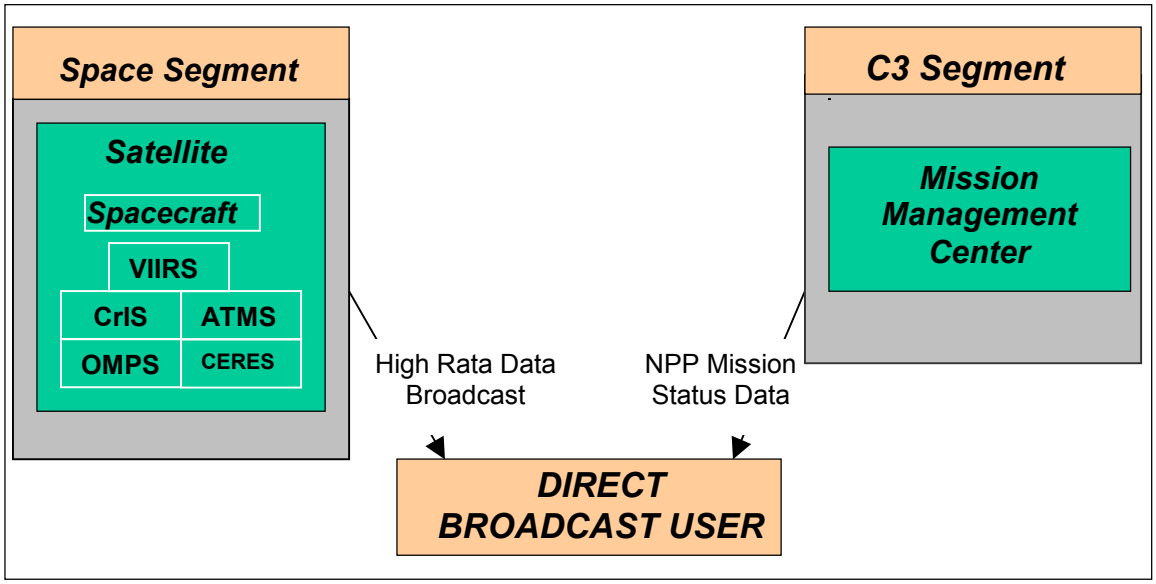
2.0 SYSTEM RELATIONSHIPS OVERVIEW

The interface between NPP Mission System and the Direct Broadcast Users provides real-time meteorological operations and science data from the NPP spacecraft instruments directly to the NPP end users. The NPP Space Segment provides a broadcast of real-time instrument data, real-time spacecraft data, and instrument housekeeping data. In normal operations broadcast data will operate continuously providing real-time data during 100% of the NPP Satellite orbit. This includes periods when the Spacecraft is performing playback of the stored mission data (SMD) over a separate link. The interface also supports a test mode to allow determination of the interface performance and diagnostics.

In support of the data broadcast, NPP Command Control and Communications Segment provides to the Direct Broadcast Users mission status information. The mission status information provides the users with sufficient information to receive the broadcast data.

Figure 2-1 depicts the NPP to Direct Broadcast Users interfaces on the segment level.

Figure 2-1 NPP to Direct Broadcast User Interface Diagram



CH-02

2.1 SPACE SEGMENT

The Space Segment (SS) is composed of the Satellite and the Ground Support Equipment. For the purposes of the IRD, only the Satellite will be addressed.

The Satellite is comprised of the Spacecraft and instruments. The Spacecraft provides narrowband and wideband communications interfaces, controls the Satellite attitude to

provide the instrument payload with a stable platform, manages power and thermal functions to maintain a sound spacecraft condition, and provides fail safe protection in the event of anomalous conditions. The instrument complement includes: Visible-Infrared Imager Radiometer Suite (VIIRS), Cross-Track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), Ozone Mapping and Profiler Suite (OMPS), and the Clouds and the Earth's Radiant Energy System (CERES). CH-02

2.2 COMMAND, CONTROL AND COMMUNICATIONS

The Command, Control, and Communications Segment (C3S) is composed of the Mission Management Center, Data Routing and Retrieval, Ground Stations, and Flight Vehicle Simulator. For the purposes of the IRD, only the Mission Management Center (MMC) is addressed.

The Mission Management Center element provides overall guidance and daily operational oversight of the NPP mission. It is the decision authority for mission configuration, prioritization, and calibration. It will be responsible for performing the operational functions of Spacecraft command and control, mission planning, resource scheduling, network management, launch and early orbit support, anomaly resolution, telemetry data processing, and the support of data delivery to users. The communication routing functions include those activities associated with the planning, scheduling and coordination of network communication links.

2.3 DIRECT BROADCAST USERS

The Direct Broadcast Users are an external entity to the NPP Project. The Direct Broadcast Users are capable of receiving real-time direct broadcast data if they have the minimum equipment for receipt of the data as specified in Section 4. The Direct Broadcast Users also receive broadcast data from other missions such as DMSP, POES, and EOS.

