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John P. Stern
Deputy General Counsel

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August 6, 2004

Received
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Policy Branch
International Bureau

Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
9300 East Hampton Drive
Capitol Heights, MD 20743

Re: Request for additional information – CyberStar Licensee LLC's File No. 19950929-00138

Dear Ms. Dortch:

I write in response to a letter from Thomas S. Tycz dated July 23rd that requested additional information concerning CyberStar Licensee LLC's (CyberStar) compliance with its construction milestones for its Ka-band authorization at 93° W.L.

Attached is the accurate Performance Specification, Exhibit B, for 93° W.L. Ka-band. This attachment should have been attached to the copy of the contract that we submitted last year.

The July 23rd letter from Mr. Tycz also requested dates and amounts of payments made under the contract and documentation that CyberStar will be able to meet its launch and operation milestone for this authorization. In light of the circumstances that led up to and necessitated Loral's Chapter 11 reorganization filing last year, CyberStar has not been able to make payments under the contract and has not proceeded with construction of this satellite.

Sincerely,

John P. Stern

S2199 SAT-LOA-19950929-00138
CYBERSTAR LICENSEE, L.L.C.
S2199

CC: Thomas S. Tycz
Louise Klees-Wallace

Encl.

Exhibit B

TELSTAR Ka 93° W SATELLITE PROGRAM
Satellite Performance Specification

December 20, 2002

Prepared for:

Cyberstar Licensee LLC
500 Hills Drive
Bedminster, NJ 07921

Prepared by:

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Change Page

Rev No.	Date	Change Rationale	Affected Pages
0	6/13/02	Initial release	several

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ILLUSTRATIONS

TABLES

1 INTRODUCTION

This document specifies the performance characteristics of the TELSTAR Ka 93° W satellite designed to provide high speed broadband Internet service to fixed user terminals. The satellite will be compatible with the launch constraints, restrictions, environments, and limitations of the Ariane, Atlas V, Delta IV and Sea Launch vehicles. The satellite will be capable of operating in a geostationary orbit at the geostationary position of 93° W longitude. The satellite design life is 18 years and it is designed to meet its performance requirements for a mission lifetime of ≥15 years including 100% eclipse operation.

The repeater consists of 64 active TWTAs (75 user beams) at Ka-band, 48 TWTAs for the forward links and 16 TWTAs for the return links. Uplink frequencies are in the 29.5 to 30 GHz band for the forward link and 28.35 to 28.6 GHz for the return link. Downlink frequencies are in the 19.7 to 20.2-GHz and 18.55 to 18.8-GHz bands for the forward link and return link respectively.

The system operates with the forward link at –3 dB OBO and the return link at –6 dB under a fully loaded condition. The satellite generates 75 user spot beams covering CONUS and 8 (TBR) gateway beams within the same region. All user spot beam antennas are autotracked to meet the pointing requirements.

1.1 APPLICABLE DOCUMENTS

The documents specified herein are applicable to the TELSTAR Ka 93° W program in their primary requirements only. Secondary documents contained therein are not applicable to the TELSTAR Ka 93° W EL program unless specifically referenced within the paragraphs of this specification and/or a pertinent paragraph of the primary applicable document.

The TELSTAR Ka 93° W Satellite specification shall take precedence over all applicable documents in case of requirements conflicts.

Unless otherwise noted herein, documents of issue at the date of TELSTAR Ka 93° W contract signing are applicable to this specification.

1.1.1 TELSTAR Ka 93° W Documents

Gateway to Satellite ICD

User Terminal to Satellite ICD

1.1.2 SS/L Documents

Spacecraft Bus to SOCC Interface Control Document

Contract Exhibit C - Product Assurance Plan

Autotrack RF Beacon Station Interface Control Document

1.1.3 Launch Services Provider Documents

Launch Vehicle to Satellite ICD

1.1.4 Standards

ANSI/MIL-STD-1815A Reference Manual for Ada Programming Language

MIL-STD-1541A Electromagnetic Compatibility Requirements for Space Systems

MIL-STD 1553B(3) Digital Time Division Command/Response Multiplex Data Bus

1.1.5 Other Applicable Documents (FOR REFERENCE ONLY)

Boeing Sea Launch Users Guide

Ariane 4/5 Users Guide

CLSB9812-0763 Atlas Launch System Mission Planner's Guide

CLSB-9902-0076 Atlas V Addendum

2 SATELLITE SYSTEM REQUIREMENTS

2.1 SATELLITE SYSTEM DESCRIPTION

The TELSTAR Ka 93°W satellite in the 93°W longitude location shall cover CONUS. The satellite shall be designed to operate in its designated geostationary orbit. The Satellite shall provide orbit raising, circularization and the mission life as specified in 2.5.2 with a total of 75 active receive and transmit beams providing coverage as described herein.

2.2 SATELLITE CONFIGURATION

2.2.1 Launch Vehicle Interface Requirements

The Satellite shall be designed to satisfy all interfaces and environmental requirements as specified in the respective Satellite to Launch Vehicle Interface Control Document. The Satellite shall be compatible with the following candidate launch vehicles, Atlas V, Delta IV H-Ded., Ariane 5 and Sea Launch.

The Satellite design shall meet the safety requirements of the candidate launch vehicle specified above.

2.2.1.1 Lift Capability.

The Satellite design shall be compatible with the launch vehicle lift capability of all the candidate launch vehicles specified in 2.2.1, such that the Mission Life specified in 2.5.2 is met (with the exceptions noted therein).

2.2.1.2 Electrical.

The spacecraft shall be designed to be compatible with the candidate launch vehicles specified in 2.2.1. Functional interfaces are limited to separation switches and isolated coil drivers for remote contact closures between the Satellite and the payload attach fitting, and wiring for dedicated spacecraft power and signal interfaces.

2.2.1.1.1 Satellite Electrical Power.

The Satellite shall provide means to transition from external power supplied via the Satellite to launch vehicle electrical interface to internal Satellite power at approximately 10 minutes, or as required for the candidate launch vehicles, before liftoff.

2.2.1.2.1 Separation Indication.

The Satellite shall detect separation from the launch vehicle and shall use this separation indication to initiate post separation sequencing. Confirmation of separation shall be obtained from launch vehicle telemetry. If post separation sequencing is not initiated automatically it shall be capable of being initiated by ground command.

2.2.1.2.2 Command and Telemetry.

Satellite command and telemetry during prelaunch shall be per the interfaces with the candidate launch vehicles specified in 2.2.1.

2.2.1.2.3 Launch Pad RF Command and Telemetry Capability.

The Satellite shall utilize the launch vehicle capability and/or the TC&R antenna via the launch vehicle RF window to transmit and receive RF commands and telemetry signals while on the launch pad.

2.2.1.3 Mechanical.

The Satellite shall be designed to be compatible with the mechanical interfaces of the candidate launch vehicles specified in 2.2.1.

The Satellite weight versus longitudinal center of gravity offset from the Satellite-launch vehicle interface plane shall be compatible with the candidate launch vehicles specified in 2.2.1.

2.2.2 Satellite Launch Mass.

The launch mass of the Satellite (dry mass and, pressurant and propellant masses) shall be compatible with the candidate launch vehicles specified in 2.2.1 and the Mission Life specified in 2.5.2.

2.2.3 Satellite Coordinate System.

The Satellite axes are defined as a right-hand triad fixed in the Satellite, with the origin at the nominal position of the center of mass. When the Satellite is in the operational configuration the +X axis (motion about the X-axis is called roll) points in the direction of orbital motion. The +Y axis (motion about the Y-axis is called pitch) is normally perpendicular to the orbit plane and points southward. The +Z axis (motion about the Z-axis is called yaw) is nominally in the orbit plane, pointing toward the center of the earth.

2.2.4 Satellite Performance Verification and Test Provisions.

The communications payload shall be designed to allow verification of all performance requirements either by test or test coupled with analysis. The test limits imposed in test procedures or test software shall take into account reasonable tolerances for test value uncertainty. When a combination of test and analysis is required, both analytical and test uncertainties shall be considered in the determination of acceptable performance. Test point selection shall take into account the related analyses when verification is by test and analysis.

2.3 MISSION REQUIREMENTS.

2.3.1 Launch Window.

The Satellite shall be compatible with a daily launch window of one hour or more while meeting the requirements of applicable launch agencies. The constraints and limitations used to define the window shall apply to the Satellite orbital location and consider all mission requirements from launch vehicle separation until transition to on-station configuration.

2.3.2 Orbit and Stationkeeping.

The Satellite shall be designed to acquire and operate in a synchronous, circular, equatorial orbit at the assigned longitudinal location. The Satellite control system shall be designed to maintain station to ±0.05° in orbit inclination and ±0.05° in longitude at the equatorial crossing, assuming Satellite Operations Control Center (SOCC) RF capabilities are compatible with the orbit determination requirements. The design shall be compliant with EIRP, saturation flux density, G/T, and all other communications performance specifications throughout the synchronous orbit mission.

When on-orbit storage is required, the spacecraft shall be designed to meet stationkeeping requirements of ±0.1° in both latitude and longitude in the 93° West geosynchronous orbit.

2.3.3 Attitude Correction Intervals.

Attitude corrections needed to meet the performance requirements of Section 3 shall be minimized.

2.4 ON-ORBIT OPERATING CONDITIONS.

2.4.1 Operational Satellites.

The Satellite design shall meet all requirements specified herein throughout its Mission Life in the on-orbit environment including storage and eclipse conditions, with allowance for degradation, wearout and radiation damage in accordance with the single event upset and radiation model specified in Appendix A of this Specification.

2.4.1.1 Single Event Upsets.

The Satellite shall be designed to mitigate the effects of single event upsets (SEU). No single SEU shall be capable of causing mission failure.

2.4.2 Ground Storage.

The Satellite shall be capable of 24 months ground storage. Periodic maintenance and refurbishment may be employed to meet the storage period.

2.4.3 On-Orbit Storage.

Any period(s) of on-orbit storage shall be included in the Satellite Mission Life.

2.4.4 Autonomous Operation.

The spacecraft bus shall be capable of providing autonomous operation including automatic housekeeping functions during the Safe and Survival State.

2.4.4.1 Safe State.

a. The Safe State shall be entered upon receipt of a ground command.

b. During normal operations phase, the spacecraft bus shall be commanded to the Safe State when the spacecraft either has more than 0.5 degrees of pointing error, or loses earth lock, or the health status monitor detects an uncorrectable failure in the attitude control subsystem, or there is a CPU failure.

c. The Safe State shall maintain the spacecraft bus and payload in power-safe and thermally safe configuration and orientation for an indefinite period of time in the event of anomalies. Mission communications need not be maintained.

d. The spacecraft bus shall disable thrusters to maintain the current attitude, switch telemetry to the wide coverage mode and select the clear command mode.

2.4.4.2 Survival State.

The Survival State is entered in the event of a severe anomaly threatening spacecraft bus survival or in the event transition to the Safe State has been unsuccessful.

a. The Survival State shall be entered upon receipt of ground command whenever the on-board health monitor detects a low voltage condition on the power bus.

b. The Survival State shall maintain the spacecraft bus and payload in power-safe and thermally safe configuration and orientation for an indefinite period of time in the event of anomalies.

c. The spacecraft bus shall be configured to minimize power usage and to maximize spacecraft bus safety.

d. The spacecraft bus shall provide capability to point the spacecraft bus X-axis towards the sun-line and point the solar arrays to the sun, switch telemetry to the wide coverage mode and select the clear command mode for an indefinite period of time while supporting troubleshooting operations.

