450-215/EO-1

BASELINE VERSION

NETWORKS AND MISSION SERVICES PROJECT

Detailed Mission Requirements (DMR) Document for the

New Millennium Program Earth Observing-1 (NMP/EO-1)

September 9, 1999

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Greenbelt, Maryland

Table of Contents

Table of Contents (continuation)

Section 1. General Information

1.1 Mission Title & Responsible Organizations

1.1.1 Title

The New Millennium Project Earth Observing-1 (EO-1)

1.1.2 Program Relationships

EO-1 is the first mission of the Earth Observing segment of the National Aeronautics and Space Administration (NASA) New Millennium Program.

1.1.3 Sponsoring/Approving Organization

The EO-1 Project Office (Code 426) is administered under the New Millennium Program, NASA Headquarters, and has overall responsibility for the project's development activities.

1.1.4 Responsibilities for Management, Project, Operations

The NMP EO-1 Project Office is located at the Goddard Space Flight Center (GSFC).

1.1.4.1 Project Roles

Program Office (Headquarters) – Dr. Ghassem Asrar, associate administrator for Earth science, has overall authority over the Earth Science Program.

New Millennium Program Manager (JPL) – Dr. Fuk Li has overall responsibility for the direction and evaluation of the New Millennium Program.

Project Center - Goddard Space Flight Center (GSFC) is responsible for overall project management. Code 470 is responsible for the Delta launch vehicle.

New Millennium Earth Orbiting Program Manager- Within GSFC, Dr. Bryant Cramer has responsibility for the direction and evaluation of New Millennium Program Earth Orbiting missions.

Project Manager for EO-1- Mr. Dale Schulz is the EO-1 Project Mission Manager, and is responsible for ensuring the performance of all functions necessary for the management of all EO-1 project mission responsibilities.

Mission Systems Engineer - Mr. Peter Spidaliere is responsible for the overall mission Systems Engineering. He is supported by the NMP team.

1.1.4.2 Support Roles

EO-1 Mission Scientist - Dr. Steve Unger has responsibility for the overall scientific aspects of the EO-1 mission.

EO-1 Mission Technologist – Mr. Nicholas Speciale has overall responsibility to ensure that the technology objectives are met.

Ground Systems Project Manager - Mr. Daniel J. Mandl oversees the development and integration of the ground data system for the NMP EO-1 mission.

Mission Director - Mr. Mr. Daniel J. Mandl is responsible for the NASA operational support of the spacecraft after launch.

Mission Operations Planning and Support System Engineer- Mr. Randy Harbaugh is responsible for accepting the project's support requirements for the managing, planning, design, implementation, procurement and integration of the operational Mission Operations Center.

Mission Manager (Networks) - Mr. Paulino (Paul) Garza is the principal point of contact for mission support services and is responsible for defining the ground stations', telecommunications and Networks data processing and spacecraft to ground system requirements. He interfaces with the SOMO organization for the implementation of capabilities and integration and testing of required functions to meet mission requirements. He also ensures that all Networks elements are operationally ready to support the mission.

SOMO Center Mission Services Manager - Mr. Richard N. Harris is responsible for coordinating all SOMO support requests of NASA resources in support of the EO-1 mission.

1.2 General Mission Information

1.2.1 Project Description

NMP's first Earth orbiting flight will validate revolutionary technologies contributing to the reduction of costs and increased capabilities for future land imaging missions. These technologies include imaging instrumentation as well as spacecraft systems.

The imaging instruments are:

- Hyperion experiment
- Advanced Land Imager (ALI)
  - Multispectral Imaging Capability
  - Wide Field of View Reflective Optics
  - Silicon Carbide Optics
- Atmospheric Corrector (AC)

The spacecraft systems' technologies are:

- X-Band Phased Array Antenna (XPAA)
- Pulse Plasma Thruster (PPT)
- Light Weight Flexible Solar Array (LFSA)
- Carbon-Carbon Radiator (CCR)
- Enhanced Formation Flying (EFF) with the Landsat-7 spacecraft.

Launch is presently scheduled for December 1999, and the mission duration is one year.

1.2.1.1 Technologies Objectives

The onboard EO-1 technologies have the following objectives:

Technology	Objective
Hyperion	The Hyperion Instrument will support ALI and LAC validation and will demonstrate the capability of hyperspectral imaging spectroscopy for both science and application demonstrations.
Advanced Land Imager (ALI)	The ALI will demonstrate an improved performance, low cost, lower mass multispectral imaging capability which could support future Landsat missions.
Linear Etalon Imaging Spectrometer Array/Atmospheric Corrector (LEISA/AC)	LEISA/AC will demonstrate a moderate resolution (250m GSD) hyperspectral imagery to support correction of land imagery due to atmospheric absorption.
X-Band Phased Array Antenna (XPAA)	XPAA will demonstrate a lightweight, high efficiency X-band Phased Array Antenna for downlinking stored EO-1 science instruments data.
Pulse Plasma Thruster (PPT)	PPT will demonstrate that the pitch wheel can be replaced with a thruster that uses Teflon propellant.
Light Weight Flexible Solar Array (LFSA)	The LFSA will demonstrate a lightweight solar blanket and shockless shaped hinge deployment mechanism to achieve 2 to 3 times the specific power over conventional solar arrays.
Carbon Carbon Radiator (CCR)	CCR is designed to have superior thermal radiating properties over conventional materials.
Enhanced Formation Flying (EFF)	EFF will demonstrate autonomous ground and on-board relative navigation and formation flying control algorithms.

1.2.1.2 Mission Ops Concept

Mission operations for the EO-1 mission will be conducted from the MOC at GSFC and supported by NASA ground stations at Spitzbergen (SGS), in Svalbard, Norway, Poker Flat Alaska, (AGS), the Wallops Ground Station (WGS), Wallops Island, Va., and the McMurdo Ground Station (MGS), Antarctica station. The Space Network (SN) will be used for receipt of housekeeping telemetry during Launch and Early Orbit (L&EO) activities. During L&EO, the Mission Operations Center (MOC) will conduct on-orbit real time operations with increased staffing support to ensure necessary coverage for key launch and in-orbit checkout periods. Thereafter, the MOC will operate during day hours, five days a week. After the nominal 1-year mission, operations will be conducted using a more autonomous procedure mode.

EO-1 will fly in formation with Landsat 7 in order to obtain sets of common data for direct comparison with its equivalent Multi-Spectral (MS)/Pan Bands.

The EO-1 ground segment is shown in Figure 1 - 1, EO-1 Ground System.

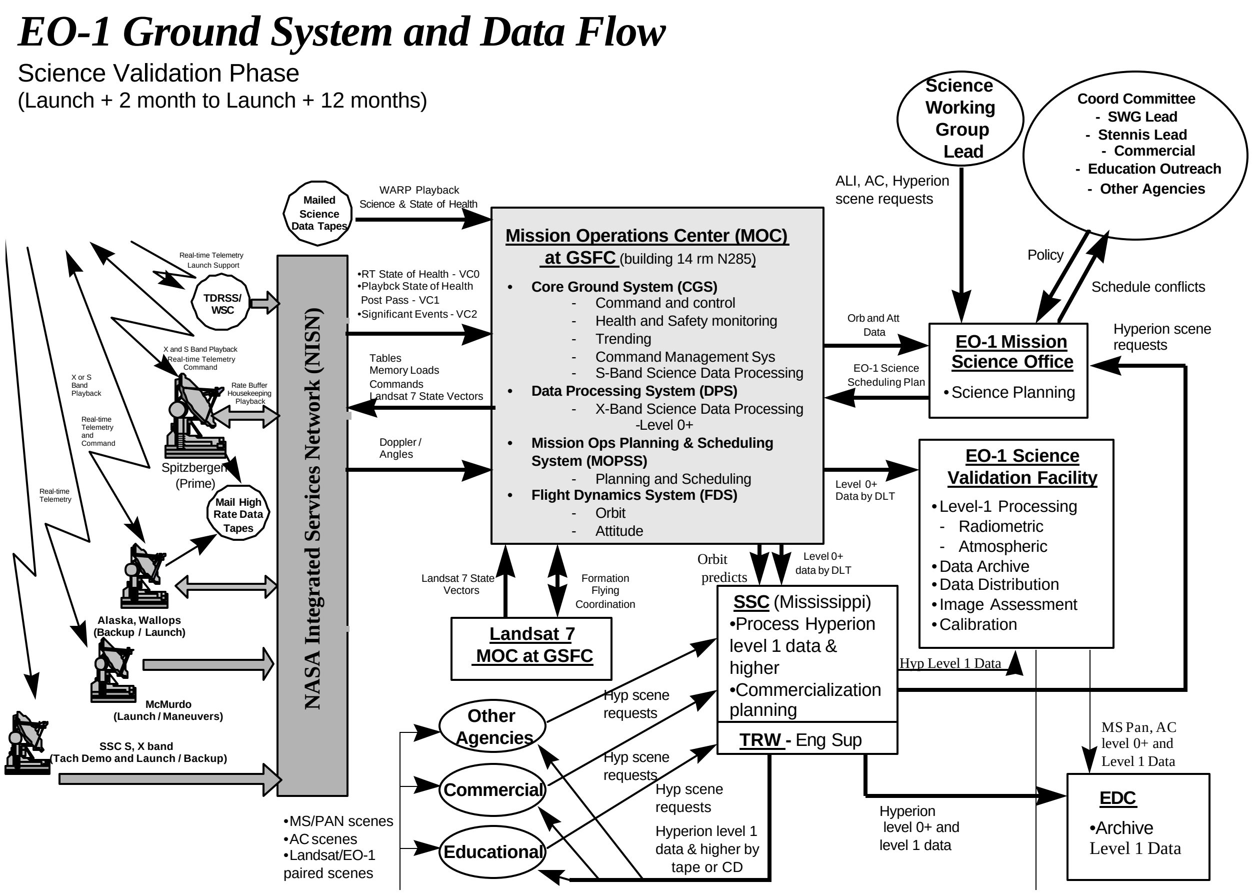

Figure 1 - 1. EO-1 Ground System Operations Overview

Functional Elements

Mission Operations Center (MOC)

The MOC is located within building 14 room N285 in GSFC and will control the EO-1 mission from launch through orbit insertion and on-orbit operations activities. The MOC is the source for spacecraft commands, and it also houses the spacecraft and science (Level Zero Processing +) data processing, tracking processing, and analysis personnel and resources. Spacecraft orbit and attitude determination is performed at the MOC, using two-way Doppler and angle data provided by the remote ground stations. The MOC will create and provide Improved Interrange Vector (IIRV) messages to the Wallops Scheduling Group (WSG) and Network Control Center (NCC) for antenna pointing. The MOC will also provide scheduling predictions and products to the ground stations and NCC, and other mission support elements as required.

Ground Stations

Communications between the spacecraft and the supporting stations are provided as follows:

- Prime, S- and X-band:
  - Spitzbergen, Svalbard, Norway (SGS) station.
- Backup/L&EO, S- and X-band:
  - Wallops Ground Station at Wallops Island (WGS).
  - Alaska station at Poker Flat, Alaska (AGS)
- Backup L&EO and maneuver support, S-band:
  - McMurdo station in Antarctica (MGS).
- Backup L&EO, S-Band
  - Whites Sands Complex (WSC) in New Mexico (S-band return only, no commanding).

Wallops Orbital Tracking Information System (WOTIS)

The WOTIS provides a focal point for Ground Network (GN) direction and operational control of the ground stations activities and resources. Responsibilities of WOTIS include scheduling and control of changes to network services and configurations, conflict resolution, emergency scheduling, scheduling of network testing support, and sending MOC provided IIRVs to the ground stations.

Standard Autonomous File Server (SAFS)

The SAFS systems are located at the ground stations and a central system at GSFC. They provide the MOC with an automated management capability for the timely off-line electronic retrieval of downlinked S-Band telemetry logged at the GN sites. This includes S-band data files for both nominal operations and the 2 Mbps backup science contingency support.

Network Control Center (NCC)

The NCC provides a focal point for Network direction and operational control of the Space Network (SN) activities and resources, including testing and simulations. As such, it provides the real time support interface between the SN and the users. Responsibilities of NCC include scheduling and control of changes to network services and configurations, conflict resolution, emergency scheduling, support of network testing, network performance and status monitoring, acquisition data generation and dissemination. The NCC is also responsible for the direction and control of SN fault isolation, NCC data base management, and development of operations procedures.