3.0 DATA FLOW DESCRIPTIONS

The interface between NPP Mission System and the Direct Broadcast Users supports the following data flows:

- NPP High Rate Data (HRD)
- Test Bit Stream
- Mission Status Data

3.1 NPP HIGH RATE DATA

The NPP HRD produced by the Space Segment consists of NPP real-time science and engineering data. The instrument data included in the HRD are all packets received by the spacecraft from the instruments. This consists of science data, instrument status data, and instrument diagnostic data. Spacecraft data in the HRD consists of spacecraft status data (i.e., housekeeping data) and the spacecraft diary. The HRD will nominally be sent 100% of the time including times of SMD playback. HRD may be disabled for periods of testing and non-nominal conditions.

3.2 TEST BIT STREAM

The satellite will generate pseudo-random bit stream test data as a test mode used for the purpose of bit error rate (BER) checking, as required. It is not a normal X-band downlink service.

3.3 MISSION STATUS DATA

The Mission Status Data is provided by the C3S and includes the necessary information the Direct Broadcast Users need for receiving the HRD from the satellite. This includes updated NPP orbit vectors and scheduled outages of the HRD service.

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4.0 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

4.1 HRD BASEBAND REQUIREMENTS

4.1.1 HRD Data Content

The Spacecraft shall broadcast the HRD consisting of real-time instrument science data (including engineering data), real-time spacecraft and instrument housekeeping data, and S/C diary.

4.1.2 HRD Data Rate

The Spacecraft shall format the HRD Broadcast for transmission at a total data rate of 15 Mbps over the X-band link.

4.1.3 HRD Availability

The Spacecraft shall continuously broadcast the HRD while the spacecraft is in normal science mode. Note: The intent is to provide broadcast with no guarantee of meeting link margins during non-nominal operations.

4.1.4 Deleted/Reserved

4.1.5 HRD CADU Format

The Spacecraft shall format the HRD in accordance to Grade 2 service defined in CCSDS 701.0-B, Advanced Orbiting Systems, Networks and Data Links: See Figure 4-1 for example downlink transfer frame format. CH-01

4.1.6 HRD Bit Error Rate

The Spacecraft shall provide the HRD to the Direct Broadcast Users with an effective bit error rate after all decoding of less than 10^{-8} under the following conditions:

(a) The ground receive station meets the minimum requirements stated in section 4.5

(b) The spacecraft is in view of the ground receive station with a minimum elevation of 5 deg.

(c) Total rain loss is less than 3dB. Note: Rain loss includes attenuation, scintillation, and degradation of G/T.

4.1.7 HRD Reed-Solomon Encoding

The Spacecraft shall use Reed-Solomon (255,223) code with an interleave depth of 4 for error correction of the CADUs.

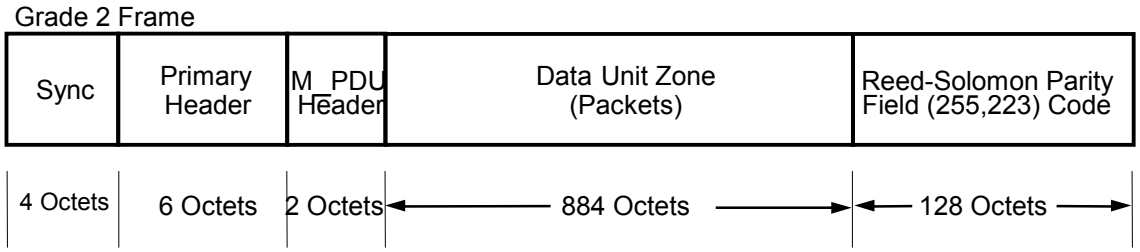

Figure 4-1: Example Channel Access Data Unit (Sync + coded VCDU)

4.1.8 HRD Constant Rate

The Spacecraft shall maintain a constant HRD broadcast rate by using fill CADUs using format as defined in CCSDS 701.0-B. CH-01

4.1.9 HRD Randomization

The Spacecraft shall randomize the HRD stream compliant with CCSDS 101.0-B. CH-01

4.1.10 HRD Convolutional Code

The Spacecraft shall encode the HRD stream with a rate ½, constraint length 7 convolutional code as defined in CCSDS 101.0-B. CH-01

4.2 TEST BIT STREAM BASEBAND REQUIREMENTS

4.2.1 Test Bit Stream Data Rate

The Spacecraft shall be capable of providing a Test Bit Stream formatted for transmission at 15 Mbps over the X-band link

4.2.2 Test Bit Stream Data Content

The Spacecraft shall generate the Test Bit Stream using the following bit transition generation function (refer to CCSDS 101.0-B): CH-01

$$h(x) = x^8 + x^7 + x^5 + x^3 + 1$$

4.2.3 Test Bit Stream Bit Error Rate

The Spacecraft shall provide the Test Bit Pattern to the ground with a bit error rate of less than 10^{-4} after convolutional decoding under the following conditions:

(a) The ground receive station meets the minimum requirements stated in section 4.5

(b) The spacecraft is in view of the ground receive station with a minimum elevation of 5 deg.