2.4.5 Regulatory Requirements.

2.4.5.1 Federal Communications Commission (FCC).

The Satellite shall operate in the frequencies and orbits assigned by the Federal Communications Commission.

2.5 SAFETY, RELIABILITY, AND LIFE.

2.5.1 Satellite Safety.

The Satellite shall be so designed that when operated in conjunction with its ground support equipment, all applicable launch vehicles or the ground control center, the probability of unsafe responses shall be minimized, particularly those related to such items as apogee motor, hold down/release devices, and thrusters. The Satellite shall be designed to meet all safety requirements of all applicable launch agencies.

2.5.2 Mission Life.

The Satellite design, including propellant expenditure, OSR degradation, and solar array degradation, shall be able to provide all specification requirements on-station for a minimum Mission Life of 15 years on the launch vehicles specified in 2.2.1 (with the following exceptions), after

a. An on-ground storage period of up to 24 months

b. Launch

c. Orbit raising operations

d. Drift orbit

e. Station acquisition

f. In-orbit test completion

2.5.3 Design Life.

The Satellite design shall assure that all equipment - excluding expendables, OSR degradation and solar array degradation - is capable of operation for a 18 year life, including worst case conditions of radiation, aging, and temperature in the space environment.

2.5.4 Reliability.

2.5.4.1 Satellite Reliability.

The probability of success of the Satellite meeting the 15 year operational end-of-life requirements following the Pre-Operational Phase as defined in this specification shall be at least 0.70 (TBR).

2.5.4.2 Pre-Operational Phase.

The Satellite design shall be such that the probability of the Satellite successfully being placed on station, oriented in the proper operational attitude and completing the in-orbit checkout, assuming successful launch and separation shall exceed 0.99.

2.5.4.3 Redundancy.

Redundancy shall be applied as required at all levels to eliminate critical failure modes and avoidable single-point failures and to achieve Satellite reliability specified in 2.5.4.1. Redundancy switching, where autonomous, shall be capable of being overridden by ground command and shall not introduce additional failure modes.

2.5.4.4 Single-Point Failures.

Single-point failure is defined as single piece part, unit, subassembly or assembly of the Satellite that, if failed, could cause the Satellite reliability to fall below the requirement in paragraph 2.5.4.1.

No credible single-point failure in the spacecraft bus, payload, payload-to-spacecraft interface, and/or single ground operator error shall permanently preclude the Satellite from supporting the mission. A credible single-point failure is defined as any failure of an active component, or of any passive component, with a probability of success of 0.99 or less for Satellite Mission Life.

All unavoidable single-point failure items shall be identified.

2.5.4.4.1 Failure Tolerance.

Failure isolation shall be provided for all units so that a single credible failure within any subsystem does not disable or degrade the performance of the Satellite beyond system requirements.

2.5.4.4.2 Fault Recovery.

The spacecraft bus design shall support detection, isolation, and recovery capabilities for any single credible fault in the spacecraft bus to ensure the health and safety of the spacecraft bus.

2.5.4.4.3 Survival Period.

The spacecraft bus shall be capable of surviving the occurrence of any single point failure without ground intervention for a minimum of 24 hours except for those failures specified in 2.4.4.1 and 2.4.4.2. Payload operation need not be preserved in the presence of the fault and during fault recovery.

The spacecraft bus shall be capable of surviving in Survival state, as defined in paragraph 2.4.4.2, for an indefinite time up to the Mission Life.

2.5.4.4.4 Power Removal.

No credible single-point failure shall prevent the successful removal of power from a failed component (for those components designed to have removable power).

2.6 ENVIRONMENT

2.6.1 Launch Environment.

The Satellite shall be designed to meet all the performance requirements specified herein after exposure to the launch site environment and the launch environment for any of the launch vehicle identified in 2.2.1.

2.6.2 Space Environment.

The Satellite design and application of parts and materials shall be such as to ensure all performance specifications are met throughout the Mission Life of the Satellite when operated in the space environment including the SEU and radiation environment defined in Appendix A of this Exhibit.

2.6.3 Outgassing.

Satellite performance throughout the Mission Life shall not be degraded below specification due to outgassing. All materials used in the Satellite design shall comply with the requirements of the Product Assurance Plan.

2.7 ON-ORBIT ANTENNA PATTERN MEASUREMENTS.

The Satellite design shall provide the capability to allow all antenna pattern measurements to be performed without losing Ka-Band command or telemetry capability.

2.8 OPERATIONS DURING COMMAND UPLINK ANOMALIES.

The Satellite shall, in the absence of on-board failures, provide uninterrupted communications services in the absence of the command uplink for up to 48 hours.

2.9 SATELLITE OPERATIONS CONTROL CENTER (SOCC) INTERFACE.

The Satellite shall provide RF links to the terrestrial tracking network and to the SOCC.

3 COMMUNICATIONS SUBSYSTEM

The TELSTAR Ka 93° W Ka-band payload shall support the following communication paths:

- The Forward path from Gateways (feeder uplink) to end users (service downlink);
- The Return path from end users (service uplink) to Gateways (feeder downlink).

The specifications in this section define the general communications services performance that shall be provided by the satellite communications subsystem operating in the Ka-band and the specific payload performance requirements. The requirements are applicable to the orbital location of 93°WL.

3.1 GENERAL REQUIREMENTS

Unless otherwise stated, the performance requirements identified in this specification shall apply under the following conditions:

a. All operating conditions, including worst-case antenna pointing and stationkeeping maneuvers

b. All environmental conditions, including the natural radiation environment specified in Appendix A

c. For any combination of operating transponders, signal types, and over the operating RF channel bandwidth

d. Over the Mission Life specified in paragraph 2.5.2

e. During sunlight, eclipse, and solar interference conditions

f. For any setting of the commandable gain controls

g. For any combination of on-orbit storage and operating modes

h. In both primary and redundant modes of operation

i. Over the specified service areas

j. At the geostationary orbit location

k. For any drive level from threshold to saturation.

l. With any combination of operating beams ranging from one beam to all 75 beams

For purpose of sizing the satellite electrical power and thermal subsystems, the forward links shall operate at –3 dB OBO and the return link shall operate at –6 dB OBO at all times.

3.2 CONFIGURATION

The TELSTAR Ka 93° W payload shall consist of two functional parts:

a. Forward transponders providing the paths from gateway beams to their associated group of user beams. Forward transponders shall be operated at a nominal output backoff of 3 dB.

b. Return transponders providing the paths from groups of user beams to their associated gateway beams. Return transponders shall be operated at a nominal output backoff of 6 dB (TBR).

Figure 3-2 is a simplified functional block diagram of the forward and return transponders.

3.2.1 Forward Path

The forward path shall be comprised of associated receiving antenna gateway beams, preselect filters, redundant broadband receivers connected to master local oscillators, input multiplexers, redundancy high power amplifier chain selection switch networks, output filters, and associated transmit antenna end user beams.

TBD

Figure 3-1. TELSTAR Ka 93° W Functional Payload Block Diagram

The primary mode of operation of the forward path transponders shall be at a highly linear operating point of the amplifier chain, as further specified herein.

3.2.2 Return Path

The return path shall be comprised of associated receiving antenna end user beams, preselect filters, redundant receivers connected to master local oscillators, combining multiplexers, redundancy high power amplifier chain selection switch networks, output filters, and associated transmit antenna gateway beams.

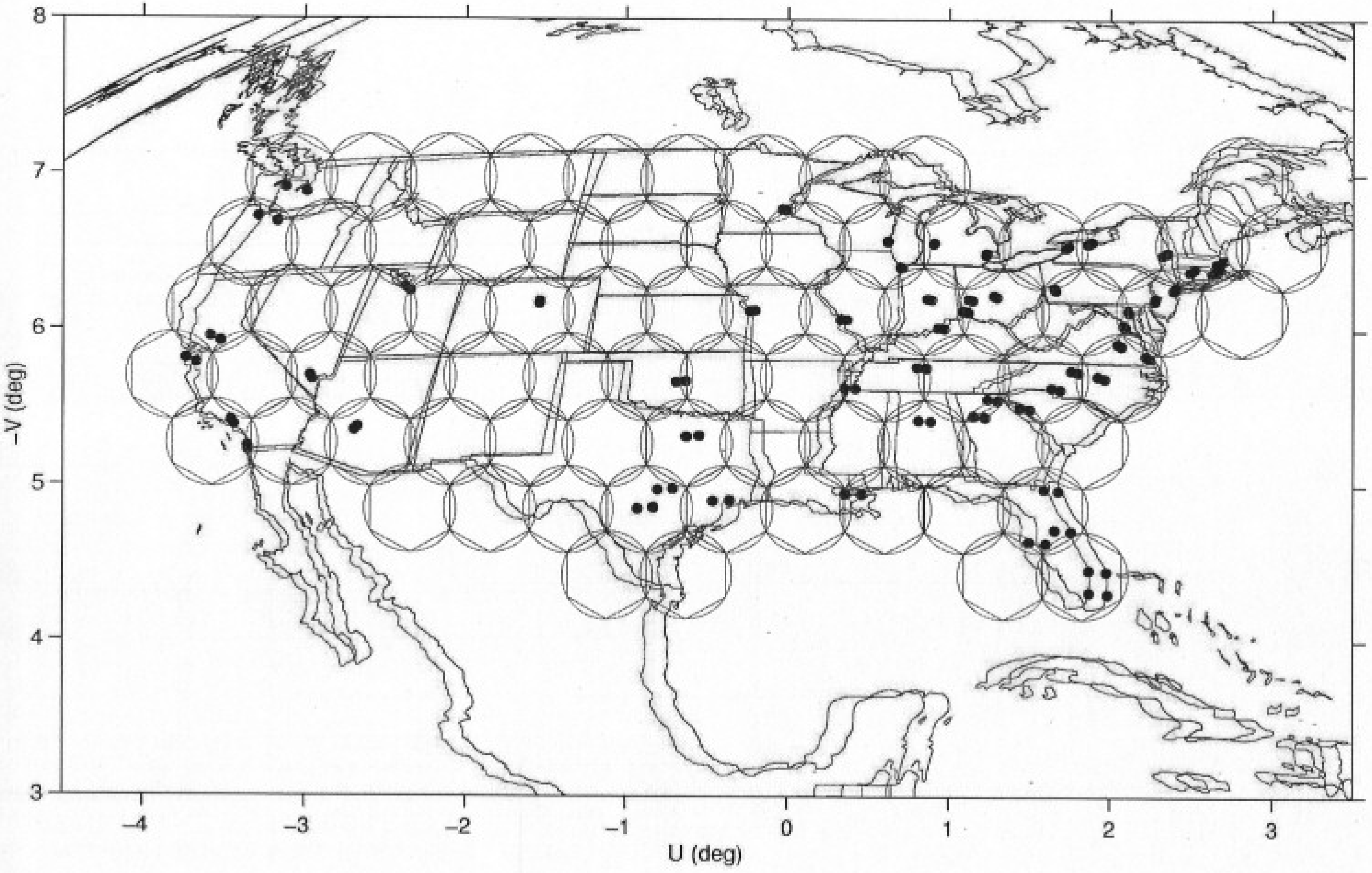
The primary mode of operation of the return path transponders shall be at a highly linear operating point of the amplifier chain, as further specified herein.

3.3 COVERAGE

The TELSTAR Ka 93° W satellite antennas shall provide user beam coverage over CONUS using a maximum of 75 spot beams with 0.55° spacing. The forward and return user beam layout is defined in Figure 3-2.