White Sands Complex (WSC)

WSC consists of three Ground Terminals (GTs) designated White Sands Ground Terminal (WSGT), Second TDRS Ground Terminal (STGT) and Guam Remote Ground Terminal (GRGT). The GTs operate and maintain the TDRS spacecraft constellation and their functional responsibilities fall within two categories: space segment operation and control, and ground segment operation and control.

The space segment consists of a constellation of satellites operating in geosynchronous orbits. A real-time, frequency translation repeater concept is used in operations of TDRSS telecommunication services for relaying signals between low-altitude earth orbiting spacecraft and the GTs.

The ground segment functions comprise the control, monitoring and maintenance of GT resources and processes, including the receipt, processing, and routing of both forward and return user services, anomaly investigation, control of systems' failovers, and contingency planning and control of the ground segment.

Science Validation Facility (SVF)

The SVF at GSFC is the principal science operations and analysis center and it is provided by the EO-1 Project. The SVF will be primarily a 5-days-a-week, day shift operation, performing instrument planning, data analysis, level 1 data processing, Landsat 7 scene comparison and validation where needed, and data distribution to the science validation team. The SVF will provide image and calibration requests to the MOC MOPSS as per MSO direction.

Mission Science Office (MSO)

The MSO is responsible for implementing mission planning activities. It serves as the sole acquisition input of mission scene requests from the DOD, commercial users and the Validation Team. Coordinating Committee members will establish scene acquisition guidelines and create long-term instrument acquisition plans which are maintained by the MSO.

NASA Integrated Services Network (NISN)/Nascom

NISN provides the voice and data communications circuits among all the supporting elements of the EO-1 mission from Integration and Test (I&T) through the launch and operations phases. This will be accomplished through the TCP/IP networks.

Nascom provides voice and data communications within GSFC facilities including TCP/IP connectivity.

Flight Dynamics Functions

Flight Dynamics support for EO-1 is provided by a team comprised of GSFC and contractor personnel from the Information Systems Center (ISC) and the Guidance Navigation and Control Center (GNCC). This team is designing, developing, integrating and testing the Flight Dynamics Support Subsystem (FDSS) for the EO-1 MOC. Team members provide pre-launch support in matters of orbit determination and maintenance, attitude, mission analysis, acquisition and scheduling data with this support extending for approximately 30 days after launch which is through the spacecraft checkout period. After that time, the operations of the FDSS will be conducted solely by members of the EO-1 Flight Operations team. Should contingencies arise, the ISC and the GNCC will provide assistance and/or consultation on an on call basis.

Launch Site

The EO-1 launch site is the Western Range at Vandenberg, California. Launch operations activities at the launch site require communications to support integration and End-to-End (ETE) testing, operations simulations, and launch. Voice and data communications are required between the launch site and GSFC. NISN provides data switching and monitoring capabilities via the TCP/IP networks.

Launch site internal requirements are defined in the EO-1 Project Requirements Document (PRD). This document describes launch site to GSFC interfaces.

1.2.1.3 Major Mission Phases

Support to the EO-1 mission will be categorized by the phases listed in Table 1-1 below.

Operational Phases	Orbit Type	Activities	Stations
Pre-launch Phase	N/A	Development of requirements, implementation of requirements via development and operation of system.	SGS, WGS, AGS, MGS, TDRSS
Launch Phase	Ascent	Final on-launch preparations; launch, launcher trajectory, injection, separation.	SGS, WGS, AGS, MGS, TDRSS
Early Orbit Phase (approx. 7 days)	Circular Polar Orbit	EO-1 activation, stabilization, deployment, initial acquisition, mission attitude established.	SGS, WGS, AGS, MGS, TDRSS
Spacecraft Checkout Phase (through day 17)	Orbit Formation Trim	Checkout and calibration of spacecraft. Validation of spacecraft control. Perform initial orbit formation trim burns.	SGS, WGS, AGS, MGS
Instrument Checkout Phase (through day 60)	Orbit Formation Trim	Checkout and calibration of instruments. Perform instrument functional and performance verification. Establish and maintain orbit formation.	SGS, WGS, AGS, MGS
Normal Operations Phase	Orbit Formation Maintenance	Maintain close separation with Landsat 7 (as close as one minute). Science validation of ALI, Hyperion and AC. Perform technology validation.	SGS, WGS, AGS, MGS
Extended Mission Phase	Circular Polar Orbit	If approved, after one year of operations.	SGS, WGS, AGS, MGS
Termination Phase	Circular Polar Orbit	Termination of mission operations.	SGS, WGS, AGS, MGS

Table 1-1. Operational Phases

1.2.2 Spacecraft/Payload Description

The EO-1 spacecraft will weigh approximately 588 Kg in the launch configuration, measuring approximately 1.9 meters in height and 1.5 meters in width. The total power at the Beginning-of-Life (BOL) is 750 watts. The spacecraft will be three-axis stabilized and nadir pointing in all mission phases. It will also maintain instrument and solar array Sun pointing.

1.2.2.1 Spacecraft/Payload Characteristics

The spacecraft consists of five main subsystems:

a. Structure. This subsystem will support and carry the EO-1 instruments and all other subsystem components.

b. Command and Data Handling (C&DH). This subsystem provides the communications link between the spacecraft and the ground, and within the spacecraft itself. Most C&DH functions are implemented within the Mongoose V processor. The MV processor provides the onboard capability to perform mission-unique functions as required, and provides autonomous operation of the spacecraft when it is not in contact with the ground.

c. Attitude Control System (ACS). The ACS provides 3-axis attitude control and determination for all phases of operations after separation from the launch vehicle. The ACS is comprised of the MV's ACS software, the Attitude Control Electronics (ACE) box, and a complement of sensors and actuators consisting of:

- Sensors
  - Gyros
  - Coarse Sun sensors
  - Star tracker
  - Global Positioning System (GPS) receivers
- Actuators
  - Reaction wheels
  - Magnetic torque rods
  - Thrusters

d. Power. The major components of the subsystem are the solar array, battery, and Power System Electronics (PSE). Power, generated by the solar panels, is supplied directly to the observatory loads. The busses are maintained at +28 volts during all mission phases. A Super Nickel-Cadmium (NiCd) battery stack supplies energy when spacecraft power requirements exceed array capability and during eclipse periods. The PSE controls battery charging and dissipation of excess energy through shunt regulators.

e. Thermal. This control subsystem will use passive thermal control elements, selected surface finish coatings, regulated conduction paths, and thermostatically-controlled heaters to regulate the internal spacecraft temperature.

1.2.2.2 Spacecraft/Payload Drawing

Figure 1-2 shows the deployed spacecraft.

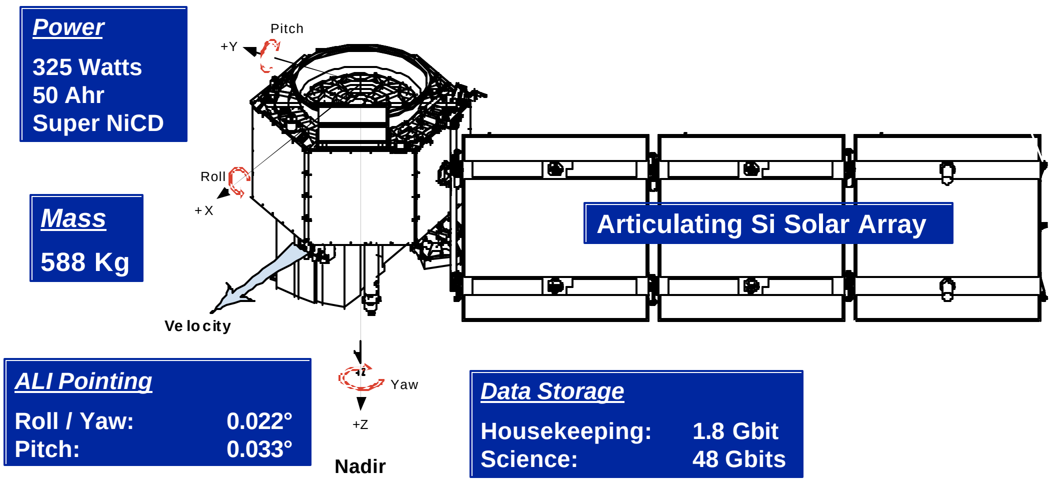

Figure 1 - 2. EO-1 Spacecraft

1.2.2.3 Spacecraft/Payload Telecommunications Subsystems

The telecommunications subsystem has both X- and S-band capabilities. The spacecraft has S-band semi omni-directional antennas and GPS patch antennae on both nadir and zenith-pointing surfaces. The S-band is intended for both command and control and housekeeping telemetry. One of the new technologies, a 64-element X-band phased array antenna is located on the nadir-pointing surface of the spacecraft. Imaging data will nominally be downlinked at a high data rate via the X-band system, but a backup capability is provided to downlink the data at a reduced rate via S-band. The data rates supported by the stations are listed in table 1 - 2 and the spacecraft RF communications subsystem is shown in figure 1 - 3 below.

The EO-1 spacecraft antenna complement is comprised of two transmit/receive S-band semi omni antennae and a transmit-only body-fixed X-band Phase Array Antenna (XPAA). One of the semi omni antennae is zenith facing and the other nadir facing. The semi omni antennae are right-hand circularly polarized (RHCP). Both antennae are connected by a diplexer to provide at least 80 percent hemispherical coverage for the spacecraft-to-GN links (70 percent for the backup payload mode). The 64-element X-band PAA provides a steerable beam which can be directed for 360 degrees of azimuth by up to 65 degrees from XPAA boresite. ACS software provides commands to vary phase of individual phase array elements to steer downlink to commanded downlink site. The PAA is left-hand circularly polarized (LHCP) with a 3 dB beam width which varies from 18 to 30 degrees depending on scan angle. Each of the 64 XPAA transmit elements contains its own solid state power amplifier.

Stations	Purpose	Band and Data Rate
Spitzbergen (SGS) (Primary)	- Uplink command - Downlink stored and real-time telemetry - Downlink stored science data - Backup downlink stored payload data	- S-band @ 2 kbps - S-band @ 1 Mbps, 32 kbps, 2 kbps - X-band @ 105 Mbps - S-band @ 2 Mbps
Wallops (WGS) and Alaska (AGS) (Backup/L&EO)	- Uplink command - Downlink stored and real-time telemetry - Downlink stored science data - Backup downlink stored payload data	- S-band @ 2 kbps - S-band @ 1 Mbps, 32 kbps, 2 kbps - X-band @ 105 Mbps - S-band @ 2 Mbps
McMurdo (MGS) (L&EO and backup Maneuver Support)	- Uplink command - Downlink stored and real-time telemetry	- S-band @ 2 kbps - S-band @ 32 kbps, 2 kbps
White Sands Complex (WSC) (Backup L&EO, Anomaly support)	- Downlink real-time H/K telemetry during launch.	- S-band @ 2 kbps

Table 1 - 2. EO-1 Data Types and Data Rates Summary

The XPAA amplifies and radiates the signal supplied via coaxial cable from a modulator/exciter, which is contained within the Wideband Advanced Recorder Processor (WARP).

The X-band exciter/modulator within the WARP consists of a modulo 4-gray differential code QPSK modulator, an upconverter and a solid state power amplifier. An internal voltage control oscillator (VCO) is used to generate the 8225 MHz carrier frequency.

The EO-1 spacecraft S-band transponders will always be operating in receive mode during normal on-orbit operation. The spacecraft will not transmit telemetry to the GN stations unless commanded by the EO-1 Mission Operations Center (MOC). The transmitter in the transponder is commandable On or Off. The S-band transponder down-converts and demodulates the received signals, recovers the baseband command data and clock signal. The recovered command data and clock signal, along with a lock indicator, are sent to the C&DH subsystem for command processing and execution. The spacecraft shall be accommodated by GN through the use of the spacecraft transponder STDN link mode.