(c) Total rain loss is less than 3dB. Note: Rain loss includes attenuation, scintillation, and degradation of G/T.

4.3 SIGNAL CHARACTERISTICS

4.3.1 RF Data Modulation

The Spacecraft shall modulate the X-band RF using Quadrature Phase Shift Keying (QPSK).

4.3.2 RF Center Frequency

The Spacecraft shall transmit the X-band RF on a center frequency of 7812 MHz.

4.3.3 RF Data Encoding

The Spacecraft shall format the data on the X-band RF using NRZ-M.

4.3.4 RF Link Margin

The spacecraft shall provide a link margin for X-band RF of at least 1.0 dB

4.3.5 NTIA Compliance

The Spacecraft X-band RF shall comply with the National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management for maximum allowed power spectral density at the ground and spectral emission masks.

4.3.6 DSN Compliance

The Spacecraft spectral power flux density falling within the Deep Space Research band of 8400 MHz to 8450 MHz shall be less than -255.1 dBW/m^2 Hz

4.3.7 Deleted/Reserved

4.3.8 Deleted/Reserved

4.3.9 RF encoding order

The Spacecraft shall generate the HRD and Test Bit Stream using the following order of processing following randomization and CADU construction:

a) differential encode

b) convolutional encode

c) split convolution code symbols onto I & Q channels such that the first convolutional symbol (G1) is placed on I and the second symbol (G2) is placed on Q

d) modulate I and Q onto the carrier simultaneously.

4.3.10 Minimum Received Eb/No

The spacecraft shall provide a minimum Eb/No of 4.4 dB at the ground receive station for conditions provided in section 4.5 and requirement 4.1.6. Note: Minimum Eb/No is required to guarantee all ground receive sites will be capable of maintaining lock on the signal. CH-01

4.4 NPP STATUS INFORMATION

4.4.1 NPP Positions Vectors

The C3S shall make available to the Direct Broadcast Users NPP position vectors of sufficient accuracy to allow Ground Station tracking of NPP.

4.4.2 NPP Satellite Status

The C3S shall make available to the Direct Broadcast Users current status of the NPP satellite.

4.4.3 HRD Predicted Outages

The C3S shall make available to the Direct Broadcast Users scheduled outages of the HRD.

4.4.4 NPP Instrument Predicted Outages

The C3S shall make available to the Direct Broadcast Users scheduled outages of any instrument data.

4.5 DIRECT DOWNLINK USER GROUND STATION CHARACTERISTICS

4.5.1 User Stations G/T

The Direct Downlink User Station G/T shall be better than or equal to G/T values shown in Table 4-1. Note: Assumes the User Ground Station has an Antenna Gain of 44.9 dBi or better (3 meter antenna with an efficiency of 55%) with surface tolerance loss of 0.3 dB or better.

Table 4-1: Ground Station Minimum G/T

Elevation [deg.]	Ground Station G/T [dB/K]
5°	22.70
40°	23.59
70°	23.65
90°	23.66

4.5.2 User Station Pointing Loss

The Direct Downlink User station degradation due to pointing loss shall not exceed 1.0 dB.

4.5.3 User Station Implementation Loss

The Direct Downlink User station implementation loss shall not exceed 2.5 dB.

4.5.4 User Station Multipath Loss

The Direct Downlink User station shall have a multipath loss of less than 0.2 dB at a 5 degree elevation.

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APPENDIX A – SAMPLE HRD LINK BUDGET

The following link budget contains sample values based on historical data. Where values are taken from the IRD, the requirement number is listed in the comments column.