Table 3-1 defines the service areas by listing the nominal center points of the coverage circles illustrated in Figure 3-2. The actual latitude and longitude of the beam center points may differ from the table, but the beams will provide coverage of the coverage area in all cases.

Figure 3-2. User Beam Layout of Telstar Ka 93°W.
Also shown is the footprint if the satellite is moved to 89°WL.



05–Mar–2001 13:36
93W, BLACK
89W with –0.5 deg AZ offset, RED
US Metropolitan Areas

Table 3-1. Nominal Service Area Definitions (TBD)

Beam Numbers	Center Point Longitude	Center Point Latitude
1		
2		
3		
4		
5		
6		
7		
8		
9		
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72		
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74		
75		

3.4 FREQUENCY PLAN

3.4.1 Frequency Allocation

TELSTAR Ka 93° W shall operate in the Ka-band using the following frequency allocation:

Forward path (gateway to satellite uplink; satellite to users downlink):

Uplink: 29.5 – 30.0 GHz

Downlink: 19.70 GHz to 20.20 GHz

Return path (users to satellite uplink; satellite to gateway downlink):

Uplink: 28.35 GHz to 28.60 GHz

Downlink: 18.55 GHz to 18.80 GHz

3.4.2 Transponder Frequency Plan

The TELSTAR Ka 93° W frequency plan is defined in Figure 3-3 for the forward and return links, including the Rain Fade Beacon and Autotrack frequencies.

Each of eight (8, TBR) gateway beams will be connected to a group of four (4) to sixteen (16) user beams, with each user beam containing at least one (1) (TBR) service channel in both the forward and return paths.

The TELSTAR Ka 93° W satellite shall support at least 128 active Ka band channels in the forward path, each with a minimum usable bandwidth of 56 MHz.

The TELSTAR Ka 93° W satellite shall support at least 128 active Ka band channels in the return path, each with a minimum usable bandwidth of 56 MHz.

3.4.3 Polarization

The 75 user beams shall be circularly polarized, with either LHCP or RHCP assigned to specific beams as defined in the connectivity assignment Table 3-2.

The eight (8, TBR) gateway beams shall be dual circular polarized.

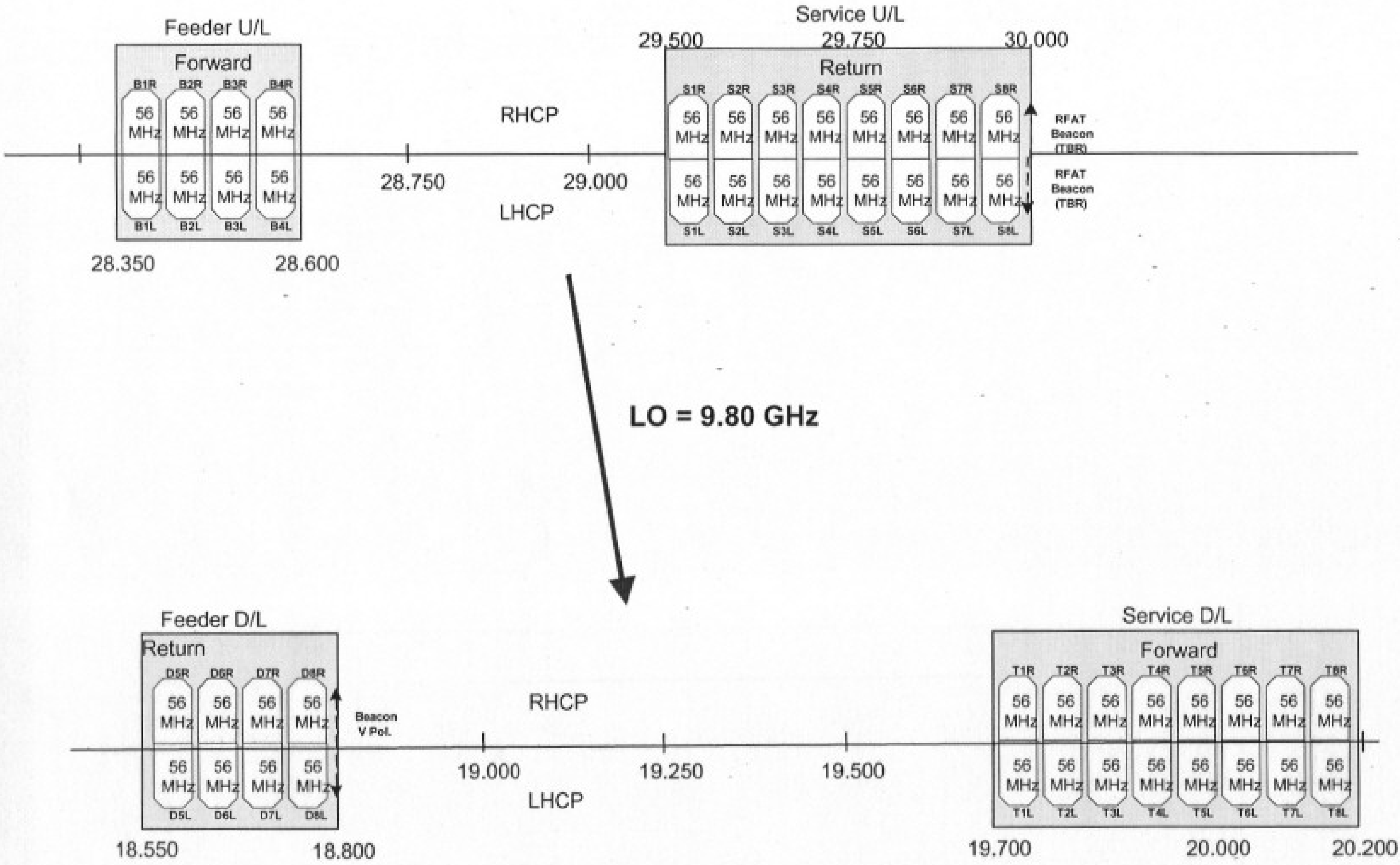

Figure 3-3. TELSTAR Ka 93° W Frequency Plan

3.5 CONNECTIVITY

The Satellite shall use 8 times (TBR) frequency reuse per the frequency plan of Figure 3-3. The connectivity between service beams and gateways (Hubs) shall be as shown in Table 3-2. Each user beam shall have up to six (6, TBR) 56-MHz channels between the Satellite and users in both the uplink and downlink. Each gateway shall provide coverage for up to sixteen (16, TBR) user beams. Table 3-2 defines the channels and polarizations for each user beam and defines the gateway polarization assignments for the feeder beams.

Table 3-2. Connectivity Assignments (TBD)

Beam	Forward Pol.	Return Pol.	Carrier	Gateway Beam
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
		.		
		.		
		.		
		.		
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27				
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75				

3.6 TRANSMIT REQUIREMENTS.

All transponders in the Satellite shall operate in a multicarrier mode and transmit multicarrier traffic.

3.6.1 Effective Isotropic Radiated Power (EIRP).

When a transponder is driven with a single carrier into saturation, the minimum EIRP shall be 61 dBW (TBR) for each Service link and shall be 61 dBW (TBR) for each Feeder link at beam center.

3.6.2 EIRP Stability

The transmit EIRP stability at saturation, under all on–orbit operating conditions including pointing error, shall not exceed ±0.5 dB (TBR) at user beam center or ±1.8 dB (TBR) at user beam EOC over any one day period.

3.6.3 Transmit Polarization Isolation and Carrier to Interference.

3.6.3.1 Polarization Isolation.

Cross-polarization isolation is the ratio of the co-polarized to the cross-polarized antenna gain toward any point within the service area when the receiving antenna is aligned for peak co-polarized signal. The downlink cross-polarization isolation shall be better than 25 dB within any of the service areas defined in Figure 3-1 and Table 3-1.

3.6.3.2 Adjacent Beam Interference.

The beam carrier to interference (C/I) of all beams of the same co-pole and co-frequency shall exceed the values in Table 3-3 and Table 3-4 for each specified beam for nominal Satellite pointing and with equal EIRP (TWTA output) at the specified frequency/polarization. These requirements are to be verified by analysis using measured test data from other planned tests as appropriate. No special tests shall be required to provide data solely for the analysis herein. Section 13 defines the carrier to interference terms used in Table 3-3 and Table 3-4.

Table 3-3. Service (Forward) Downlink C/I

Beam Numbers	Minimum C/ITx (dB) (TBR)
1	17
2	17
3	17
4	17
5	17
6	17
7	17
8	17
9	17
10	17
11	17
12	17
13	17
39	17
40	17
41	17
42	17
43	17
44	17
45	17
46	17
47	17
48	17
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53	17
54	17
55	17
56	17
57	17
58	17
59	17
60	17
61	17
62	17
63	17
64	17
65	17
66	17
67	17
68	17
69	17
70	17
71	17
72	17
73	17
74	17
75	17

Table 3-4. Feeder (Return) Downlink C/I

Beam Numbers	Minimum C/ITx (dB) (TBR)
1	20
2	20
3	20
4	20
5	20
6	20
7	20
8	20

3.7 RECEIVE REQUIREMENTS

3.7.1 Gain to Noise Ratio (G/T)

The Satellite G/T for the forward and return transponders of the Ka-band communications up-links shall not be less than 15 dB/K. The G/T calculation shall assume an earth temperature of 290°K and maximum repeater gain.

3.7.2 G/T Stability

The total G/T stability, under all on–orbit operating conditions including pointing error, within the service regions of shall not exceed:

±0.5 dB for 24 hours at center of the beam

±2.4 dB at edge of beam over 100% of the time over any one day period.

±1.04 dB over the mission life at center of the beam

±2.9 dB at edge of beam over 100% of the time over the Satellite mission life.

3.7.3 Receive Cross-Polarization Isolation and Carrier to Interference

3.7.3.1 Cross-Polarization Isolation

Cross-polarization isolation is the ratio of the co-polarized to the cross-polarized antenna gain toward any point within the service area when the transmitting antenna is aligned for peak co-polarized signal. The uplink Cross-polarization isolation shall be better than 25 dB within any of the service areas defined in Figure 3-2 and Table 3-1.

3.7.3.2 Adjacent Beam Interference

The adjacent beam carrier to interference (C/I) of all beams of the same co-pole and co-frequency shall exceed the values in Table 3-5 and Table 3-6 for each specified beam for nominal Satellite pointing. These requirements are to be verified by analysis using measured test data from other planned tests as appropriate. No special tests shall be required to provide data solely for the analysis herein. Section 13 defines the carrier to interference terms used in Table 3-5 and Table 3-6.

Table 3-3. Service (Return) Uplink C/I

Beam Numbers	Minimum C/ITx (dB) (TBR)
1	20
2	20
3	20
4	20
5	20
6	20
7	20
8	20
9	20
10	20
11	20
12	20
13	20
39	20
40	20
41	20
42	20
43	20
44	20
45	20
46	20
47	20
48	20
49	20
50	20
51	20

Beam Numbers	Minimum C/ITx (dB) (TBR)
14	20
15	20
16	20
17	20
18	20
19	20
20	20
21	20
22	20
23	20
24	20
25	20
26	20
27	20
28	20
29	20
30	20
31	20
32	20
33	20
34	20
35	20
36	20
37	20
38	20
52	20
53	20
54	20
55	20
56	20
57	20
58	20
59	20
60	20
61	20
62	20
63	20
64	20
65	20
66	20
67	20
68	20
69	20
70	20
71	20
72	20
73	20
74	20
75	20

Table 3-4. Feeder (Forward) Uplink C/I

Beam Numbers	Minimum C/ITx (dB) (TBR)
1	22
2	22
3	22
4	22
5	22
6	22
7	22
8	22

3.7.4 Saturation Flux Density (SFD), Gain and Level Control.

Each transponder shall be capable of being independently commanded to operate in either of two operational modes:

a. Fixed gain mode (FGM)

b. Automatic Level Control (ALC) mode

The SFD is the flux density required at the Satellite receive antenna, transmitted from the edge of coverage of a service beam, at channel center frequency that drives the corresponding output amplifier into saturation. Saturation is defined as the point at which the slope of P_{out} vs. P_{in} is zero, measured in the fixed gain mode.