EO-1 DMR
Baseline
Sep 9, 1999

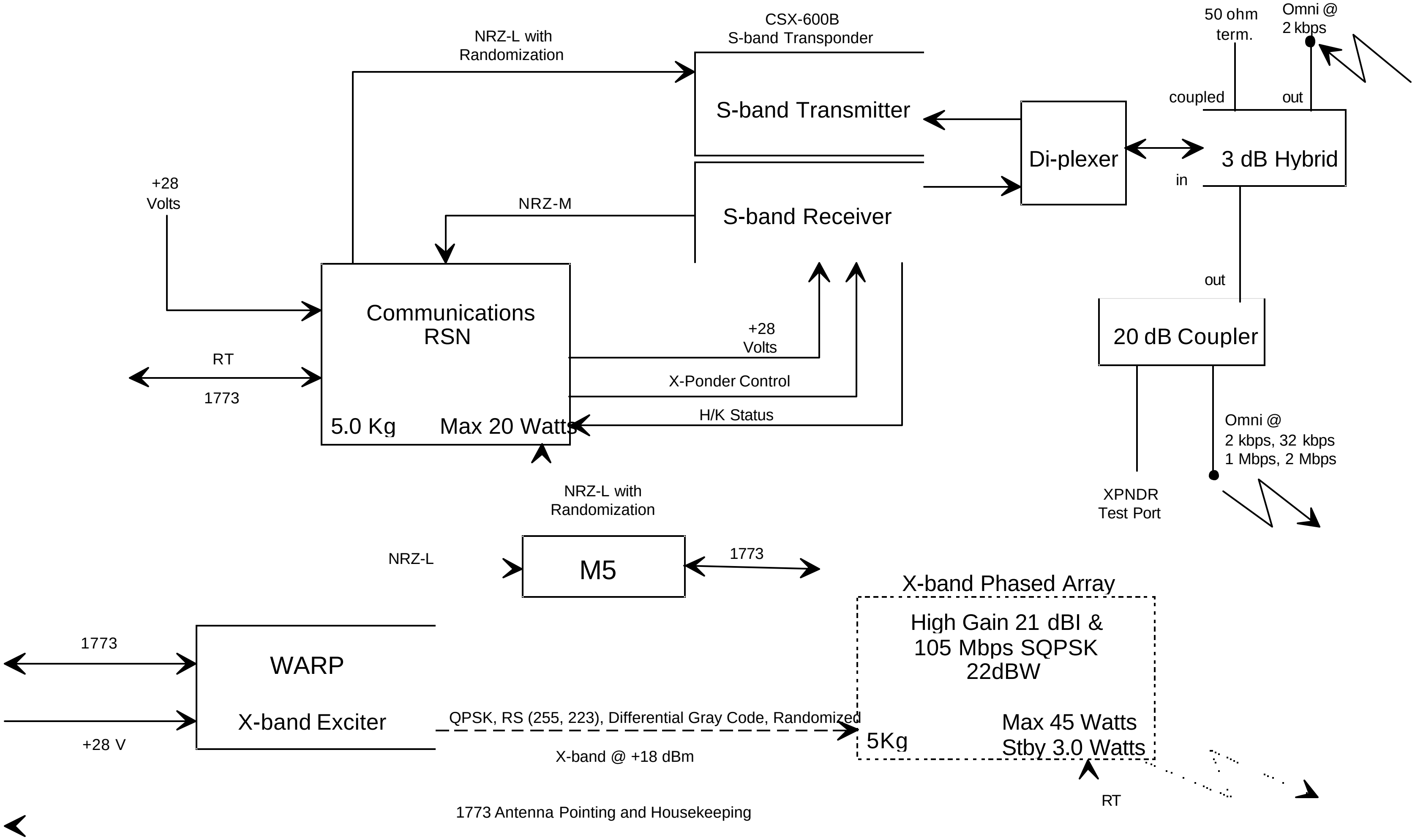

Figure 1-3. Spacecraft RF Subsystem Block Diagram

1.3 General Launch Information

The EO-1 spacecraft will be launched on a Delta 7320 launch vehicle co-manifested with the Argentine's Satelite de Aplicaciones Cientificas - C (SAC-C) from Vandenberg Air Force Base (VAFB), California. EO-1 is presently scheduled for a December 1999 launch, and the launch window is constrained by the requirement to be in the same plane as the Landsat 7 spacecraft. This limits the window to one or two minutes once every day.

Refer to the 501-601/Network Operations Support Plan for the Delta Launch vehicle for details of launch operations.

1.3.1.2.1 Major Mission Events

Major mission events for the launch phase are summarized in table 1 - 3 below. These data is provided for information only. The actual mission events will be provided via ISI within a month of launch.

Needs update

Event	Time (Min:Sec)	Station Visibility (Nominal Launch)
Liftoff	0.00	***TBS***
Solid Motor Burnout (3)	1.04	
Solid Motor Separation (3)	1.50	
Main Engine Cutoff	4.21	
Vernier Engine Cutoff	4.27	
Stage 1-2 Separation	4.29	
Stage 2 Ignition	4.35	
Jettison 10 ft. Composite Fairing	5.00	
First Cutoff - Stage 2 (Second Engine Cutoff 1)	10.48	
Stage 2 Restart	50.00	
Second Cutoff - Stage 2 (Second Engine Cutoff 2)	50.14	
Separate EO-1 Spacecraft	55.00	
Separate Portion of Dual Payload Attachment Fitting	59.10	
Separate SAC-C Spacecraft	63.20	
Spitzbergen (SGS), Norway * AOS - LOS	75.24 - 86.52	
Poker Flat (AGS), Alaska * AOS - LOS	89.28 - 99.35	
Second stage Evasive Burn Ignition	100.00	
Third Cutoff - Stage 2 (Second Engine Cutoff 3)	100.05	
Second Stage Depletion Burn Ignition	108.20	
Stage 2 Depletion	109.00	
McMurdo (MGS), Antarctica * AOS – LOS	126.19 – 138.6	
Spitzbergen (SGS), Norway * AOS - LOS	174.18 – 187.05	***TBS***

Table 1 - 3. Major Launch Events

1.4 Orbit/Trajectory

The nominal operational orbit will be a circular polar orbit with a mean altitude of approximately 705 kilometers, with a inclination of 98.2 degrees, an orbital period of 98.9 minutes and a descending node that will be one minute behind that of Landsat-7's descending node at the time EO-1 is launched.

During the EO-1 mission operations phase, the spacecraft orbit will be controlled so that it maintains an orbit with high precision relative to Landsat 7 (one minute behind Landsat 7 on the same ground track). This will be performed via a ground command initially, switching to autonomously with ground support confirmation as a demonstration of new technology after approximately 90 days. Formation flying with Landsat 7 will enable the same scenes to be taken from both spacecraft at nearly the same time and under nearly the same environmental conditions. Refer to figure 1 - 4 below for the relative orbit between the spacecraft.

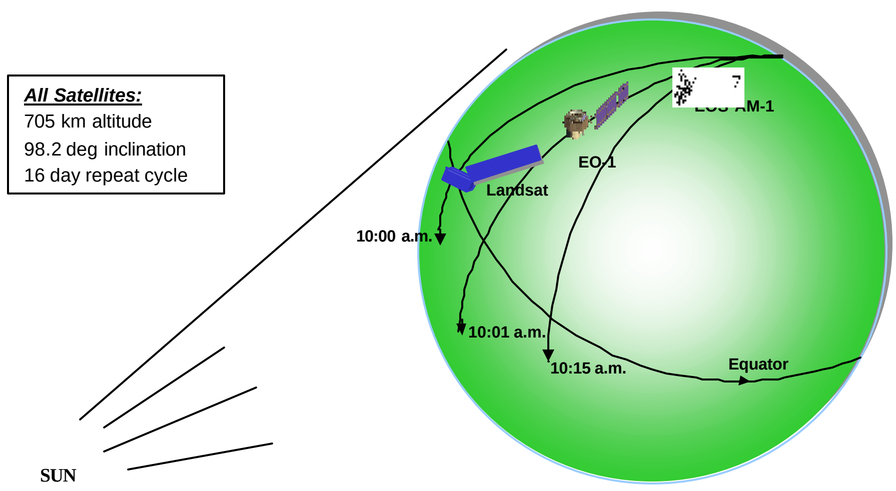

Figure 1 - 4. EO-1 Orbit Relative to Landsat 7 Spacecraft

1.5 References

1.5.1 Aerospace Data System Standards

Consultative Committee for Space Data Systems (CCSDS) Recommendations

1.5.1.1. CCSDS 401.0-B-2; Radio Frequency and Modulation Systems; Part 1: Earth Stations and Spacecraft

1.5.1.2. CCSDS 101.0-B-3; Telemetry Channel Coding

1.5.1.3. CCSDS 701.0-B-2; Advanced Orbiting Systems, Networks and Links: Architectural Specification

1.5.1.4. SMRD 3.1.7

1.5.2 Other Project/Technical Documentation

1.5.2.1. EO-1 Radio Frequency Interface Control Document, STDN 450-RFICD-EO1/STDN, April 1999.

1.5.2.2. EO-1 Mission Requirements Request (MRR) /Project Service Level Agreement (PSLA)

1.5.2.3 NASA Spacecraft to Ground Interface Control Document, Version 2, dated June 26, 1998 (or latest version).

1.5.2.4 EO-1 Ground Functional and Performance Requirements, dated March 30, 1999 at: eo1.gsfc.nasa.gov

Section 2. RF Telecommunications

2.0 Summary

The GN and SN Detailed Mission Requirements Document presents requirements that are levied on NASA's Network. The GN includes the S-band and X-band antenna ground stations at Spitzbergen, Svalbard, Norway, (SGS), Poker Flat Alaska, (AGS), the Wallops Ground Station, Wallops Island, Va., (WGS) and the McMurdo, Antarctica station (MGS). The SN includes the Tracking and Data Relay Satellites, the White Sands Complex, and the Network Control Center (NCC). The EO-1 mission support will be required from the SN for support of EO-1 launch and early orbit operations, and emergency support during the mission. The EO-1 launch is planned for December 1999, and early orbit support will be limited to the first 60 days. Emergency support will be limited to times when the health and welfare of the mission are in jeopardy. The mission lifetime requirement is 1 year. The assigned EO-1 spacecraft ID is 189 hexadecimal.

The EO-1 mission will require the following SN and GN support:

<u>SN</u>

- 15 passes (approx.) with average 30 mins. each - first full day
- 1 or 2 passes with average 20 mins. each – for special operations

<u>GN</u>

- 15 passes per day - first week
- Up to 8 passes per day - first 60 days
- 3 passes per day – normal operations through one year
- 1 to 2 additional supports per week - for special operations

Note

Special operations may consist of orbit maneuvers, and instrument lunar and solar calibrations, throughout the mission period.

On S-band, the nominal telemetry downlink rate will be 1 Mbps, which includes stored housekeeping, event, new technology, and real-time data. The spacecraft also has a real-time housekeeping data only downlink mode, at 2 kbps or 32 kbps. SN will support 2 kbps data rate only. The 2.0 Mbps S-band downlink is a backup to the X-band science data, which is normally downlinked at 105 Mbps rate to the GN. The X-band signal is transmitted using LHCP.

The spacecraft communicates with the ground using two S-band RHCP semi omni antennae. The data is transmitted simultaneously through both antennae. At certain angles, there may be nulls in the antenna pattern, mainly for uplink mode, due to interference between the two antennae.

Further RF communications details are contained in the EO-1 GN/SN Radio Frequency (RF) Interface Control Document (ICD), dated April 1999.

2.1 RF Link Properties

2.1.1 Frequency Utilization Summary

EO-1 frequency utilization is shown in table 2 - 1 below.

2.1.2 Telemetry and Command Frame Structure

2.1.2.1 Telemetry Frame Structure

The EO-1 telemetry system is CCSDS compliant for both S-band and X-band data.

Link Frequency	Link Mode	Modulation	Data Rate/ Encoding Scheme	Data Type	Mod Index CMD	Mod Index TLM	Purpose and Remarks
S-Band Uplink 2039.65 MHz	Uplink	PCM/PSK/PM	2.0 kbps on 16 kHz sub-carrier	NRZ-M	0.5 rad		Real-time command, Doppler tracking
S-Band Downlink 2215.0 MHz (Note 1)	Downlink	PCM/BPSK/PM	1.0 Mbps Randomized, Reed-Solomon and CRC	NRZ-L		1.57 rad	Stored/real time housekeeping telemetry
	Downlink	PCM/BPSK/PM	32 kbps, or 2 kbps Randomized, Reed-Solomon and CRC	NRZ-L		1.57 rad	Real-time housekeeping telemetry
	Downlink	PCM/BPSK/PM	2.0 Mbps Randomized, Reed-Solomon and CRC	NRZ-L		1.57 rad	Stored payload/science data (backup to X-band)
X-Band Downlink 8225. 0 MHz	Downlink	PCM/QPSK/PM	I Ch: 52.5 Mbps Q Ch: 52.5 Mbps (I:Q Power Ratio	NRZ-L		1.57 rad	Science Data

			1:1)				

Notes: 1. S-band links are 1/2 rate convolutionally encoded.