			Value for elevation				
	Parameter	Units	5 deg	40 deg	70 deg	90 deg	Comments
1	Transmitter Power	dBW	10.00	10.00	10.00	10.00	
2	Antenna Gain	dB	7.00	1.00	-5.00	-2.00	Current Gain for EOS Aqua as documented in Space to Ground RF ICD
3	Passive Loss	dB	2.00	2.00	2.00	2.00	Cables, Splitters, etc.
4	EIRP	dBW	15.00	9.00	3.00	6.00	Items 1+2-3
5	Space Loss	dB	179.36	171.83	169.10	168.62	Range = 2835, 1192, 870, and 824 Km
6	Atmospheric Attenuation	dB	0.65	0.10	0.07	0.06	
7	Rain Loss	dB	3.00	3.00	3.00	3.00	4.1-6 & 4.2-3 Includes attenuation, scintillation, and G/T degradation.
8	Polarization Loss	dB	1.10	1.28	2.15	1.10	
9	Pointing Loss	dB	1.00	1.00	1.00	1.00	4.4-2 3 meter antenna with 0.15 deg pointing error
10	Multipath loss	dB	0.2	0.0	0.0	0.0	4.4-4 Ground multipath
11	Received isotropic power	dBW	-170.31	-168.21	-172.32	-167.78	Items 4-5-6-7-8-9-10
12	User Ground Terminal G/T	dB/K	22.70	23.59	23.65	23.66	4.4-1 Clear Sky, includes surface tolerance degradation of 0.3 dB
13	Data Rate	dB	71.76	71.76	71.76	71.76	15 Mbps
14	Implementation Loss	dB	2.50	2.50	2.50	2.50	4.4-3
15	Boltzmann's constant	dBHz K/W	-228.60	-228.60	-228.60	-228.60	
16	Received Eb/No	dBW	6.73	9.72	6.67	10.21	Items 11+12-13-14-15
17	Required Eb/No	dBW	4.4	4.4	4.4	4.4	BER 10-5 with Convolutional
18	Margin	dBW	2.33	5.32	1.27	5.81	Required margin is 1.0 dB

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APPENDIX B – TBR/TBD LISTING

Number	Description	Resolution Plan	Date
	NONE		

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APPENDIX C – REQUIREMENTS TRACEABILITY MATRIX

HRD Rqmt No.	Trace	Trace-Comment
4.1.1	LVL2: 3.2.2.5	
4.1.2	LVL2: 3.1.11	
4.1.3	LVL2: 3.2.3.4.4.1	
4.1.4	Deleted/Reserved	
4.1.5	LVL2: 3.2.11	
4.1.6	LVL2: 3.2.11	
4.1.7	LVL2: 3.1.11	
4.1.8	LVL2: 3.1.11	
4.1.9	LVL2: 3.1.11	BER
4.1.10	LVL2: 3.1.11	BER
4.2.1	LVL2: 3.1.11	BER testing
4.2.2	LVL2: 3.1.11	BER testing
4.2.3	LVL2: 3.1.11	BER testing
4.3.1	LVL2: 3.2.2.5	
4.3.2	LVL2: 3.1.11	
4.3.3	LVL2: 3.2.2.5	
4.3.4	LVL2: 3.1.11	
4.3.5	LVL2: 3.2.2.5	
4.3.6	LVL2: 3.2.2.5	
4.3.7	Deleted/Reserved	
4.3.8	Deleted/Reserved	
4.3.9	LVL2: 3.2.2.5	
4.3.10	LVL2: 3.2.11	
4.4.1	LVL2: 3.4.3.6	
4.4.2	LVL2: 3.4.3.6	
4.4.3	LVL2: 3.4.3.6	
4.4.4	LVL2: 3.4.3.6	
4.5.1	LVL2: 3.2.2.5	
4.5.2	LVL2: 3.2.2.5	
4.5.3	LVL2: 3.2.2.5	
4.5.4	LVL2: 3.2.2.5	

CH-01

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APPENDIX D – ABBREVIATIONS AND ACRONYMS

ATMS	Advanced Technology Microwave Sounder	
BER	Bit Error Rate	
C3S	Command, Control, and Communications Segment	
CADU	Channel Access Data Unit	
CCSDS	Consultative Committee for Space Data Systems	
CERES	Clouds and the Earth's Radiant Energy System	CH-02
CrIS	Cross-Track Infrared Sounder	
dB	Decibel	
DMSP	Defense Meteorological Satellite Program	
DoC	Department of Commerce	
DoD	Department of Defense	
EOS	Earth Observing System	
GSFC	Goddard Space Flight Center	
HRD	High Rate Data	
ICD	Interface Control Document	
IPO	Integrated Program Office	
IRD	Interface Requirements Document	
MMC	Mission Management Center	
NASA	National Aeronautics and Space Administration	
NOAA	National Oceanic Atmospheric Administration	
NPOESS	National Polar-Orbiting Operational Environmental Satellite System	
NPP	NPOESS Preparatory Project	
NRZ-M	Non Return to Zero - Mark	
NTIA	National Telecommunications and Information Administration	
OMPS	Ozone Mapping and Profiler Suite	CH-02
POES	Polar-orbiting Operational Environmental Satellite	
QPSK	Quadrature Phase Shift Keying	
RF	Radio Frequency	
SMD	Stored Mission Data	

SS	Space Segment
TBD	To Be Determined
TBR	To Be Resolved
TRD	Technical Requirements Document
VCDU	Virtual Channel Data Unit
VIIRS	Visible-Infrared Imager Radiometer Suite