The saturation flux density at the edge of coverage shall be -107 dBW/m2 (TBR) with the gain set at the maximum level. Gain adjustment shall allow the SFD level to be set from –87 to -107 dBW/m2 (TBR) at the edge of coverage.

3.7.4.1 Saturation Flux Density (SFD) Stability.

In both operating modes, excluding antenna variations, the SFD stability shall be better than 0.7 dBp-p diurnally and 1.1 dBp-p over life. The variation in SFD between any two transponders shall not exceed ±3 dB.

Commands may be used to compensate for seasonal and long–term drifts and receiver failures in order to meet the above stability; such commands, if used, shall not be required more frequently than once per month.

3.7.4.2 Fixed Gain Mode.

In the fixed gain mode a Flux Control Attenuator (FCA), that is ground commandable over a 31 dB range with a resolution of at least 1 dB steps, shall be available to set the incident flux density necessary to saturate each transponder (SFD). Gain steps not used by the spacecraft for initial gain setting may be available for seasonal gain adjustments. Upon entering the FGM mode, gain shall automatically be set to the commandable state corresponding to the lowest gain.

3.7.4.3 ALC Mode.

In the ALC mode the FCA control by command is disabled. The ALC circuit shall provide sufficient gain to saturate the power amplifier with an incident flux density of -99 dBW/m2.

The ALC mode shall operate on the average power in the transponder (signals plus noise) and shall have a time constant greater than or equal to 10 ms and less than 100 ms.

A commandable TWTA drive adjust attenuator following the ALC circuit shall be provided to adjust the TWTA drive downward from the level required for saturation by a total of 14 dB in steps with a nominal resolution of 0.5 dB. This attenuator may have additional steps that can be used to adjust the nominal TWTA drive and correct for long term drifts in order to meet stability requirements given in 3.7.4.1.

Command override of this ALC function shall be provided for enabling of the FGM.

3.7.4.4 ALC Dynamic Range.

The ALC minimum dynamic range shall be 14 dB. With the TWTA drive adjust attenuator set for TWTA saturation, the TWTA output power level shall not vary more than 1.0 dBp-p over this dynamic range.

3.8 TRANSPONDER CHARACTERISTICS.

3.8.1 Frequency Response and Gain Slope.

3.8.1.1 Gain Flatness

The overall gain flatness is defined as the response measured between the input to the transmission channel, including the receive antenna, and the output of the transmission channel, including the transmit antenna.

The gain flatness shall comply with the values shown in Table 3-7 and Table 3-8 for the forward path and return path respectively.

The frequency offsets are defined with respect to the center frequency of each channel.

Table 3-5. TELSTAR Ka 93° W Forward Channel Gain Flatness (dB) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

Table 3-6. TELSTAR Ka 93° W Return Channel Gain Flatness (dB) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

3.8.1.2 Gain Slope

The overall gain slope is defined as the gain slope measured between the input to the receive antenna and the output of the transmit antenna. The maximum overall gain slope at any point within the usable bandwidth of each type of transponder shall not exceed the values presented in Table 3-9 and Table 3-10.

Table 3-7. TELSTAR Ka 93° W Forward Path Overall Gain Slope (dB/MHz) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

Table 3-8. TELSTAR Ka 93° W Return Path Overall Gain Slope (dB/MHz) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

3.8.2 Group Delay Response and Group Delay Slope

3.8.2.1 Group Delay Response

The transponder overallgroup delay measured between the input to the transmission channel, including the receive antenna, and the output from the transmission channel, including the transmit antenna, shall comply with the values shown in Table 3-11 and Table 3-12 for the forward path and return path respectively.

The frequency offsets are defined with respect to the center frequency of each channel.

Table 3-9. TELSTAR Ka 93° W Forward Channel Group Delay (nsec) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

Table 3-10. TELSTAR Ka 93° W Return Channel Group Delay (nsec) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

3.8.2.2 Group Delay Slope

The transponder overall group delay slope measured between the input to the transmission channel, including the receive antenna, and the output from the transmission channel, including the transmit antenna, shall comply with the values shown in Table 3-13 and Table 3-14 for the forward path and return path respectively.

The frequency offsets are defined with respect to the center frequency of each channel.

Table 3-11. TELSTAR Ka 93° W Forward Channel Group Delay Slope (nsec/MHz) (TBD

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

Table 3-12. TELSTAR Ka 93° W Return Channel Group Delay Slope (nsec/MHz) (TBD)

Offset from Center Frequency (MHz)	±14	±21	±25	±28
Specification (dB)				

3.8.3 Adjacent Channel Rejection

Rejection of adjacent channels into a particular channel in forward transponders shall comply with the values given in Table 3-15 and Table 3-16. For the return transponders, the values in the table shall provide the isolation between the four beams that drive that transponder when measured from the center of the channel for the desired beam.

Table 3-13. Forward Transponder Adjacent Channel Rejection (TBD)

Offset from Center Frequency (MHz)	±32	±60	±100
Specification (dB)			

Table 3-14. Return Transponder Adjacent Channel Rejection (TBD)

Offset from Center Frequency (MHz)	±32	±60	±100
Specification (dB)			

3.8.4 Pulsed Transient Response.

The provisions of this paragraph shall not be tested but they describe the design limits of the transponder when driven by the Satellite bus.

When driven by a discontinuous (pulsed) signal, the transponder amplitude and phase responses shall be within ±0.5 dB and ±3.0 degrees of their respective steady state values. This shall apply within 200 ns of the start of the transient and remain within tolerance until the signal is removed. The start of the output transient is measured from the time at which the transponder output power is 1 dB above the output power at zero drive (see a., below). This specification applies to all transponders and shall be demonstrated under the following conditions:

Transponder drive is pulsed from zero drive to that drive which produces single carrier saturation. Zero drive is defined as a level 20 dB less than that required to produce single carrier saturation;

Any combination of pulse "on" times from 25 μs to 1 ms;

Any combination of pulse "off" times from 100 ns to 1 ms;

Transponders randomly selected to be simultaneously pulsed (Maximum spacecraft bus power transient limited to no more than 700 watts in 1.2 ms).

3.8.5 Amplitude Linearity.

The carrier-to-third-order intermodulation product of any transmission channel shall meet the requirements of Table 3-17. The two signals may be anywhere in the center 50% of the channel bandwidth such that the intermodulation products also fall within the channel bandwidth and the two signals shall be of equal output amplitude.

Table 3-15. Carrier to Third Order Intermodulation Product Ratio (TBR)

Output Level Back-Off {Each of Two Carriers} (dB Sat)	Maximum C/3IM (dBc)	
	BOL @ Center of Band and Ambient Temperature	EOL
-6	24.0	21.6
-9	26.2	21.8
-13	30.7	25.8
-20	31.0	30.0

3.8.6 Total Phase Shift.

The total phase shift for a transponder shall not exceed the values given in Table 3-18.

Total phase shift is defined as the maximum shift of carrier phase when a single unmodulated carrier is varied from saturation to 20 dB below saturation (fixed gain mode).

Table 3-16. Total Phase Shift (TBR)

Input Level (dB Sat)	Maximum Relative Phase Shift (degrees)
	For Carriers @ 18 GHz & 20 GHz
0	16.0
-3	11.0
-6	9.0
-9	5.0
-12	4.0
-15	2.5
-20	0 (Reference)

3.8.7 AM/PM Conversion Coefficient.

The AM/PM conversion coefficient is defined as the slope of the total phase shift characteristic with a single carrier. The AM/PM conversion coefficient for any transponder shall conform to the limits given by Table 3-19.

Table 3-17. AM/PM Conversion Coefficient (TBR)

Input Level (dB Sat)	Maximum Relative Phase Shift (degrees)
	For Carriers @ 18 GHz & 20 GHz
0	7.0
-3	3.0
-6	2.1
-9	1.7
-12	1.4
-15	1.3

3.8.8 Frequency Conversion

The frequency conversion from the up-link to the downlink shall be accomplished by a net frequency subtraction. Frequency inversion of the spectrum between the up-link and downlink shall not be allowed.

3.8.9 Frequency Stability

Channel frequency stability shall be better than ±0.25 ppm over one diurnal cycle and ±2.5 ppm over the mission life.

3.8.10 Spurious Outputs

Spurious outputs include unwanted products resulting from frequency conversion stages, oscillators, harmonics, image frequencies, and leakage, but does not include:

a. Intermodulation products generated within the receivers, LTWTAs or channel amplifiers due to multiple communications carriers.

b. Signals from the cross-polarized transponders as attenuated by the receive antenna polarization isolation.

The specifications of this section shall be met for all transponder gain settings and for single and multiple carrier illumination at levels required to produce saturation.

3.8.10.1 Spurious Outputs Within The Transmit Frequency Bands.

In the transmit frequency bands of 18.55 to 18.8 GHz and 19.7 to 20.2 GHz, the level of any discrete spurious signals as measured at the input to each Ka-band transmit antenna shall not exceed -50 dBc.

The intermodulation products from a single carrier at a level required for single carrier saturation and harmonics of the receiver conversion frequency shall be at least 55 dB below the single carrier level, measured at the transponder output. Leakage of the second harmonic of the local oscillator shall be below –50 dBc measured at the transponder output. These specifications shall be met when the gain of the transponder that generates the product is equal to the gain of the transponder that transmits the intermodulation under all environmental test conditions and throughout the Satellite maneuver life.

For single carrier operation in any transponder at a level required for saturation to 10 dB below the level required for saturation, spurious sidebands induced by any mechanism in the repeater, including power-supply switching waveforms, cathode heater waveforms, etc., shall be at least 55 dB below the single carrier level measured at the output of the transponder.

3.8.10.2 Spurious Outputs Not In The Transmit Frequency Bands.

For any frequency not in the transmit bands of 18.55 to 18.8 GHz and 19.7 to 20.2 GHz, the total averaged power resulting from the sum of all spurious signals as measured at the input to each transmit antenna shall not exceed -40 dBW in any 4 kHz band, excluding harmonics of the normal output signals.

3.8.10.3 Harmonically Related Spurious Outputs.

The harmonically related spurious outputs shall be at least 40 dB below the transmitted carrier.

3.8.11 Passive Intermodulation

The subsystem design shall provide at least 3 dB margin (transmitted power) against multipacting and degradation due to PIMs. If analysis of a component or system shows more than 6 dB of margin, no test for multipaction or PIMs shall be required.

3.8.12 Phase Noise

The single sideband phase noise power spectral density imposed on a signal by the local oscillator in the payload shall be below the limits specified in Table 3-20.

Table 3-18. Single Sideband Phase Noise (TBR)

Offset from Carier	Maximum SSB Phase Noise (dBc/Hz)
100 Hz	-68
1 kHz	-82
10 kHz	-88
100 kHz	-93
>1 MHz	-120

3.8.13 TWTA Overdrive Capability

The transponders shall be designed to withstand, without any subsequent degradation of performance, operation at 3 dB above the input level required for saturation indefinitely, and 6 dB (TBR) above the input level required for saturation for 24 hours.