Table 2 - 1. Frequency Utilization Summary

Refer to figure 2-1 for the S-band and X-band telemetry data format, and to table 2-2 for the virtual channel assignments.

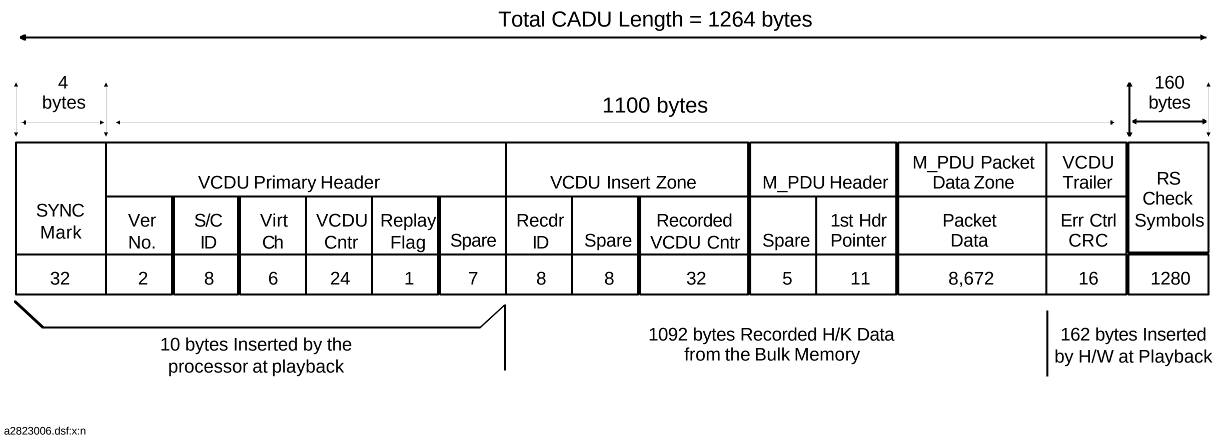

Figure 2 - 1. S-Band and X-Band Telemetry Data Format

2.1.2.2 Command Frame Structure

The EO-1 command system is also CCSDS compliant. Refer to figure 2 - 2 for the command data format. Further telemetry and command data interface details are contained in the EO-1 Spacecraft to Ground Interface Control Document (ICD), version 2, dated June 26, 1998.

2.2 Networks

2.2.1 SN Requirements

The SN SSA service is required to support the launch and early orbit phase of the EO-1 mission to maximize the amount of time for real-time housekeeping telemetry contacts. SN will support 2 kbps telemetry data only. There are no requirements for tracking or forward services. The SN requirements are listed in tables 2-3 and 2-4, and the SN support configuration is shown in figure 2-4.

VC	Data Type	2 Kbps (S Band)	32 Kbps (S Band)	1 Mbps (S Band)	2 Mbps (S Band)	105 Mbps (X Band)	Storage Medium
0	R/T State Of Health, Table Dumps, Software Dumps, Spacecraft Events Dump	Y	Y	Y	Y	N	Real time from Station
1	P/B State Of Health (VR1)	N	N	C	C*	N	FTP'd to server post pass
2	P/B Spacecraft Events (VR2)	N	N	C	C*	N	Transfer post pass playback
3	P/B State Of Health from WARP	N	N	N	C	C	AMPEX Tape
4	P/B GPS B Packet (VR3)	N	N	C*	C*	N	FTP'd to server post pass
6	Hyperion SWIR	N	N	N	C	C	AMPEX Tape
7	Hyperion VNIR	N	N	N	C	C	AMPEX Tape
8	ALI MS / PAN	N	N	N	C	C	AMPEX Tape
9	LEISA / AC	N	N	N	C	C	AMPEX Tape
11	Retransmit State Of Health (VR1)	N	N	C*	C*	N	FTP'd to server post pass
12	Retransmit Spacecraft Events (VR2)	N	N	C*	C*	N	FTP'd to server post pass
14	Retransmit GPS B Packet (VR3)	N	N	C*	C*	N	FTP'd to server post pass
62	Fill Data from WARP	N	N	N	C (WARP)	C (WARP)	Not stored
63	Fill Data from C&DH	Y	Y	C	Y (from M5)	Y (WARP)	Not stored

Y - Will occur
C - Occurs on command
C* - Occurs on command (not routinely planned)
N - Will not occur

Table 2-2 Virtual Channel Assignments

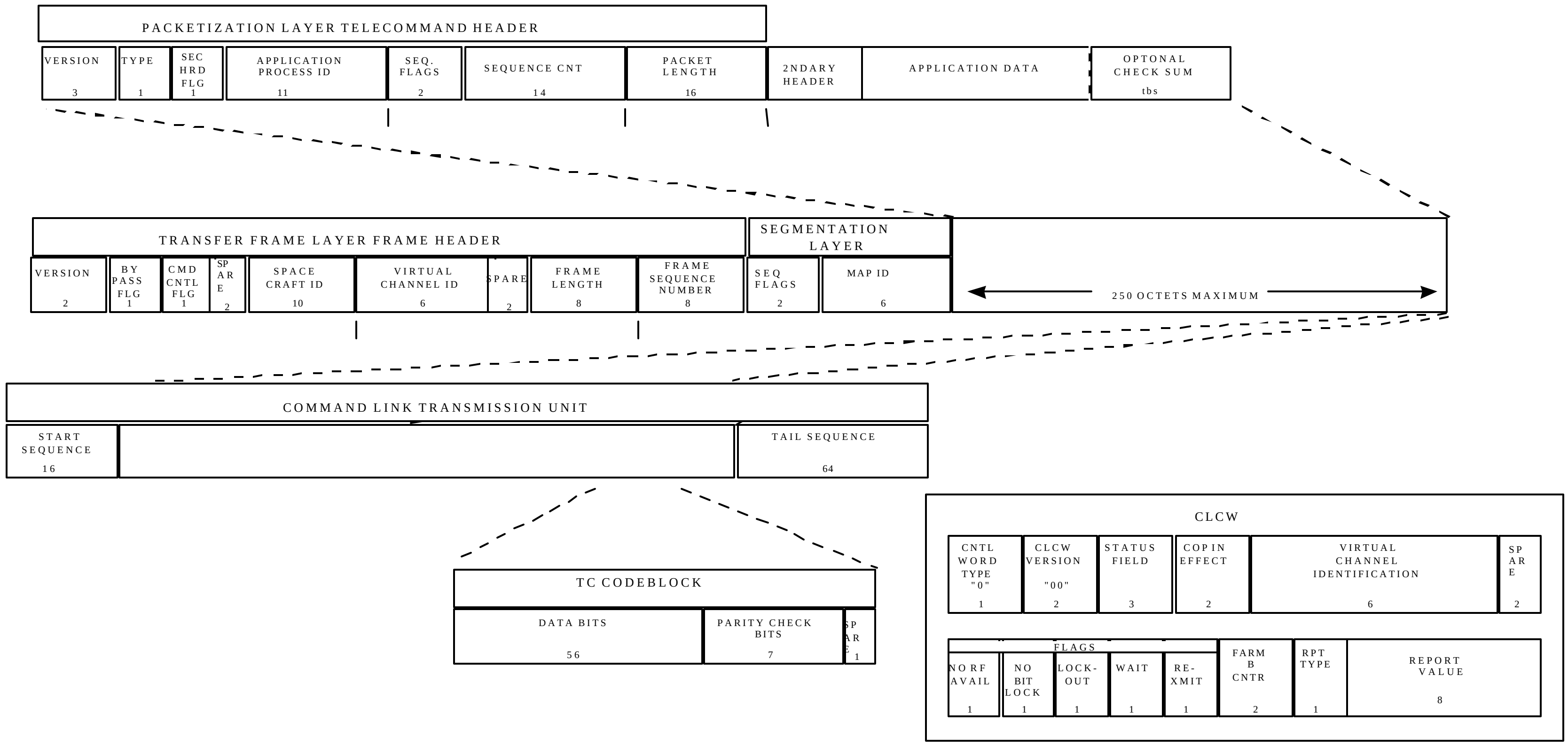

Figure 2-2. S-Band Command Data Format

Requiremen t No.	Requirement Description	Response
	Scheduling/Acquisition Data	
221.1	The SN NCC shall accept requests via voice, e-mail or facsimile from the EO-1 MOC for scheduling the SN service, generating Ground Control Messages Requests (GCMRs) to reacquire SSA services as required (but not to change data rates), and providing status on the SN operations in support of EO-1	
221.2	The SN NCC shall accept an IIRV of the EO-1 orbit from the EO1 MOC. The vector shall be provided by FTP.	
	Tracking	
	There are no SN requirements to provide tracking data services.	
	Telemetry	
221.3	The SN shall provide SSA Return services (DG2 noncoherent mode) to EO-1 during the launch and early orbit checkout of the EO-1 spacecraft.	
221.4	EO-1 will use the SSA return link during separation and for approximately 15 orbits.	
221.5	After the initial checkout, the following TDRS support may be requested for EO-1: a. Initial lunar scan - (1 orbit duration) at approx. launch + 3 weeks. b. Initial solar calibration - (1 orbit duration) at approx. launch + 4 weeks. c. Initial orbit maneuver – (1 orbit duration) at approx. launch + 1 to 2 weeks) d. Inclination burn - (1 orbit duration) at approx. launch + 6 months. e. Emergency - (duration as required) - if significant contingency occurs.	
221.6	The EO-1 contacts will be as long as required for mission critical events.	

Table 2 - 3. SN Requirements Summary

221.7	The SN shall provide SSA Return service to EO-1 to support spacecraft anomaly investigations.	
221.8	The data rate for the SSA service will be 2 kbps.	
221.9	The SN shall time-annotate EO-1 telemetry Virtual Channel Data Units with an accuracy of at least 10 milliseconds.	
221.10	The throughput delay (time of reception from the satellite to transmission to the MOC) at the SN for R/T telemetry shall be less than 4 seconds.	(Requirement deleted.)
221.11	SN shall transmit all data to the MOC via TCP/IP protocol using the SMEX header as specified in the EO-1 Space to Ground ICD.	
221.12	The SN shall provide a BER of 10E-5 at the output of WSC bit synchronizer interface.	
	Command	
	There are no SN requirements to provide command data services.	

Table 2 - 3. SN Requirements Summary (Cont.)

Mission Phase	**Service Name**	**Data Group**	**Data Type/ (BPSK Modulation)**	**Data Rate**	**Mod Index (rad)**	**Contacts Day**	**Duration**
L&EO	SSA	DG2	Single channel	2 kbps	1.57	15	30 mins.
Special Operations	SSA	DG2	Single channel	2 kbps	1.57	1 or 2	20 mins.