The transponder is not required to meet communications payload specified performance during overdrive.

3.8.14 Auto Restart.

The TWTAs shall have an automatic restart capability in the event of spurious switch-offs (SSOs). In the event of a subsequent spurious switch-off within a three-minute period, the TWTA shall shut off completely, and restart shall be accomplished by command only. In the event no second switch off occurs within 3 minutes, the automatic restart shall be re-enabled.

3.9 SELF INTERFERENCE.

Each transponder shall meet the G/T and other performance requirements when all transponders are operating at the maximum output power over the full input range and in the presence of the TT&C, command, telemetry and ranging signals and the autotrack beacon signals.

3.10 RAIN FADE BEACON.

The Satellite shall provide a 20.199798 (TBR) GHz, TBD coverage beacon to be used by the gateways to assess downlink rain fade levels. The polarization of this beacon shall be linear-vertical. The beacon shall produce an EIRP of not less than 18 dBW in the TBD coverage areas.

3.11 AUTOTRACK BEACON

The Satellite shall receive a 29500.5 (TBR) MHz linearly polarized spread spectrum beacon from a ground transmitter. The primary and backup beacons will have similar orthogonal spread spectrum codes with the same frequency spread. The RF Autotrack beacon ground location is TBD.

3.12 INTERSATELLITE LINKS (ISL) (OPTIONAL)

The satellite shall be able to interconnect directly to another satellite of the Loral family. The expected orbital locations and angle off Nadir of other satellites for intersatellite connectivity are listed in Table 3-21.

Table 3-19. Other Satellites Positions for ISLs

Satellite Longitude	Angle Off Nadir from TELSTAR Ka 93° W EL (degrees)
-115.0	79.0
-89.0	88.0
-81.0	84.0
105.5	84.0

The TELSTAR Ka 93° W EL satellite shall be able to establish interconnections with up to 2 satellites. Each link shall meet the requirements as specified in the following subsections.

3.12.1 Frequency

Intersatellite links shall operate in the 65GHz to 70GHz frequency band. Specific frequencies are TBD. As an option, optical ISLs may be implemented.

3.12.2 Bandwidth

Each ISL shall provide up to TBD MHz of bandwidth.

3.12.3 Connectivity

For each intersatellite connectivity, up to 2 ISLs shall be implemented. One transmit link and one receive link shall be established with one other satellite. Each link shall operate independent of the other links.

The interconnectivity to be established between Gateways and Users through ISLs is TBD.

3.12.4 EIRP

When a transponder is driven with a single carrier into saturation, the minimum EIRP, at peak of beam, shall be 105 dBW (TBR).

3.12.5 G/T

The Satellite G/T for the ISL transponder shall not be less than TBD dB/K at the peak of beam. The G/T calculation shall assume a space temperature of 10°K and maximum repeater gain.

4 DATA HANDLING SUBSYSTEM

4.1 ITEM DEFINITION

The Data Handling Subsystem (DHS) shall interface with the Communication Payload, the Attitude Control Subsystem (ACS), the Telemetry, Command, and Ranging (TC&R) Subsystem, the Electrical Power Subsystem (EPS), the Propulsion Subsystem (PS), the Thermal Control Subsystem (TCS), and the Mechanisms Subsystem. The DHS shall provide onboard hardware and firmware to provide the necessary support required by the above subsystems during all phases of the mission, from separation from the launch vehicle to the final de-orbit maneuvers. The DHS provides the digital functions of the overall Satellite command and telemetry system.

4.2 FUNCTIONAL OPERATION

The Data Handling Subsystem shall provide all digital command, control and telemetry functions of the telecommand and telemetry requirements of the satellite. The RF functions shall be provided by the TC&R Subsystem (Section 6).The DHS shall provide the following operational capabilities:

a. Decryption, detection, decoding, validation, and execution, if required, of commands from the TC&R receivers

b. Autonomous generation and dissemination of commands to the payload and other subsystems

c. Gathering, formatting, and encoding of subsystem telemetry to be transmitted to the ground

d. Execution of firmware as required by every subsystem

e. Configuring the subsystems for normal operation

f. Configuring the subsystems for emergency operations

g. A satellite clock for use with time-tagged commands

h. Time-tagged command capability

i. Block command capability

j. Real-time command capability

k. Failure detection and recovery management

l. Specification performance during launch, orbit raising and geostationary on-orbit environments

m. Activation of the redundant on-board processor for health assessment without placing it in control

n. Primary to redundant switching without loss of satellite configuration

4.3 COMMANDS

4.3.1 Command Types

The command subsystem shall be capable of executing real-time, time-tagged and stored command sequences. DHS issued commands shall be individually addressable to each subsystem's units, including distinctive addressing between redundant units.

4.3.1.1 Telecommand Execution

The probability of successfully executing a correct telecommand shall be at least 0.99995 for a single attempt through the command beam with illuminating flux densities of –90 and –100 dBW/m^2.

4.3.1.2 Telecommand Rejection

The probability of responding to any invalid signal, including "no command carrier" and at illumination flux densities up to –65 dBW/m^2 shall not exceed 1×10^{-9}.

4.3.2 Command Override

All onboard-automated commands or functions shall be capable of override via telecommand.

4.3.3 Stored Command Execution

4.3.3.1 Command Execution

After verification of stored commands, a telecommand shall be required to initiate execution of the stored command sequence.

4.3.3.2 Stored Command Sequences

Command sequence capability of 8-32 command sequences shall be provided. Each command sequence shall be capable of calling for the execution of another command sequence.

4.3.4 Time-Tagged Commands

A commandable range of not less than 16 years shall be provided for time-tagged commands.

4.3.5 Hazardous Commands

All commands with potential to result in mission failure shall require two commands. The first command shall enable the command and the second shall initiate the command.

4.3.6 Command Security

The satellite shall have an NSA Authorized Command Security (CS) subsystem associated with the command system. The purpose of CS is to prevent unauthorized entities from entering any command into the satellite. This shall be accomplished by means of cryptographically secure authorization signatures, based on secure keys and portions of commands, which are decrypted on-board.

The CS subsystem shall be fully compatible with the command system, which shall be capable of operating in CLEAR mode or SECURE mode. A CS on-board unit is associated with each command base band chain. When in SECURE mode, only authenticated commands shall be passed to the command decoders; others shall be rejected and the telemetry system shall telemeter an indication of command rejection.

When in SECURE mode, a time-out function on each on-board CS unit shall automatically switch both base band chains to CLEAR mode if no command is authenticated within a period up to 24 hours (selected period is proprietary). Each timer shall be reset for each authenticated command by the associated CS unit. Upon trip of the control safety system, both base band chains shall be switched to CLEAR mode.

The satellite shall be capable of being launched in CLEAR mode and remain in CLEAR mode through acquisition and deployments.

The CLEAR/SECURE modes of the command security subsystem shall be selectable by telecommand.

All circuitry associated with the selection of either the CLEAR mode or the SECURE mode shall be single failure tolerant such that selection of either of these two modes is not prohibited. When in the CLEAR mode, circuitry for command security functions shall in no way interfere with commanding. This shall include any failure modes that may be introduced by the implementation of the CS subsystem. Except when operating in the SECURE mode, failure of the command security hardware shall not allow selection of CLEAR mode for that command path until commanded to CLEAR mode by the remaining command base band chain.

At power-up each decryptor shall default to CLEAR mode with the default key selected (key Programmable Read-Only Memory (PROM) address of zero), and a Variable Command Count (VCC) value of zero.

It shall be possible to index to a new key or select a new value for VCC for each decryptor unit at any time while in SECURE mode. This initialization process shall consist of selecting a system cryptographic key by sending the key selection command.

All telemetry required to operate the command security system shall be provided in a manner that is unambiguous and at a rate that is consistent with command operations.

Each decryption devise shall contain at least three different key patterns. It shall be possible to select from these key patterns by telecommand. Key address zero will designated the default key.

4.4 TELEMETRY

4.4.1 Telemetry Parameters

The DHS shall gather, format, encode and provide as a baseband signal to the TC&R Subsystem the following telemetry, as a minimum:

a) Satellite, command processing channel, and telemetry processing channel identifications

b) Satellite separation events and pyrotechnic command enable status

c) Communications subsystem status, power amplifier temperatures, receiver pair temperature, channel gain setting, and helix current and anode voltage for Traveling Wave Tube Amplifiers (TWTAs) and RF switch position

d) TC&R subsystem equipment ON/OFF status, receiver signal strength, CLEAR/SECURE mode status, VCC, and other status

e) Power subsystem main bus voltage and current, battery charge/discharge current and status, selected battery cell voltages and pressure, solar array current, and solar array shunt currents

f) Thermal subsystem thermistor data, selected heater ON/OFF status, and selected control status

g) Ka-band uplink power (measured at output of channel amplifier)

h) Propulsion subsystem tank pressures, thruster firing history, and latch value status

i) ACS sensor data, control loop data, thruster selection, selected control mode parameters, wheel speed, motor current, and other subsystem status

4.4.2 Dwell Telemetry

The capability to dwell on up to any eight telemetry words shall be provided. This capability shall not preclude normal telemetry simultaneously. This mode shall be selected only by telecommand.

4.5 FAILURE DETECTION AND RECOVERY MANAGEMENT

The DHS shall provide an autonomous failure detection and recovery capability. This capability shall allow the satellite to recover from failures such that the satellite is either automatically restored to service or placed in a safe mode of operation such that ground operator failure analysis can take place. If placed in a safe mode of operation, service restoration shall be by telecommand.

4.5.1 Safe Mode

As a minimum the following actions shall be implemented, as appropriate, for those failures requiring the safe mode:

a. automatically switch the TC&R transmitters to high power mode

b. automatically connect the TC&R transmitters to the wide beam omni antennas

c. select the clear command mode

d. disconnect all but essential loads from the EPS power bus

4.6 SATELLITE CONFIGURATION MAINTENANCE

The satellite configuration shall be maintained when switching from a primary to secondary unit. This satellite configuration shall include which other units are on, what command and telemetry signal paths are in use, and the enable/disable status of FDIR functions.

4.7 SATELLITE CLOCK

4.7.1 Clock Accuracy

The satellite clock shall be accurate to within 1 minute per month. Telecommand adjustment to meet this requirement is permitted.

4.7.2 Clock Resolution

The clock resolution shall not be greater than 1.0 second.

4.7.3 Clock Rollover

The clock shall not rollover after being initially set for a period of not less than 16 years.

4.8 FIRMWARE

Firmware shall include support to other subsystems to implement their control algorithms, as required All automated firmware shall be capable of being disabled by telecommand. Key parameters such as heater setpoints, voting margins, control sensor selection, attitude control gains, and battery management parameters if implemented in firmware shall be capable of being modified by telecommand or memory upload

4.8.1 Memory Margin

Memory sizing shall provide a minimum of 15% (TBR) allocated for reprogramming after launch

4.8.2 Timing Margin

There shall be a minimum of 15% timing margin available for reprogramming after launch

4.9 INTERFACES

As a minimum, the DHS shall provide the subsystem interfaces specified herein.

4.9.1 Communication Payload

The DHS shall receive and issue all commands necessary to configure and control the payload communication equipment. The DHS shall collect and format all telemetry necessary to verify configuration and operation of the payload communication equipment.

4.9.2 Telemetry, Command and Ranging Subsystem (TC&RS)

4.9.2.1 Command

The DHS shall accept telecommands from the TC&RS to provide control of all of the satellite's possible configurations. The DHS shall provide for inputs from two, redundant receivers and cross-strap them to the decoders to preclude single-point failure loss of the telecommand function.

4.9.2.2 Telemetry

The DHS shall provide outputs to two, redundant transmitters for baseband transfer of telemetry. The DHS shall provide two telemetry baseband subcarriers:

a. normal telemetry; bi-phase L, PCM/BPSK on a 48 kHz subcarrier

b. dwell telemetry, bi-phase L PCM/BPSK on a 72 kHz subcarrier

4.9.2.3 Telemetry

The DHS shall collect and format TC&R Subsystem telemetry.

4.9.3 Attitude Control Subsystem (ACS)

4.9.3.1 Initiation

The DHS shall provide the on/off commands for the ACS.

4.9.3.2 Telecommands and Telemetry

The DHS shall receive and distribute telecommands to the ACS units. The DHS shall collect and format telemetry from the ACS units.

4.9.3.3 Reconfiguration

The DHS shall provide reconfiguration commands to the ACS for hardware/software reconfiguration purposes.

4.9.4 Electrical Power Subsystem

4.9.4.1 Battery Monitoring

The DHS shall monitor battery voltages, temperatures and cell pressures sufficiently to assure proper operation of the batteries. The DHS shall determine the battery state of charge for purposes of battery energy management.

4.9.4.2 Battery Recharge

The DHS shall autonomously issue commands to the battery heaters and charge rate controllers to control battery recharge after each eclipse. The DHS shall issue overriding charge rate or heater on/off telecommands.

4.9.4.3 Telemetry

The DHS shall collect and format EPS telemetry.

4.9.5 RF Autotrack Subsystem

The DHS shall receive and distribute telecommands to the RFAT units. The DHS shall collect and format telemetry from the RFAT units.

4.9.6 Thermal Control Subsystem

4.9.6.1 Heater Control

The DHS shall autonomously control heater on/off settings based on telecommand settable on/off temperature set points. DHS controlled heaters shall have telecommand override capability.

4.9.6.2 Telemetry

The DHS shall collect and format all TCS temperature telemetry.

4.9.7 Propulsion Subsystem

4.9.7.1 Valve Control

The DHS shall provide enable/disable commands to the propulsion subsystem pyro and latch valves.

4.9.7.2 Telemetry

The DHS shall collect and format all Propulsion Subsystem telemetry.

4.9.8 Mechanisms

4.9.8.1 Deployables

The DHS shall issue telecommands for all satellite deployables.

4.9.9 Telemetry

The DHS shall collect and format all deployables and motorized mechanism position status.

5 ATTITUDE CONTROL SUBSYSTEM

5.1 OPERATIONAL REQUIREMENTS

The Attitude Control Subsystem (ACS) shall comprise those mechanical and electronic elements required to perform the following functions:

a. Sense satellite attitude and rates

b. Provide satellite attitude stabilization following launch vehicle separation

c. Orient the satellite during transfer orbit and support orbit raising maneuvers including Perigee Velocity Augmentation (PVA)

d. Perform Earth acquisition maneuvers

e. Provide on-board control of roll, yaw, and pitch attitude and ground control of roll, pitch, and yaw thrusters

f. Provide communication subsystem user spot beam antenna bias, slew, and autotrack capability

g. Provide the telemetry subsystem information from which the above may be determined and/or accomplished

5.2 ATTITUDE DETERMINATION

The satellite ACS equipment shall provide adequate knowledge of satellite attitude control states during all phases of the mission to satisfy all mission requirements including inclined orbit operation up to 3°. The equipment shall also be used to generate on-board control error signals.

5.3 ATTITUDE CONTROL

The satellite ACS equipment shall maintain attitude stability and utilize the ACS equipment to generate the control signals necessary for the operation of all the actuators that control the satellite attitude and for the implementation of the maneuver sequences required.

Pointing accuracy to meet the communications service requirements specified in Section 3 shall be maintained the entire duration of the on-orbit maneuver lifetime and during all modes of operation. The ACS autotrack function shall collect antenna pointing sensor data and direct the user spot beam antenna positioning mechanisms to meet the antenna pointing requirements as defined in Section 2.1.

5.4 REACQUISITION

Provision shall be made for reacquisition of the satellite attitude and antenna autotrack-pointing attitude in the event of loss of Earth pointing at any time throughout satellite life.

5.5 OPERATIONAL AUTONOMY

The attitude and stationkeeping concept shall support up to 7 days of spacecraft autonomy in the absence of failures. Autonomy means that no human generated bus commands are required for 7 days to maintain the satellite in the specified stationkeeping box and within its antenna pointing allocations. More frequent telecommanding may be generated and uplinked by the ground computer or generated by the spacecraft computer, without human intervention, to allow for optimum performance.

Where normal operation of the subsystem requires switching of attitude references (e.g., to avoid Sun interference), control electronics, control modes, control parameters, etc., such switching shall not result in transient errors that violate the required pointing accuracy.

5.6 CONTROL BIAS CAPABILITY

The satellite shall include means of biasing ±3.0° in pitch and ±0.5° in roll by telecommand, with the zero error settings of the ACS. The system shall be capable of maintaining appropriate bias values in each of the modes of operation. The bias offset shall be commandable over the full bias range in increments of less than 0.01°.The satellite ACS shall provide a means to slew and bias the user spot beam antennas. The system shall be capable of maintaining antenna bias values in the autotrack mode of operation.

5.7 IN-ORBIT ANTENNA PATTERN MEASUREMENT CAPABILITY

The satellite shall include the capability to permit antenna patterns for all coverages to be measured from the Gateway(s), for comparison with similar pre-launch measurements, in sufficient detail to assure that no significant change has occurred as a result of exposure to the launch and injection environment.

5.8 SUN/MOON INTERFERENCE

The Earth sensor design and geometrical arrangement shall provide a means of avoiding Sun and Moon interference. This interference may be avoided by selection of the appropriate control sensor and detector by telecommand. Inadvertent exposure to the Sun shall not damage or cause permanent degradation to the sensor.

5.9 SAFE MODES

In general, the design shall include safe modes in order to assure the safety of the satellite and its subsystems, especially the solar array power, thermal conditions, and Telemetry, Command, and Ranging (TC&R) link, and to minimize expended propellant mass under failure conditions. The satellite design shall incorporate automatic on-board provisions to inhibit autonomous thruster firings during sensor failure or loss of sensor signal conditions, and to inhibit excessively long thruster firings and prevent excessive satellite body rates.

5.10 SHADOW MODE

It shall be possible to switch control from one control channel to another, check out all back-up sensors and control electronics (not actuators) and switch over redundant units by telecommand while maintaining communications specification performance.

5.11 ACS REDUNDANCY

The ACS shall include, as a minimum, two independent control channels. All ACS sensors, electronics, and actuators (excluding the solar array drive assembly, the antenna pointing mechanisms, SPT gimbals and RF autotrack antenna feeds) shall be redundant. Cross-strapping shall be provided so that redundant units can be switched in and out of the control channel and failed units can be isolated while maintaining communication specification performance. The central processing units shall be re-programmable in the event of an in-orbit failure requiring the ACS algorithms to be modified.

5.12 SENSOR FIELDS-OF-VIEW

All ACS sensors shall have fields-of-view such that sensor performance is unaffected by satellite glint or reflections.

5.13 ACTUATORS

All actuators shall be capable of providing a minimum torque margin of two under worst-case conditions.

5.14 COMMANDS

Control capability over all attitude control states and modes of operation shall be provided. It shall also be possible to override and/or inhibit any automatic switchover function by telecommand. All selectable control parameters shall be settable by telecommand.

5.15 TELEMETRY

Sufficient telemetry shall be provided to verify all telecommands and to determine both the subsystem configuration and the state of all units in the subsystem. The telemetry shall also be sufficient to monitor each parameter to the degree and accuracy necessary to maintain satellite attitude control and antenna pointing.

6 TRACKING, TELEMETRY, AND COMMAND

The Telemetry, Command, and Ranging (TC&R) Subsystem shall provide the Satellite telecommand and telemetry interface with earth stations and ground support equipment for orbit raising and on-station operations. The TC&R Subsystem provides the RF functions of the overall Satellite command and telemetry system.

6.1 GENERAL REQUIREMENTS

The TC&R subsystem shall operate at C-Band for launch and orbit raising operations and shall operate at Ka-Band for on station operation. For each C-Band and Ka-Band operation, the TC&R subsystem shall consist of two functionally redundant command processing channels, two functionally redundant telemetry channels and two functionally redundant ranging channels, utilizing the command receivers and telemetry transmitters. The satellite TC&R antenna polarizations shall be compatible with linearly polarized ground station antennas during normal on-station operations.

6.1.1 Command

The command equipment shall consist of antennas and receivers. The command antenna coverage shall be consistent with the requirements for all mission phases. The command sensitivity shall be less than or equal to -85 dBW/m^2 during orbit raising and -95 dBW/m^2 on-station for incident angles within the command antenna coverage.

6.1.2 Telemetry

For each C-Band and Ka-Band, the telemetry equipment shall provide two redundant Radio Frequency (RF) channels for the transmission of diagnostic data acquired by the telemetry processing equipment from sensors, transducers, thermistors, switches, voltage monitors, etc. Telemetry data shall be transmitted through the telemetry antenna whose coverage will be consistent with all phases of mission requirements. Ranging

The satellite ranging base band output of each receiver shall be routed to the appropriate telemetry transmitter where, upon telecommand, the ranging tones shall be modulated onto the downlink carrier. The on-orbit ranging channel performance shall be met with an incident flux density of-85 dBW/m2 for incident angles within the command antenna coverage.

The satellite ranging system shall be compatible with an overall ranging system capable of determining the satellite range to within ±30 m.

6.1.3 TC&R/Communications Compatibility

TC&R subsystem operations shall be capable of being conducted simultaneously with communications subsystem operations, without measurable degradation or interference to either subsystem for all specified incident flux densities.

6.1.4 Telemetry Transmitter

The telemetry transmitter performance shall satisfy the requirements of the performance summary in Table 6-1. The telemetry transmitter shall accept one or more bi-phase modulated subcarriers from the DHS and the ranging tones from the command receiver if commanded by the ground. These subcarriers shall phase modulate the carrier frequency at an index of 1.0 ±0.1 radian if only one subcarrier is selected, 0.7 ±0.1 radian if two subcarriers are selected, and 0.6 ±0.1 radian if three subcarriers are selected. Selection of subcarriers to be transmitted shall be by telecommand.

Table 6-1. Telemetry RF Performance

Parameter	Performance
Frequency	Orbit Raising (TBD), On Station (TBD)
Modulation characteristics	
Type	Phase
Indices	1.0 ±0.1 radian peak for single subcarrier
	0.7 ±0.1 radians peak per subcarrier for 2 subcarriers
	0.6 ±0.1 radians peak per subcarrier for 3 subcarriers
Control functions	Transmitter ON/OFF
	Ranging modulation ON/OFF
	Telemetry modulation ON/OFF
EIRP	6.0 dBW minimum (TBR), ±Z Omnis (wide-angle), Orbit Raising
	9.0 dBW minimum (TBR), Global Horn, On-Station
Spurious outputs	-62 dBc in-band (TBR - Excluding dc/dc converter frequencies, <-50 dBc out-of-band)

Provision shall be made to operate the two telemetry transmitters on different carrier frequencies. Transmitter ON/OFF control and ranging ON/OFF control shall be provided.