Table 2 - 4. SN - SSA Return Link Requirements Overview

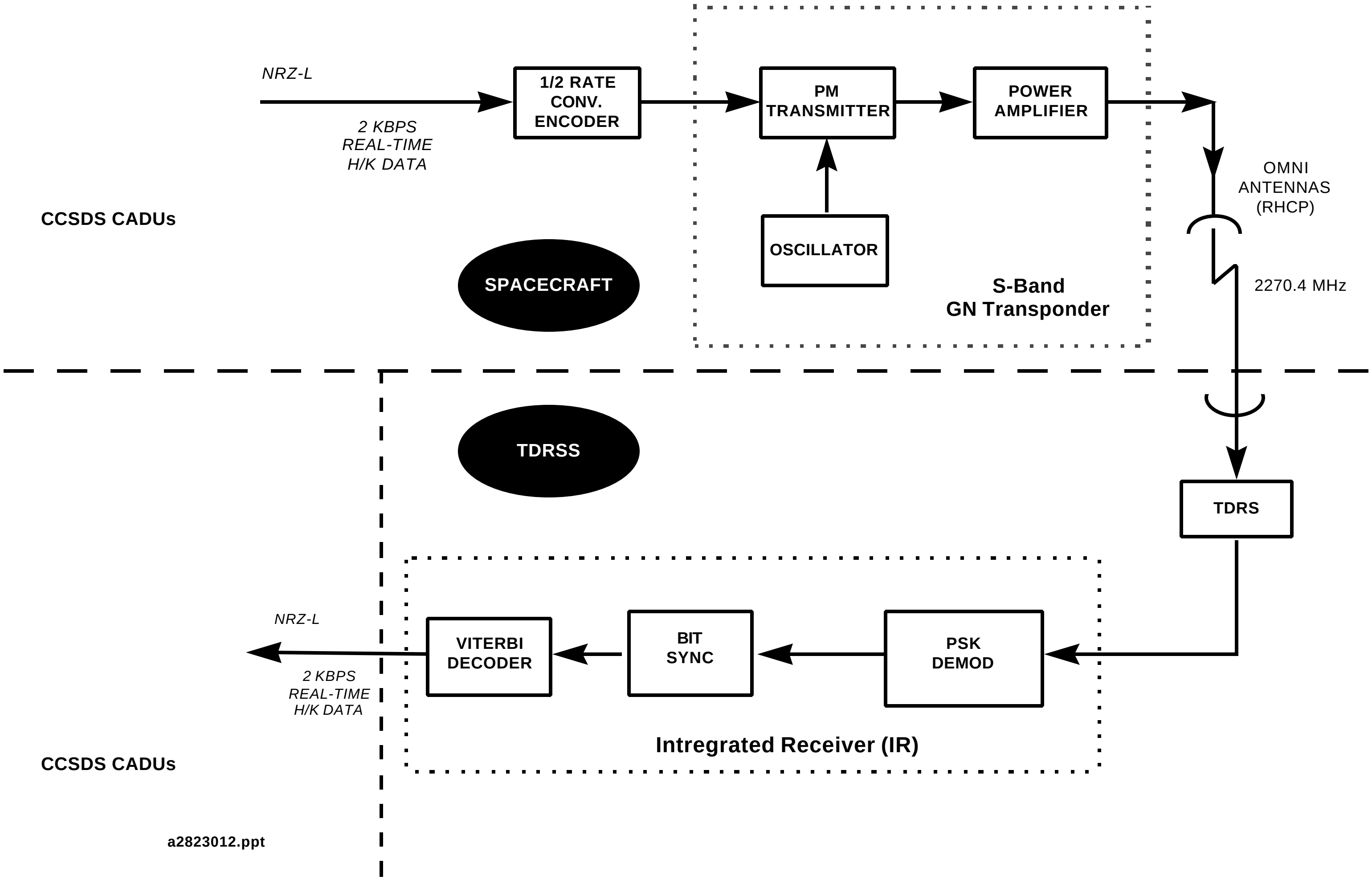

Figure 2 – 3. Spacecraft/SN S-band Downlink Configuration

2.2.2 DSN Requirements

Not applicable

2.2.3 GN Requirements

Upon request from the E0-1 MOC, the Wallops Flight Facility (WFF) is required to arrange spacecraft support from the ground stations at Spitzbergen (SGS), Norway, the Wallops Ground Station (WGS) at Wallops Island, at Poker Flat (AGS), Alaska, and at McMurdo (MGS), Antarctica. The GN requirements are listed in tables 2-5 and 2-6, and the GN support configuration is shown in figures 2-5, 2-6, 2-7 for S-band downlink, X-band downlink, and S-band uplink respectively.

Requirement No.	Requirement Description	Response
	Scheduling/Acquisition Data	
223.1	Wallops Scheduling Group (WSG) shall automatically generate schedules for the ground stations based on requests from the EO-1 MOC and according to mission generic scheduling rules.	
223.2	The WSG shall accept IIRVs of the EO-1 orbit from the MOC for distribution to the ground stations. The vectors shall be provided via FTP.	
223.3	During L&EO, WSG shall receive and process acquisition data updates so that the stations can be ready to support within 30 minutes of receipt from GSFC. For MGS during launch, the MOC will e-mail the updated vector directly to MGS. MGS will then manually input the new vector into their system in preparation for the first pass.	
223.4	In case of S/C emergency, ground stations will provide support according to their call-in period as follows: WGS = 30 minutes, SGS, MGS and AGS = 2 hours.	
	Tracking	
223.5	The GN (except MGS) shall provide the MOC FDSS angle tracking and Doppler data as scheduled.	
223.6	Doppler Tracking. The GN (except MGS) shall generate 2-way Doppler during each pass as commanded by the MOC. Initial acquisition will be non-coherent, then MOC will command the spacecraft to coherent mode.	

Table 2 - 5. GN Requirements Summary

	Tracking (cont.)	
223.7	The 3-sigma tracking accuracy required from GN (except MGS) is as follows: Noise / Bias Doppler: 1.0 mm/sec / 0.0 Angles: 0.01 degrees / 0.08 degrees	
	Telemetry	
223.8	The GN shall provide S- and X-band telemetry data services during the EO-1 mission life cycle.	
223.9	The GN shall time tag EO-1 telemetry data with an accuracy of at least 10 milliseconds.	
223.10	The throughput delay (time of reception from the satellite to transmission to the MOC) at the GN for real time telemetry shall be less than 4 seconds.	
223.11	The data rates for each station and link are specified in table 2-5 below.	
223.12	GN shall receive S-band telemetry downlink, process and transfer in real-time housekeeping VC0 and VC2 data to the MOC via TCP/IP protocol.	
223.13	GN shall perform telemetry data derandomization prior to distribution to the MOC. The MOC will perform Reed Solomon data decoding. Stations shall use downlinked CRC value to evaluate telemetry data quality.	
223.14	GN shall provide data quality annotation to each S-band telemetry frame which is determine based on frame lock status and check of downlinked CRC.	
223.15	GN shall receive S-band telemetry downlink, and transfer all S-band data to the SAFS within 1 hour. The MOC will retrieve data from SAFS as required.	

Table 2 - 5. GN Requirements Summary (Cont.)

	Telemetry (cont.)	
223.16	In the event of a problem with the real time transmission, the GN shall provide the SAFS capability to transfer stored telemetry via File Transfer Protocol (FTP) to the MOC post-pass.	
223.17	GN shall receive S-band 2 Mbps science data (backup for X-band), and transfer data to the MOC via SAFS FTP post pass.	
223.18	All stations, except MGS, shall receive X-band 105 Mbps science data, record to Ampex recording system model DIS260, and mail to the MOC as follows: Period / Stations / Mailing Frequency - Launch + 60 days: WGS — Daily; Either AGS or SGS — Daily - After L+60 days: Either AGS or SGS — Twice a week - S/C Anomaly: WGS — Within 24 hours Tapes will contain EO-1 data only and be labeled with time and pass number information.	
223.19	The GN shall be capable of storing and maintaining all raw telemetry data for up to 7 days for S-band data and 30 days for X-band data or as directed by the MOC.	(TBD)
223.20	The GN shall replay S-Band or send the backup X-Band tape as requested by the MOC.	
223.21	The GN shall monitor data quality during the X-band downlinks. The baseband quality parameters shall be collected on a per channel basis and consist of the number of frame syncs detected, number of R/S errors and virtual channel counts.	(Depends on Project providing DQM equipment)
223.22	The GN shall forward the X-band data quality information as a report sent electronically within 2 hours after each pass.	
223.23	The GN shall provide a BER of 10E-5 at the output of the station bit synchronizer interface.	
223.24	During L&EO and Contingency Ops, the Wallops station shall acquire and record selected X-band data which shall be sent on next available express delivery to MOC.	

Table 2 - 5. GN Requirements Summary (Cont.)

	Command	
223.25	The GN shall provide S-band command data services during the EO-1 mission life cycle. Details are provided in the EO-1 Space-to-Ground ICD.	
223.26	The command data rate will be 2 kbps NRZ-M formatted data which phase-shift-key modulates a 16 kHz sinusoidal subcarrier. The command data bit clock shall be coherent with the 16 kHz subcarrier.	
223.27	The GN shall generate an alternating one/zero idle pattern at the PSK modulator when carrier is locked and no commands are being transmitted. The commands will override the idle pattern when uplinking commands to the spacecraft.	
223.28	The GN 11-meter antenna stations shall provide a minimum EIRP of at least 97-dBm (94-dBm for 10-meter McMurdo station) signal at the uplink antenna output.	
223.29	The GN shall not introduce errors into the EO-1 command data at a BER greater than 10E-6 referenced to the spacecraft differential decoder output.	
	Station Status Monitoring	
223.30	The GN (except MGS) shall provide station status data to the MOC every ten seconds formatted as defined in the Space to Ground ICD. This shall include status on the following information: • station configuration • signal levels • antenna • carrier and telemetry lock status (S- and X-band) • telemetry and command statistics to include per VC S-band telemetry quality	
223.31	The GN (except MGS) shall provide post-pass pass summary report regarding contact related operations, i.e. command, telemetry, tracking, and record activities, etc. within two hours after the pass.	

Table 2 - 5. GN Requirements Summary (Cont.)

Stations	Purpose	Band and Data Rate
Spitzbergen (SGS) (Primary)	- Uplink command - Downlink stored and real-time telemetry - Downlink stored science data - Backup downlink stored payload data	- S-band @ 2 kbps - S-band @ 1 Mbps, 32 kbps, 2 kbps - X-band @ 105 Mbps - S-band @ 2 Mbps
Wallops (WGS) and Alaska (AGS) (Backup/L&EO)	- Uplink command - Downlink stored and real-time telemetry - Downlink stored science data - Backup downlink stored payload data	- S-band @ 2 kbps - S-band @ 1 Mbps, 32 kbps, 2 kbps - X-band @ 105 Mbps - S-band @ 2 Mbps
McMurdo (MGS) (L&EO and Backup Maneuver Support)	- Uplink command - Downlink stored and real-time telemetry	- S-band @ 2 kbps - S-band @ 32 kbps, 2 kbps