Each on-station telemetry transmitter shall provide two power output levels: (1) a high-power mode for use with a global horn antenna during normal on-station operation, and (2) a low-power mode for use with a high-power TWTA and omni (wide-angle) telemetry antennas during emergency operations. Power mode control shall be by telecommand.

Each orbit-raising telemetry transmitter shall provide one power output levels: (1) a high-power mode for use with the omni telemetry antennas during ground testing and launch operations, and

(2) a low-power mode for use with a high-power TWTA and omni (wide-angle) telemetry antennas during normal orbit-raising operations.

6.1.5 Spurious Emissions

Spurious emissions originating within the TC&R subsystem shall meet the requirements of Section 3.24

6.2 COMMAND RECEIVER

The command receivers performance shall satisfy the requirements of the performance summary in Table 6-2 The on-station command receiver channels shall respond to RF inputs in the 29-GHz band (TBR). The orbit-raising command receiver channels shall respond to RF inputs in C-Band.

Table 6-2. Command Receiver Performance Summary

Parameter	Performance
Frequency characteristics	
Frequency	On Station: (TBD), Orbit-Raising: (TBD)
Carrier modulation	FM, ±400 kHz deviation
Base band	16 kHz command subcarrier or ranging tones
Dynamic range	TBD
Outputs	
Command	Cross-strapped to the command decoders
Ranging	Routed to the associated telemetry transmitter on command for turn-around ranging operations

6.2.1 Receiver Protection

The command receiver performance shall not be degraded after being subjected at any antenna to flux densities of up to –50 dBW/m^2 in any frequency band with the receiver either powered or unpowered.

6.3 RANGING EQUIPMENT PERFORMANCE

The ranging signal shall consist of sequential ranging tones which are Frequency Modulated (FM) on one of the two command and ranging uplink carriers. These tones shall be demodulated in the command receiver operating at the selected uplink frequency, and then shall be routed to the associated transmitter for retransmissions to the ground station. It shall be possible to simultaneously command on one uplink frequency and range on the other. The downlink ranging tones may be transmitted alone or simultaneously with one of two telemetry modulation sources. Telemetry transmission shall not be adversely affected by ranging operations. Performance characteristics for the ranging function are given in Table 6-3.

Table 6-3. Ranging Performance Characteristics

Parameter	Performance
Uplink carrier frequency	TBD
Flux density dynamic rang	TBD
Uplink antenna coverage	Similar to command (not performed at minimum gain)
Uplink modulation	FM ±400 kHz peak
Simultaneous command and ranging	Provided, using separate carrier for each
Baseband	Sequential tones, in 100 Hz to 50 kHz band
Simultaneous telemetry and ranging	Provided; ranging plus up to two telemetry subcarriers can be transmitted on either telemetry transmitter
Downlink modulation	PM

6.4 TC&R ANTENNA PERFORMANCE

The TC&R antennas shall be designed to provide coverage consistent with mission requirements during all normal phases of the mission and retain maximum operational capability under abnormal or emergency conditions. The receive and transmit antennas polarization shall be horizontally linear.

6.4.1 Antenna Coverage

The TC&R subsystem antennas shall provide the following coverage as a minimum:

a. a global coverage horn for normal on-station operations

b. omni antennas suitable for transfer orbit and on-orbit emergency coverage

6.5 EMERGENCY OPERATIONS

The TC&R subsystem shall be designed to retain operational capability under abnormal or emergency conditions down to a bus voltage of 95 Vdc (TBR).

7 ELECTRICAL POWER SUBSYSTEM

The Electrical Power Subsystem (EPS) shall generate, store, condition, and distribute electrical power as required by the various satellite loads in fulfilling all phases of the satellite mission during its mission lifetime including 100% eclipse operations.

The EPS shall be designed, manufactured, and tested to meet worst-case power requirements for all anticipated satellite modes of operation including all the communications modes specified in Section 3.

The EPS shall also provide sufficient power for other satellite loads to maintain full operating capacity at all times in all other subsystems.

7.1 SOLAR ARRAY

The power output of the solar array in the worst-case condition with one circuit failure at end of mission life shall be sufficient to support the maximum design satellite load. The power output shall be based on measurement and analysis of the array components and space degradation predictions. An appropriate modeling uncertainty shall be applied to the array power calculations based on in-orbit array performances versus past predictions. In addition, 2% power margin shall be required for design up to CDR. The array optical characteristics shall be measured. Analysis shall be done to determine the array temperature for use in power capability analysis.

7.1.1 Design Load

The solar array design load shall be based on operation of the payload forward link TWTAs at 3 db output backoff (OBO) and the return link TWTAs at 6 dB OBO (TBR).

7.2 BATTERY

The energy storage device for supplying power to the satellite during eclipse and/or transient load conditions shall consist of two batteries. The batteries shall be sized to satisfy the dual requirements of support to the satellite through the launch sequence until such time as the solar array is able to support the satellite bus and subsequently through the semiannual eclipse season at 100% satellite design load for the mission life of the satellite. The maximum Depth of Discharge (DOD) shall not exceed 80%. The maximum DOD shall not be exceeded in the worst-case conditions throughout mission life including the allocation of one failed cell per battery.

It shall be possible to recondition each battery independently while the other remains connected to the main bus and on trickle charge. Telemetry data shall be provided for implementation of deep reconditioning.

Battery charging shall be autonomous and accomplished by controlling current as the primary variable. Battery operating modes shall be implemented by telecommand.

7.3 POWER CONDITIONING AND CONTROL

The power conditioning and control equipment shall transfer and transform the bus voltage from either the array or the batteries to the satellite loads in a form suitable for each load. The transfer from solar array to battery and vice versa shall be automatic, stable, and smooth. Each load shall be able to draw power from one of two main buses including independent means of supplying power to redundant loads.

Circuitry and/or Radio Frequency (RF) and electrostatic discharge (ESD) shielding shall be provided where appropriate on the power circuitry to prevent interference, either conducted or radiated from degrading the satellite performance.

In the event of a load failure, protection shall be provided to ensure no permanent degradation of the power subsystem performance.

All satellite loads shall be protected from damage in the event of a main bus undervoltage condition occurring. Reconnection of Traveling Wave Tube Amplifiers (TWTAs) after an under voltage disconnect shall be by telecommand only. De-rating factors shall take into account the stresses that components are subjected to during periods of undervoltage, including conditions which arise during ground testing while the bus voltage is slowly brought up to its nominal value. Capability of providing the worst-case currents for fault clearing or for transient loads with any combination of batteries on-line shall be provided.

Connections shall be provided to allow external power sources to provide power during ground testing and prelaunch operations.

The EPS shall be stable under load transients including the TWTA power transients specified in 3.29.

7.4 COMMANDS

As a minimum, the EPS shall have the following configuration control via telecommand:

a. selection of battery charge rate

b. battery heater control

c. independent adjustment of the solar array position

d. individual load reconnection following automatic bus undervoltage switch-off

7.4.1 Telemetry

As a minimum, the EPS shall provide the following parameters via telemetry:

a. power bus voltage and current

b. battery voltage and charge/discharge current

c. battery cell group voltage

d. selected battery cell pressure

e. battery temperature

f. battery charge/discharge system status

g. solar array wing positions

h. solar array wing current

i. low voltage converter current and output voltage

8 THERMAL CONTROL SUBSYSTEM

The thermal control subsystem shall be primarily a passive design and shall maintain all satellite equipment and structures within their relevant design temperature ranges, under all conditions experienced during the period starting with pre-launch activities, and throughout the mission lifetime, including in-orbit storage with the communications payload powered off.

8.1 DESIGN MARGIN

The design shall provide margins of 10° C between the temperature extremes expected by the units during the contract mission life and the temperature range over which the units operate safely (qualification temperature range).

All heaters shall be sized to maintain components 10° C above their minimum qualification temperatures, except where redundant, autonomously controlled heaters or thermostatically controlled heaters are used, in which case the heater shall be sized to maintain components 5° C above their minimum qualification temperatures.

8.1.1 Thermal Design

Whenever heaters are required to ensure that unit performance specifications will be met, the heaters and their control thermisters shall be redundant.

Normal Satellite thermal control shall not require telecommands except for enabling selected heaters. All automatically controlled heaters shall have redundant control thermisters and telecommand override capability.

The thermal design of the Satellite shall take into account the degradation of thermal control items over mission life. Degradation factors shall include, but not be limited to, solar absorption, plume impingement, electrostatic discharge.

All externally exposed, dielectric thermal control surfaces shall include means to mitigate electrostatic charge build-up.

8.2 TELEMETRY

In-flight telemetry temperature measurements shall be provided in a quantity and with a sampling rate sufficient to allow verification of the thermal performance of the satellite and the timely detection of anomalies.

9 PROPULSION SUBSYSTEM

The satellite propulsion subsystem shall include all components and assemblies associated with storing, conditioning, routing, controlling, and expelling propellant, as required to change the satellite's attitude and angular or linear velocity. The propulsion subsystem includes all propulsion hardware and propellants required to achieve placement into geosynchronous orbit from the geo-transfer orbit, all on-orbit operations and end-of-life (EOL) de-orbit maneuver. Liquid bi-propellant thrusters shall be utilized during the various operational phases following separation from the launch vehicle until the end of mission life including all major velocity maneuvers, apogee injection, and final de-orbit maneuver.

All performance and operational requirements shall be met in the event that any single propulsion electro-explosive device fails to activate. The Main Satellite Thruster (MST) shall be isolated from the propellant supply system after the last apogee velocity correction using latching isolation valves.

The subsystem shall include functional redundancy through the use and interconnection of multiple thrusters, valves, and fluid control components to provide full thruster control redundancy. Each thruster shall be individually isolated with a latch valve or solenoid valves. The full propellant load shall be available to each thruster of the primary and redundant set.

Based on mission analyses, sufficient propellant shall be provided to satisfy the translation velocity and rotational impulse required by the satellite to attain initial geostationary orbit and during the mission lifetime.

It shall be possible to predict depletion of xenon to an accuracy of 3 months anytime during the last

5 years of the SPT portion of the mission life and it shall be possible to determine the end of biprop Stationkeeping (SK) capability to an accuracy of 6 months at least 2 years prior to the end of mission life. The accuracy of the system shall be 1 month or better at 3 months prior to the end of SK capability.

Fuel loading and off-loading shall be possible at the launch site.

Each thruster shall be capable of performing 1.3 times the nominal number of starts and 1.3 times the throughput corresponding to the operating sequence that would be required if the functionally redundant thruster were inoperable throughout the entire mission. The maximum duty cycle of the 22-N thruster shall not exceed 55% during normal in-orbit operation.

9.1 PROPELLANT LOAD

Based on mission analyses, sufficient propellant shall be provided to satisfy the translation velocity and rotational impulse required by the satellite to attain initial geostationary orbit and during the mission lifetime including EOL de-orbit maneuver. Propellant loading will be maximized without unduly increasing the mission risk.

Propellant loading and off-loading shall be possible at the launch site.

9.2 THRUSTERS

The position and orientation of thrusters shall be such that required performance is attained while disturbances and impingement due to thruster plumes are minimized.

All thrusters shall be capable of unrestricted, pulse-mode operation which may be initiated either on-board or by telecommand throughout all phases of the mission.

Each thruster shall be capable of performing 1.5 times the nominal number of starts and propellant throughput corresponding to the operating sequence that would be required if the functionally redundant thruster were inoperable throughout the entire mission. The maximum duty cycle of the 22-N thruster shall not exceed 55% during normal in-orbit operation.