Table 2 - 6. GN Stations and Link/Data Rates Summary

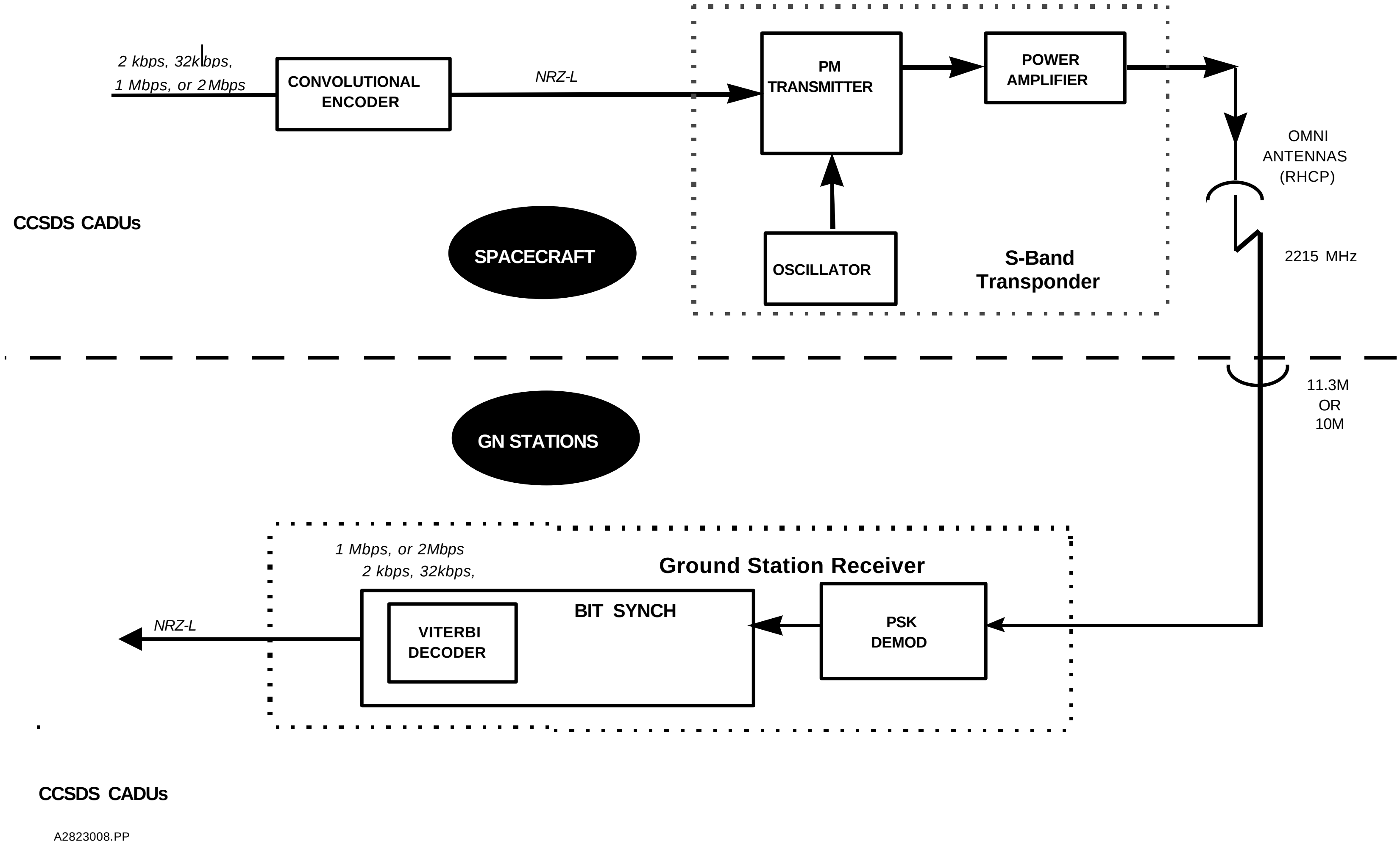

Figure 2 – 4. Spacecraft/GN S-band Downlink Configuration

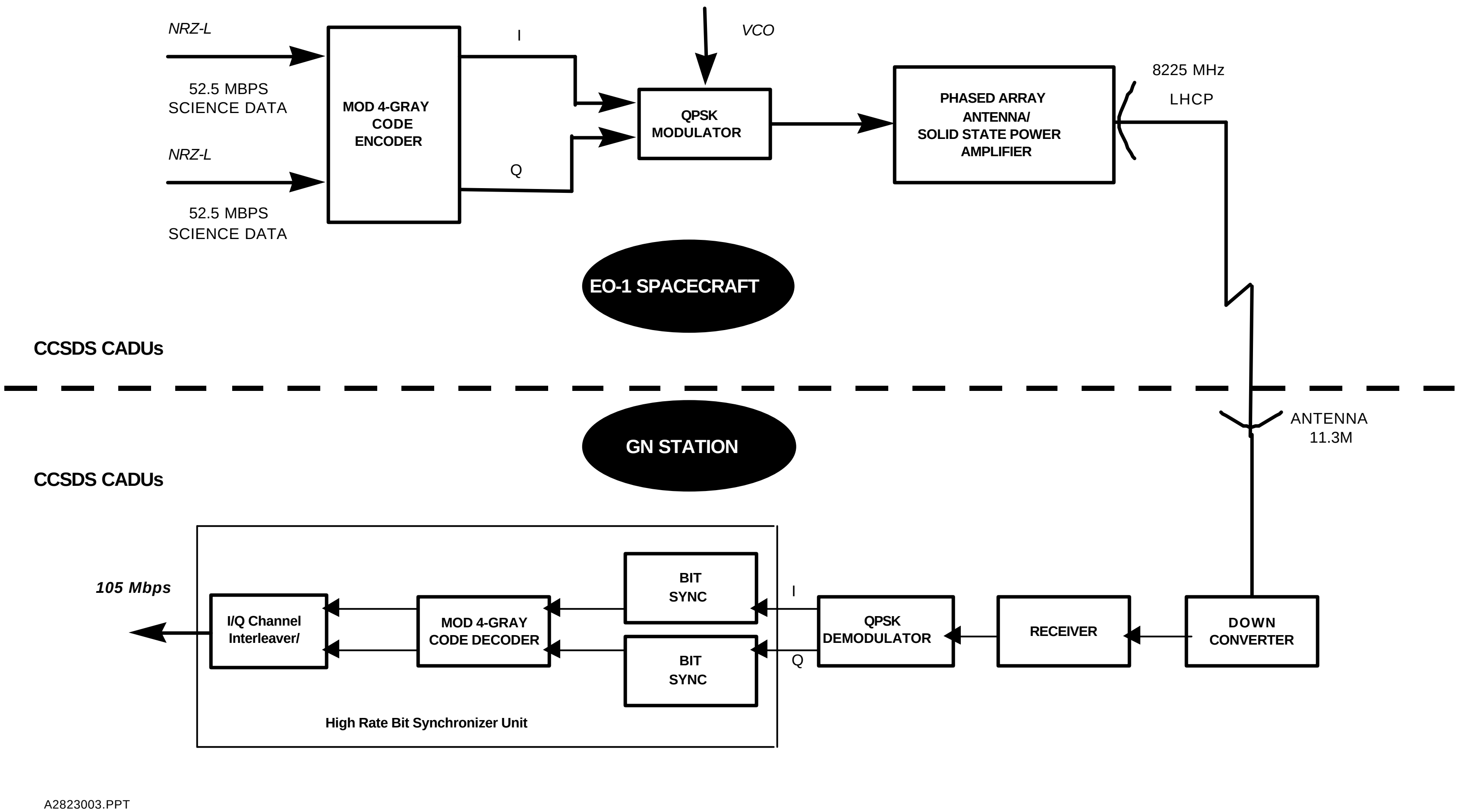

Figure 2 – 5. Spacecraft/GN X-band Downlink Configuration

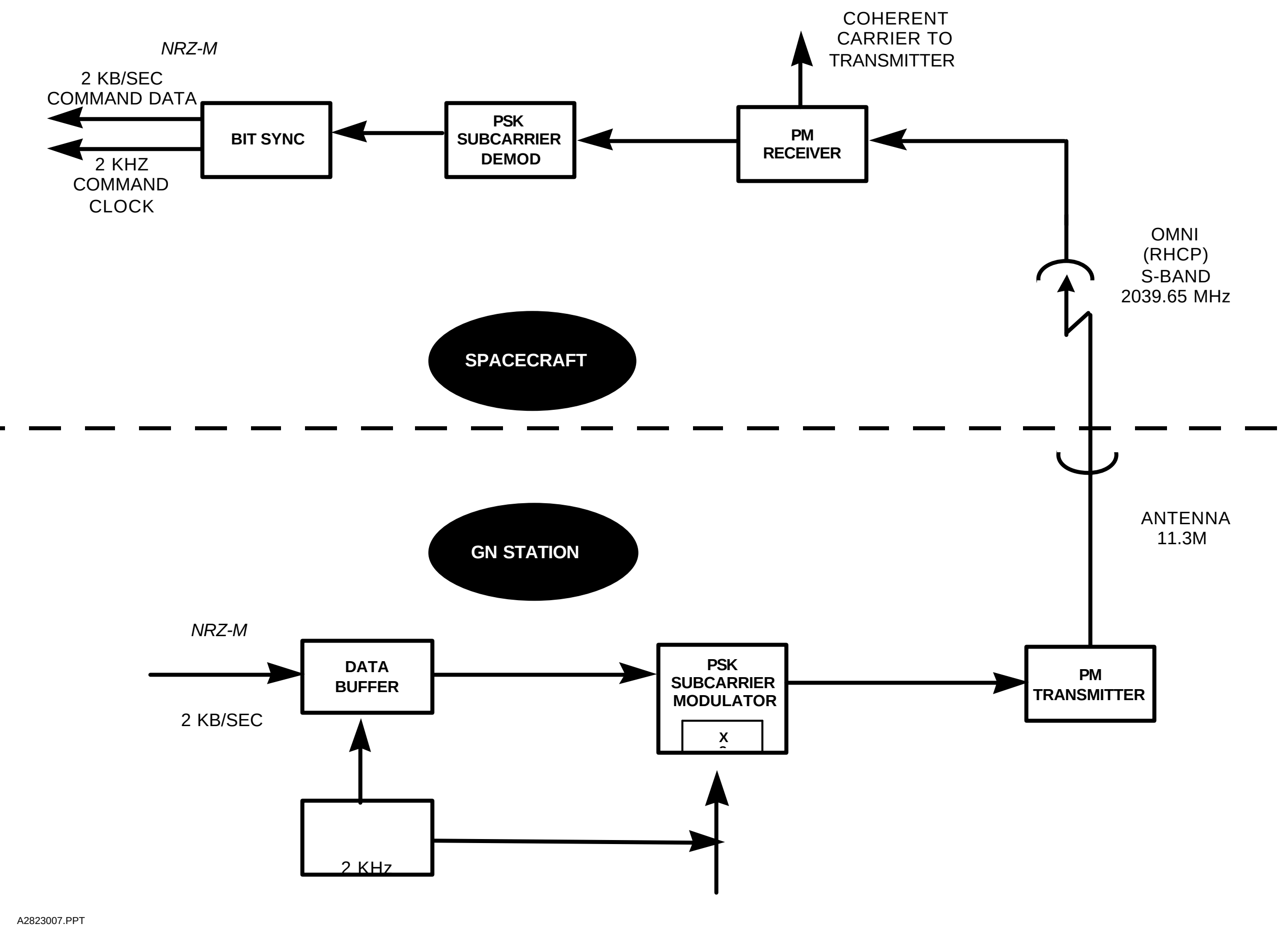

Figure 2 – 6. GN/Spacecraft S-band Uplink Configuration

2.2.4 Interagency Requirements (Non-SOMO)

The DOD radar tracking network shall provide skin tracking data to the EO-1 mission from spacecraft separation to approximately four and a half-hours.

Requirement No.	Requirement Description	Response
	Tracking	
224.1	Skin tracking. The DOD radars listed below shall provide to the EO-1 MOC 46-character tracking data from spacecraft separation for approximately four and a half hours.	
224.2	The following radar stations shall provide the number or passes: <u>Trackers</u> <u>No. of passes</u> Vandenberg (VD4F) 1 Kaena Point (KPTQ) 2	

Table 2-7. DOD Tracking Radar Requirements

Section 3. Testing and Training

3.0 Summary

Testing is required between the EO-1 spacecraft and the NASA support systems to verify that the capability to provide operational support has been implemented as required. Detailed information on the tests required to verify the stated capability will be developed over time, along with a schedule for coordinating project and support organization resources for conducting those tests. This information will be documented in the Integrated Test Plan which will be available in the EO-1 Home Page at http://E01.gsfc.nasa.gov. In general, compatibility and integrated testing will be conducted during a period between 12 months and until just prior to launch to ensure proper systems' support preparation. These tests will involve spacecraft and ground subsystems or simulators early on, and actual flight and support hardware as the launch date approaches.

3.1 Integrated Testing

3.1.1 EO-1 project will have an integrated testing approach for mission preparation including spacecraft compatibility, GN, SN, and all ground systems readiness to support the EO-1 mission.

3.1.2 The integrated testing will include the following categories of tests:

3.1.2.1 Software Validation (Category S).

S1: Core Ground System (CGS) Acceptance Test

S2: Mission Operations Planning and Scheduling System (MOPSS) Acceptance Test

S3: SN and GN Acceptance Testing

S4: Flight Dynamics Support Subsystem (FDSS) Acceptance Test

S5: Data Processing System (DPS) Acceptance Test

S6: Year 2000 (Y2K) Test

3.1.2.2 Mission Readiness Test (Category T)

T1: Spacecraft to MOC Interface Test

T2: Spacecraft – MOC –MOPSS – CMS – FDSS Interface Test

T3: Spacecraft – MOC - MOPSS – DPS - SVF Interface Testing

T4: RF Compatibility Test

T5: MOC to Ground Stations Interface Test

T5.1 MOC to TDRSS Interface Test

T6: MOC – WR – Interface Test

T7: Fully Integrated End-to-End System Test

3.1.2.3 Simulations (Category M)

M1: Launch Simulations

M2: Normal Operations Simulations

M3: Contingency Simulations

M4: Launch Rehearsal

3.1.3 Each test or simulation shall have test/sim sheets to include the following:

- Overview
- Requirements to be tested
- Participating elements
- Prerequisites
- Test data source
- Test Scenario
- Test Procedures

3.1.4 Each test and simulation activity will identify specific requirements to be tested. However, the EO-1 mission general functional test requirements are listed in table 3 - 1 below.

Requirement No.	Requirement Description	Response
314.1	The Compatibility Test Van (CTV) shall test for RF, command, telemetry and transponder interface compatibility for S-band, both GN and SN (no command), and X-band, GN only.	
314.2	The CTV shall provide the MOC with a direct RF link to TDRS for system end-to-end testing with the EO-1 spacecraft.	
314.3	The CTV shall provide the project with raw and encoded spacecraft data recorded during compatibility testing. This data shall be copied and used during subsequent I&T testing and simulations.	
314.4	MOC and WOTIS systems shall demonstrate the capability of scheduling GN and support resources as required.	
314.5	MOC and NCC shall verify the capability of scheduling SN resources via voice request, or e-mail ,or facsimile.	
314.6	MOC, WSG, GN, NCC and SN systems shall demonstrate the capability to exchange IIRV and tracking data (GN only) using the required formats.	
314.7	GN and SN shall have the capability of generating test data from various electronic media, i.e., CD ROM, FTP, magnetic tape sources, etc. for data flows, I&T and simulations activities.	
314.8	MOC and supporting elements shall verify the capability to receive and process test data and generate products as required.	
314.9	All elements shall verify correct man-machine interface capabilities throughout testing and simulations process.	
314.10	Simulations shall validate operational procedures for normal and contingency modes for the required mission phases.	
314.11	All elements shall demonstrate capabilities of failure identification and corrective action procedures.	

Table 3 - 1. General Functional Test Requirements Summary

3.2 Integrated Simulations and Test Tools

The EO-1 project virtual simulator and actual spacecraft recorded data in appropriate electronic media, i.e., CD ROM, magnetic tapes, etc. will be used as the test data source throughout the entire mission preparation. The spacecraft data for testing will be available by March 1, 1999.

3.3 Training

Each EO-1 mission element shall define and control their corresponding systems operations certification program. Project training requirements, above and beyond the standard certification program, are not fully defined as of the time this document was written.

Mission operations training will be accomplished by operations personnel for each element during mission simulations. The FOT receives training as part of the work they perform during spacecraft integration and test activities.

Section 4. Mission Operations

4.0 Summary

The MOC will operate and control the EO-1 mission from pre-launch through the life cycle of the spacecraft. The MOC will utilize SN and GN resources, as well as other supporting elements as required, to achieve the mission objectives. The MOC is developed and operated by non-SOMO resources.

The mission operations procedures are documented in EO-1 Mission Procedures Document. The requirements for the MOC are documented in the EO-1 Ground Functional and Performance Requirements with further details in the EO-1 Space to Ground ICD. All three documents are located on the EO-1 project web site:

http://eo1.gsfc.nasa.gov

4.1 MOC Interface Requirements with SN/GN

Requirement No.	Requirement Description	Response
	Mission Operations Planning & Scheduling System (MOPSS)	
41.1	Schedule activities/commands relative to orbital/GS and/or TDRSS events.	
41.1	Allow for the user to manually schedule activities and/or commands.	
41.1	Display, allow selection, and transmit GS schedule for WSG.	
41.1	Receive and display GS schedule from WSG.	
	Core Ground System (CGS)	
41.1	The CGS shall be capable of accepting and processing telemetry from SN and GN stations. The EO-1 data rates and encoding formats are defined in the EO-1 Space-To-Ground ICD.	

Table 4 - 1. MOC Interface Requirements with SN/GN.

	Core Ground System (CGS) (cont.)	
	The CGS shall be capable of sending command data to the EO-1 spacecraft via the SN and GN stations at 2 kbps. The commands shall conform to the CCSDS COP-1 protocol and data formats as defined in the EO-1 Space-To-Ground ICD.	

Table 4 - 1. MOC Interface Requirements with SN/GN (cont.)

Section 5. Ground Communications and Data Transport

5.0 Summary

NASA Integrated System Network (NISN) is required to provide voice and data circuit interfaces to support EO-1 operations from pre-launch testing through launch and operational phases. This function includes voice and data interfaces between MOC facilities at GSFC and VAFB launch site, SN and GN facilities, and Swales facilities, and other GSFC facilities as required. All elements shall have the capability to communicate via network communications services using Transmission Control Protocol/Internet Protocol (TCP/IP) . The overall mission configuration is shown in figure 5-1 for normal operations and in figure 5-2 for pre-launch and L&EO operations.

Data and voice line requirements are identified in tables 5-1 and 5-2 respectively.

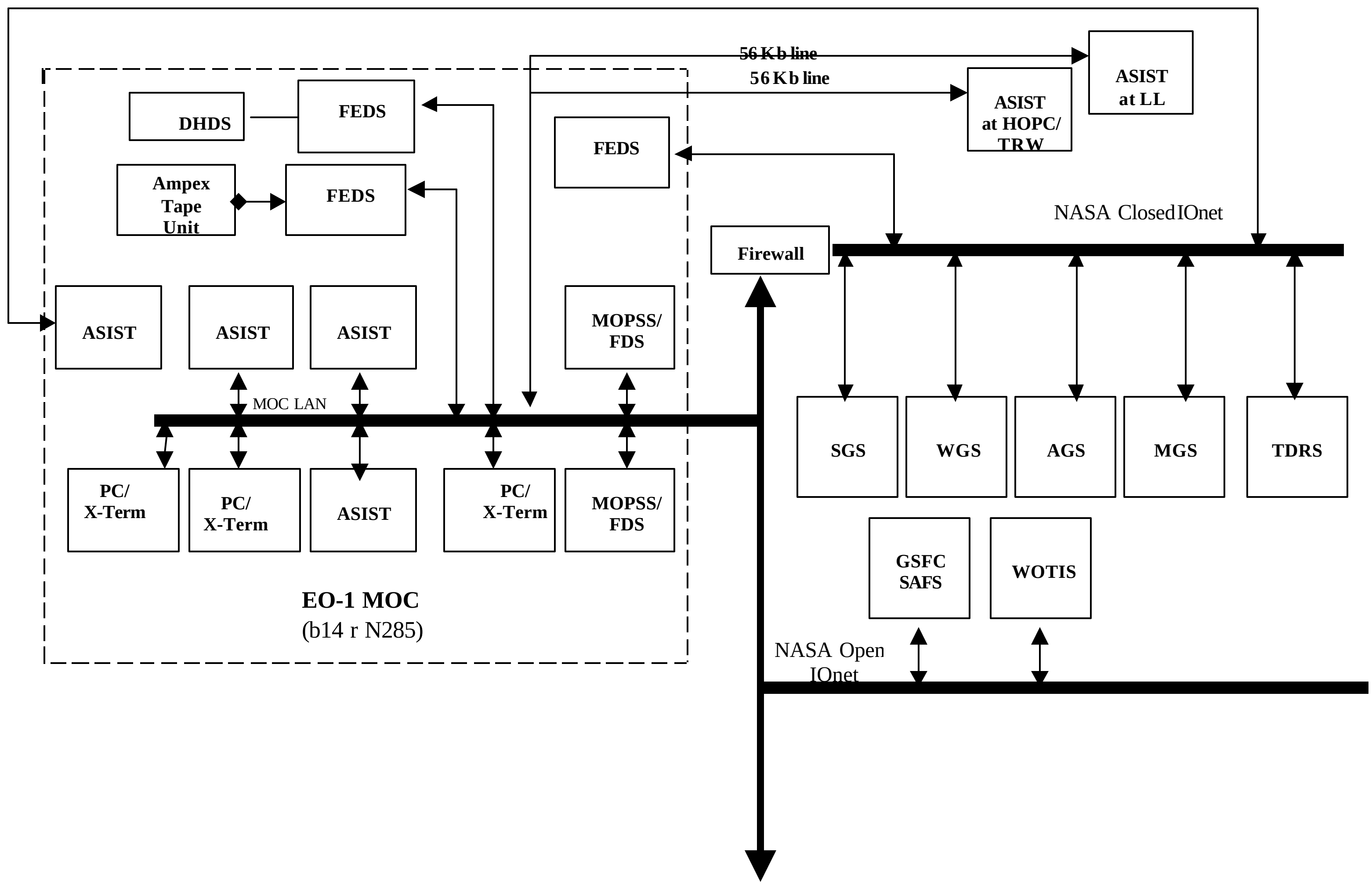

Figure 5-1. EO-1 Data Link Operational Configuration

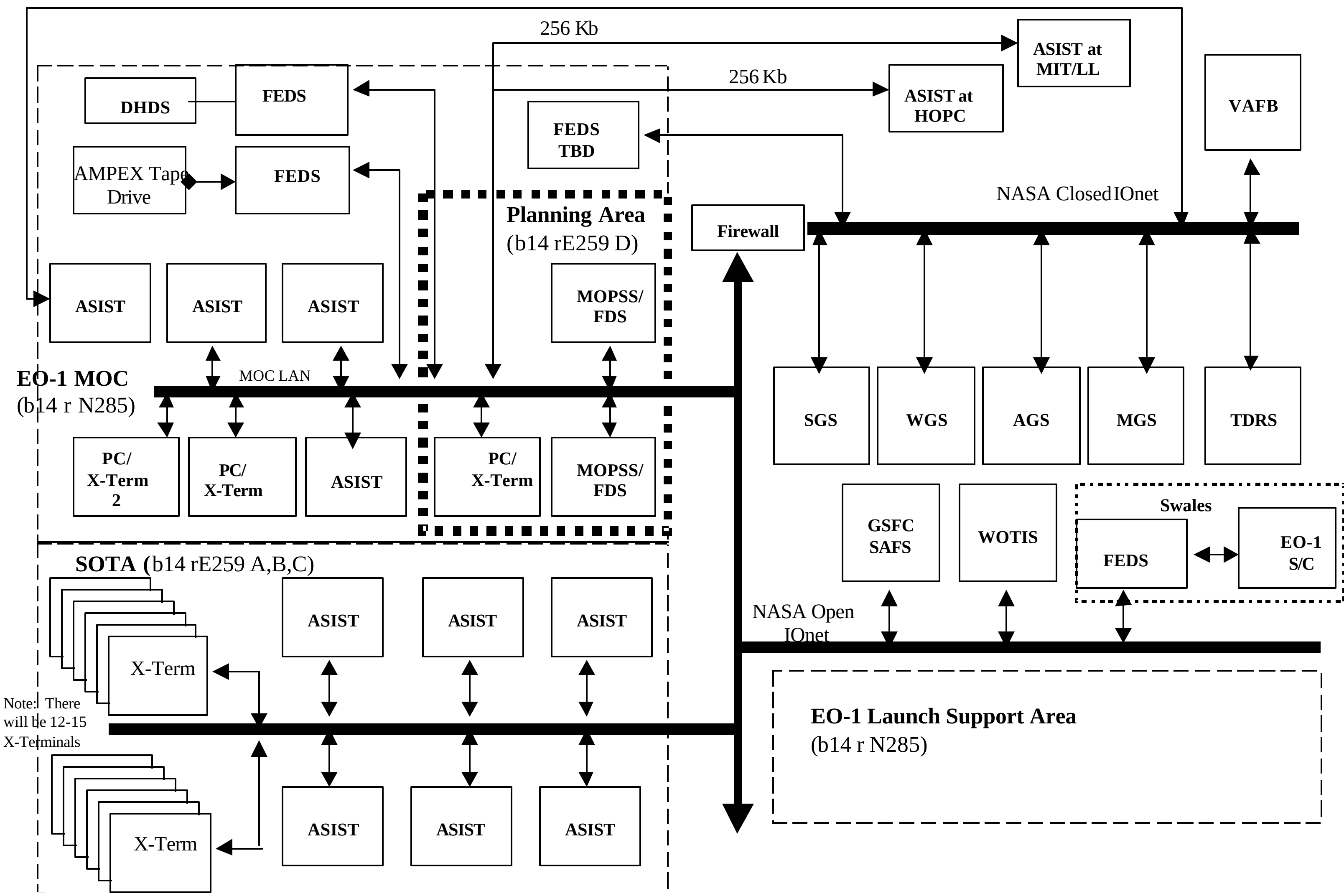

Figure 5.2.. EO-1 Data Link for Testing and Early OrbitConfiguration

5.1 Table of Connectivity

The telemetry and command data line assignments are detailed in table 5 - 1, Data Link Requirements. Similarly, voice line assignments for the various mission phases are contained in table 5 - 2, Voice Link Requirements.

Item #	From	To	1-Way or 2-Way	Data Source	Source Data Rate or Volume	Delivery Time	Service Dates(s) and Duration	Purpose and Remarks
1	EO-1 MOC	SWALES	2	Command and Telemetry	32kbps	Continuous	Present to end of mission	Open Ionet, TCP/IP
2	EO-1 MOC	GSFC bldg. 7	2	Command and Telemetry	1 Mbps	Continuous	May 99 to September 99	Open Ionet,TCP/IP
3	EO-1 MOC	VAFB	2	Command and Telemetry	T-1		September 99 to Jan 00	Closed Ionet,TCP/IP
4	WSC	EO-1 MOC	1	Telemetry	2kbps		May 99 to end of mission	Closed Ionet.TCP/IP
5	EO-1 MOC	WGS, AGS, SGS	2	Command and Telemetry	650kbps	Real-time	May 99 to end of mission	Closed Ionet, TCP/IP
6	EO-1 MOC	MGS	2	Command and Telemetry	128kpbs	Real-time	May 99 to end of mission	Closed Ionet, TCP/IP
7	EO-1 MOC	TRW Redondo Beach	2	Telemetry	256kb	Real-time/offline	May 99 to L+60 days	Science data TCP/IP Open Ionet
8	EO-1 MOC	TRW Redondo Beach	2	Telemetry	56kbps	Real-time/offline	L+ 60 days to end of mission	Science data TCP/IP Open Ionet
9	EO-1 MOC	MIT LL	2	Telemetry	56kbps		L+60 to end of mission	Science data TCP/IP Open Ionet
10	EO-1 MOC	MIT LL	2	Telemetry	256kbps		May 99 to L+60 days	Science data TCP/IP Open Ionet
11	WGS, AGS, SGS	EO-1 MOC	1	Tracking data	32kbps	FTP	May 99 to end of mission	Open Ionet
12	WGS, AGS, SGS	EO-1 MOC	1	Station Status Pkts. .	32kbps		May 99 to end of mission	S and X Band
13	WGS	SAFS	1	Logged DL S-band data	1.8 GB	in 1 hour	May 99 to end of mission	Open Ionet
14	GSFC SAFS	EO-1 MOC	1	State of Health recorder dump	1.8 GB	in 1 hour	May 99 to end of mission	Open Ionet
15	WGS, AGS, SGS	SAFS	1	Logged downlinked S-Band data	1.8 GB	in 1 hour via FTP	May 99 to end of mission	Open Ionet

Table 5 - 1. Data Link Requirements

Item #	From	To	1-Way or 2-Way	Mission Phase	Service Dates(s) and Duration	Purpose and Remarks
1	EO-1 MOC	WGS, SGS, AGS, MGS	2	Pre-Launch and normal ops	May 99 thru mission life	Pass coordination
2	EO-1 MOC	WSC	2	Pre-Launch and normal ops	May 99 thru mission life	Pass coordination
3	EO-1 MOC	VAFB	2	Launch	May 99 – Jan 00	Operations net
4	EO-1 MOC	VAFB	2	Launch	May 99 – Jan 00	Management net
5	EO-1 MOC	VAFB	2	Launch	May 99 – Jan 00	Launch operations net
6	EO-1 MOC	VAFB	2	Launch	May 99 – Jan 00	Engineering 1
7	EO-1 MOC	VAFB	2	Launch	May 99 – Jan 00	Engineering 2
8	EO-1 MOC	VAFB	2	Launch	May 99 – Jan 00	Engineering 3

Notes: 1. CCL's not included in this table
2. Closed Circuit TV not included in this requirement

Table 5 - 2. Voice Link Requirements

Section 6. Data Processing

6.0 Summary

EO-1 data processing takes place in the MOC. The MOC systems provide the off-line function to process EO-1 scenes. The EO-1 scenes will be processed through radiometric, atmospheric, and geometric correction processes. Paired EO-1/Landsat 7 scenes will then be archived and distributed in the SVF. Data processing is not a SOMO requirement.

The mission operations procedures for data processing and archiving are documented in EO-1 Mission Procedures Document. The requirements for the Data Processing System are documented in the EO-1 Ground Functional and Performance Requirements. Both documents are located on the EO-1 project web site:

http://eo1.gsfc.nasa.gov

Section 7. Trajectory and Attitude Support

7.0 Summary

During the first 30-60 days of EO-1 operations, the MOC will perform Flight Dynamics orbit and attitude computations to support the spacecraft as it moves into a Formation Flying configuration with Landsat-7 and is initially operated in that formation. After a successful period of MOC based operations, the operations related to Formation Flying will be transitioned to an onboard autonomous mode using the AUTOCON-F flight software. While onboard control of Formation Flying is prime, the MOC Flight Dynamics Support Subsystem (FDSS) will closely monitor this function. The FDSS in the MOC will continue to provide orbit and attitude product generation and validation of orbit and attitude functions throughout the life of the mission. The FDSS products will be utilized for operational timeline planning by the Mission Operations Planning & Support System (MOPSS), as inputs for various computed commands and table loads and in support of image planning and processing.

The GSFC Flight Dynamics Facility (FDF) shall provide flight dynamics service support during launch and early orbit phase and during contingencies as requested by the EO-1 project. (TBD)

7.1 Flight Dynamics Support Subsystem

The FDSS will be hosted on both a personal computer using the Windows NT operating system, as well as, on an HP (TBS) workstation each located in the MOC.

The mission operations for the FDSS are documented in the EO-1 Mission Procedures Document. The requirements for the FDSS are documented in the EO-1 Ground Functional and Performance Requirements. Both documents are located on the EO-1 Project website:

http://eo1.gsfc.nasa.gov

The FDSS shall provide the functions listed in table 7 - 1 below:

Requirement No.	Requirement Description	Response
71.1	FDSS shall provide acquisition data to NCC and WSG for distribution to the SN and GN.	
71.2	FDSS shall provide PSAT style product to WSG for system operations.	
71.3	FDSS shall perform EO-1 spacecraft orbit determination using 2-wan coherent Doppler data and angle tracking data.	

Table 7 - 1. FDSS Requirements

7.2 Flight Dynamics Facility

FDF requirements are listed in table 7 - 2 below.

Requirement No.	Requirement Description	Response
72.1	During spacecraft's thermal vacuum testing, CTV shall measure and provide MMFD with the spacecraft one-way Doppler data and system data delays to evaluate the EO-1 TXCO center frequency. During the early phase, additional one-way Doppler passes will be evaluated by MMFD to verify the TXCO center frequency.	
72.2	During pre-launch testing and through the EO-1 launch and early orbit phase, MMFD shall provide support for acquisition data generation for DOD C-band radars (see table 2-6 of this DMR)	
72.3	During pre-launch EO-1 testing activities MMFD shall provide acquisition data for scheduled S-band tracking of the COBE spacecraft.	

Table 7 - 2. FDF Requirements

72.4	During pre-launch EO-1 testing activities MMFD shall provide Type 8 acquisition data for TDRS testing.	
72.5	MMFD shall provide the launch vehicle insertion vector to the FDSS in the EO-1 MOC 30 minutes after separation.	
72.6	During the first 6 hours of the EO-1 mission, MMFD shall receive and pre-process several passes of C-band data and FTP this to the EO-1 MOC in an ASCII data set format.	
72.7	During pre-launch testing, through the EO-1 launch and early orbit phase, and during contingencies, MMFD shall provide support for metric tracking data evaluation on GN S-band 2-way Doppler and angle data.	

Table 7 - 2. FDF Requirements (cont.)

Appendix A. Glossary

ACS	Attitude Control System
ADS	Attitude Determination System
AGS	Alaska Ground Station
ALI	Advanced Land Imager
AOS_1	Advanced Orbiting System
AOS_2	Acquisition of Signal
APID	Application Identifier
BER	bit error rate
BPSK	Bi-Phase Shift Keying
CADU	Channel Access Data Unit
CCSDS	Consultative Committee for Space Data Systems
CGS	Core Ground System
CLCW	Command Link Control Word
CMD	Command
CTV	Compatibility Test Van
CVCDU	Coded Virtual Channel Data Unit
D/L	Downlink
DG	Data Group
DMR	Detailed Mission Requirement
DSN	Deep Space Network
DSS	Deep Space Station
EIRP	Effective Isotropic Radiated Power
ETR	Eastern Test Range
EO-1	Earth Observing-1
FDF	Flight Dynamic Facility

FDSS	Flight Dynamic Support Subsystem
FSW	Flight Software
FTP	File Transfer Protocol
Gbps	Giga bits per second
GDSCC	Goldstone Deep Space Communications Complex
GMT	Greenwich Mean Time
GPS	Global Positioning System
GS	Ground Station
GSFC	Goddard Space Flight Center
H/S	Health and Safety
HK	Housekeeping
HW	Hardware
I&T	Integration and Test
ICD	Interface Control Document
IIRV	Improved Interrange Vector
IP	Internet Protocol
kbps	Kilobits per second
L&EO	Launch and Early Orbit
LAN	Local Area Network
LHCP	Left Hand Circular Polarization
LOS	Loss of signal
LV	Launch Vehicle
LZP	Level Zero Processing
Mbps	Megabits per second
MGS	McMurdo Ground Station
MHz	Million hertz
MMFD	Multi Mission Flight Dynamics
MOC	Mission Operations Center
MP	Mission Planning

MS	Multi-Spectral
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NCC	Network Control Center
NISN	NASA Integrated System Network
NMP	New Millennium Program
NORAD	North American Air Defense
PAN	Panchromatic
PM	Phase Modulated
R/T	Real Time
RCS	Reaction Control System
RF	Radio Frequency
RHCP	Right Hand Circular Polarization
RPM	Revolution Per Minute
RS	Reed Solomon
S/A	Solar Array
SAC-C	Satelite de Aplicaciones Cientifica - C
SAFS	Standard Automated File Service
SFDU	Standard Formatted Data Unit
SGS	Spitzbergen Ground Station
SN	Space Network
SOH	State of Health
SSA	S-band Single Access
SSR	Solid State Recorder
SVF	Science Validation Facility
SW	Software
SWIR	Science Wave Infra-Red
TBD	To Be Determined
TBS	To Be Supplied

TC	Telecommand
TCP	Transmission Control Protocol
TDRSS	Tracking and Data Relay Satellite System
TLM	Telemetry
U/L	Uplink
VAFB	Vandenberg Air Force Base
VC	Virtual Channel
VCDU	Virtual Channel Data Unit
WGS	Wallops Ground Station
WOTIS	Wallops Orbital Tracking Information System
WSC	White Sands Complex
WR	Western Range

Distribution

Distribution List

	Copies
D. Mandl, Code 584	1
P. Spidaliere, Code 730	1
N. Speciale, Code 730	1
R. Harbaugh, Code 581	1
R. Harris, Code 450	1
W. Watson, Code 450	1
R. Stelmaszek, Code 450.3	1
R. Flaherty, Code 451	1
R. Clason, Code 451	1
D. Littmann, Code 451.1	1
B. Gioannini, Code 451.3	1
Garza, Code 452.2	1
J. Christo, Code 453.4	1
S. Currier, Code 452	1
R. DeFazio, Code 572	1
G. Fisher, Code 452	1
G. Kientz, Code 241	1
S. Kremer, Code 452	1
R. Stanley, Code 453.4	1
S. Bundick, Code 567	1
B. Corbin, Code 567	1
R. Chimiak, Code 583	1
Y. Wong, Code 450.4	1
G. Gustafson, ITMI	1
J. Hengemihle/MicroTel	1
P. Boldosser, ATSC	1
J. Braun, ATSC/TSS	1
T. Gross, ATSC	1
J. Hendrickson, ATSC	1
J. Howard, ATSC	1
N. Jansen, ATSC	1
A. Kost, ATSC	1
R. Rodriguez, ATSC/CSD	1
T. Russell, ATSC/NIA	1
R. Reider, ATSC	1
B. Trout, ATSC	1
R. Zimmerman, ATSC	1
J. Golden, HAMRS	1
L. Alexander, DEC	1
J. Smolinski, CSC	1
M. Haugh, CSC	1
T. Spangler, SWALES	1

L. McConville, ATSC	1
P. Peskett, ATSC/Wlps	1