10 STRUCTURE SUBSYSTEM

The structure subsystem shall provide the mechanical support for the other subsystems in a configuration that meets the system requirements of thermal control; sensor and antenna fields-of-view; mass properties; alignment; launch vehicle interface; and assembly, integration, and test.

The structure shall be capable of sustaining all direct and cumulative load combinations occurring during qualification testing, ground handling, transportation, launch, orbit operations, and main satellite thruster firing without permanent degradation. In final orbit, the structure shall have and maintain throughout the satellite design lifetime the dimensional relationships required to enable all functional operations to be performed within the limits imposed by these specifications. The structure shall also provide protection to other subsystems against excessive loads during environmental testing, ground handling, transportation, launch, and orbit maneuvers.

The satellite structure shall be dynamically compatible with the specified launch vehicles. There shall be sufficient frequency separation between resonance of the major subassemblies to avoid dynamic coupling. The structural analysis model shall be updated to reflect results of structural tests. The adequacy of the selected frequency-sensitive elements shall be verified for coupled loads analysis inputs

Composite fiber material structures shall take into consideration, dimensional stability effects due to thermal cycling, moisture, cracking and solar radiation.

Thrusters and sensors for three-axis control shall not be blocked by stowed deployable parts of the structure

Dynamic and strength characteristics of all deployable parts of the structure shall be compatible with the launch vehicle dynamic environment. After deployment; the dynamic response of the deployable structures shall remain de-coupled from the satellite attitude control dynamics for >15 years in orbit.

10.1 DESIGN LOADS

The satellite structural design shall be based on design loads derived as follows:

Flight Limit Loads (FL)	Maximum expected flight load
Design Load (DL)	1.3 x FL

Flight limit loads shall be based on the maximum possible launch weight for the satellite, including full propellant tanks and the worst-case envelope of all launch vehicles where compatibility is required.

10.2 MARGINS OF SAFETY (BASED ON DESIGN LOADS)

Margins of safety shall be no less than shown in the following tables:

Table 10-1. Margin of Safety for Metallic Structure

0.0	Yield
0.25	Ultimate Stress
0.1	Elastic Buckling

Table 10-2. Margin of Safety for Composite Structure

0.25	First Ply Based on: Maximum Strain Theory Maximum Stress Theory Polynomial Failure Theory

Table 10-3. Margin of Safety for Pressure Vessels

ed Operating Pressure Burst

10.3 ACCESSIBILITY

Access to components for maintenance and other activities shall be provided to the maximum practical extent. Disassembly of alignment critical structural elements shall be minimized and, if required, require realignment.

11 MECHANISMS AND ACTUATORS

All mechanisms and actuators shall be designed for and demonstrate a lifetime of ≥15 years and provide a torque margin of ≥3:1 under worst-case expected operating conditions.

Where restraint mechanisms are required, solid debris that results from the operation of these mechanisms shall be contained.

Any component using mechanisms shall be designed to minimize the static and dynamic disturbances to the spacecraft when operating the mechanism. The operation of mechanisms shall not alter the thermal balance, or cause an out-of-tolerance condition for the control system of the Satellite.

11.1 ROTATING DEVICES

The design of continuously rotating mechanisms that utilize ball bearings shall incorporate provisions for lubrication. For equipment utilizing slip ring and brush devices for power transfer, the design shall, to the extent practical, eliminate mechanisms by which shorting may be encountered within the device. Any motor driven device, once deployed or released, shall be capable of being operated at any time during the mission.

11.2 DEPLOYMENT MECHANISMS

Special attention shall be given to torque margins, thermal environmental effects, and mechanical alignments.

Deployment of the solar arrays and antennas shall be confirmed by attitude rate and solar array current

11.3 ANTENNA AUTOTRACK MECHANISM

The satellite shall provide an autotrack positioning mechanism for each user spot beam antenna. The mechanisms shall position the antennas in response to signals received from the ACS autotrack function.

11.4 MECHANISM REDUNDANCY

All moving and deployment mechanisms shall be electrically and mechanically redundant to the maximum extent practical. A non-redundant drive motor must be specifically approved and supported by detailed failure rate analysis down to the mechanical component level.

11.5 HOLD DOWN/RELEASE DEVICES

All hold down/release devices used in the Satellite shall be functionally redundant to ensure their operation under the worst environmental conditions including activation commands, electronic drive circuits, initiators and actuators. The hold down/release devices shall be easily accessed for their inspection, installation or removal, without affecting the alignment of the system, or disturbing other subsystems.

11.6 COMMANDS

As a minimum, the following telecommand controls shall be provided for the hold down/release devices:

a. Enabling and disabling of the device

b. Arming of the device

c. Activation of the hold down/release device.

It shall be possible to conduct command/response testing to verify proper connectivity between mechanisms and holddown/release devices and the on-board command source.

11.7 TELEMETRY

As a minimum, the following telemetry data shall be available for the hold down/release devices and/or mechanisms:

a. Enabled/disabled status

b. Armed/disarmed status

c. To the extent possible, position telemetry of adjustable deployable appendages.

12 RF AUTOTRACK SUBSYSTEM

The RF Autotrack (RFAT) subsystem is part of the Communication Subsystem and shall provide the equipment to provide precision pointing of the spot beam antennas.

12.1 RF BEACON

The RFAT subsystem shall interface with the ground originated autotrack beacon specified in Section 3. The beacon signal shall be processed by the RFAT subsystem to provide user spot beam antenna pointing data to the ACS autotrack function to meet the EIRP, G/T and Adjacent Beam Interference requirements. The RF beacon transmit characteristics shall comply with FCC requirements. The RFAT tracking receiver shall be designed to be compatible with the RF beacon .

12.2 BEACON REDUNDANCY

The RFAT subsystem autotrack beacon receiver shall have the capability to autonomously switch to the ground backup beacon in the event of signal loss from the primary beacon.

12.3 COMMANDS

All commands to the RF Autotrack subsystem shall be issued by the ACS subsystem. Telecommands for the RFAT subsystem shall be relayed to the ACS via the DHS. As a minimum the following telecommand capability shall be provided (TBR):

a. beam primary/redundant override

b. N/S and E/W antenna select override

c. primary/redundant LNA select

d. tracking receiver select

12.4 TELEMETRY

Telemetry shall be collected from the RFAT subsystem by the DHS with the exception of receiver selection status (TBR). Minimum RFAT subsystem telemetry shall include (TBR):

a. selected beam status

b. N/S and E/W antenna select status

c. primary/redundant LNA select status

d. tracking receiver select status (collected and included in ACS telemetry)

13 NOTES

C/I definitions for TELSTAR Ka 93° W, Ka-band Satellite

Definitions:

C/I_i is the Carrier to Interference Ratio for ith beam in dB

θ_i is the angular coverage area of the ith beam

$Pout_i$ is the tube power of the ith beam in watts

$Loss_{out\,i}$ is the repeater output loss of the ith beam in power loss factor

G_i is the gain of the ith beam in power equivalent

cov is the list of co-frequency coverage regions or beams of which i is one.

Transmit:

$$\left.\frac{C}{I}\right|_i(\theta_i) = 10\log_{10}\left(\frac{G_i(\theta_i)}{\sum\limits_{\mathrm{cov}\neq i} G_{\mathrm{cov}}(\theta_i)}\right)$$

Receive:

$$\left.\frac{C}{I}\right|_i(\theta_i) = 10\log_{10}\left(\frac{G_i(\theta_i)}{\sum\limits_{\mathrm{cov}\neq i} \max\left(G_i(\theta_{\mathrm{cov}})\right)}\right) \qquad \text{(TBR)}$$

RADIATION ENVIRONMENT FOR ELECTRONIC COMPONENTS

ANNEX A

TO

EXHIBIT B

PERFORMANCE SPECIFICATIONS

RADIATION ENVIRONMENT FOR ELECTRONIC COMPONENTS

1.1 INTRODUCTION

All satellite components, excluding the solar array, shall be in compliance with the space environmental conditions set forth in this Annex.

1.2 RADIATION ENVIRONMENT

Table A-1. Electron Flux

Energy, E [MeV]	Electrons [cm-2 sec-1] (Solar Maximum)
0.04	4.46 x 107
0.10	3.02 x 107
0.50	2.71 x 106
1.00	4.37 x 105
1.50	1.08 x 105
2.00	3.51 x 104
2.50	9.05 x 103
3.00	3.23 x 103
3.50	1.35 x 103
4.00	3.99 x 102
4.5	1.05 x 102
5.00	3.63 x 100

Table A-2. Proton Flux (Including Solar Flares) and Alpha Particles

Energy E, [MeV]	Protons [cm-2 sec-1] (Energy Greater than E)	Alpha Particles [cm-2 sec-1] (Energy Greater than E)
0.01	2.74×10^7	—
0.03	2.03×10^7	—
0.05	1.51×10^7	—
0.10	7.21×10^7	—
0.50	1.04×10^5	—
1.00	4.51×10^2	1.74×10^1
4.00	1.60×10^2	8.00×10
10.00	6.63×10^1	3.32×10
30.00	6.63×10^1	3.32×10
60.00	6.63×10^1	3.32×10
100.00	1.49×10^1	7.45×10^{-1}

Table A-3. Cosmic Ray Spectrum

Galactic Cosmic Rays Representative Fluences	
Charge (Element)	**Particles [cm-2 sec-1]**
1 (Hydrogen)	4.000
2 (Helium)	0.500
8 (Oxygen)	0.030
14 (Silicon)	0.007
26 (Iron)	0.003
Abundance by Charge Groups Compared to He Given Above	
$3 < z = 5$	1/48
$6 < z = 9$	1/16
$10 < z = 14$	1/75
$15 < z = 19$	1/600
$20 < z = 30$	1/200
$30 < z$	1/8000000
Seasonal Variations in Solar Energy	
Season	**Relative Solar Intensity**
Summer Solstice	0.968
Vernal Equinox	1.008
Winter Solstice	1.014
Autumnal Equinox	0.993

Table A-4. Meteoroid Flux Model by MASS per NASA SP 8013 dated March, 1969

Mass, M [g]	Events [m^{-2} day^{-1}]
1×10^{-12}	1.9×10
1×10^{-11}	1.3×10
1×10^{-10}	7.1×10^{-1}
1×10^{-9}	3.3×10^{-1}
1×10^{-8}	9.3×10^{-2}
1×10^{-7}	2.0×10^{-2}
1×10^{-6}	3.8×10^{-3}
1×10^{-5}	2.3×10^{-4}
1×10^{-4}	1.5×10^{-5}
1×10^{-3}	8.8×10^{-7}
1×10^{-2}	5.5×10^{-8}
1×10^{-1}	3.3×10^{-9}
1	2.3×10^{-10}

Table A-5. Meteoroid Velocity Distribution per NASA SP 8013 dated March, 1969

Velocity [km/s]	Percent of Total
0 - 9	0.0
9 - 12	4.6
12 - 15	25.4
15 - 18	25.7
18 - 21	14.0 Mean: 20 km/s
21 - 24	9.3
24 - 27	5.6
27 - 30	4.7
30 - 33	3.0
33 - 36	1.9
36 - 39	1.2
39 - 42	1.0
42 - 75	3.6
75 and up	0.0

Table A-6. Meteoroid Penetration Thickness and Crater Diameter

Penetration Thickness in Aluminum [cm]	Crater Diameter in Aluminum [cm]	Events (m^{-2} day^{-1})
0.001	0.005	7.0×10^{-1}
0.004	0.020	3.5×10^{-1}
0.010	0.050	1.0×10^{-1}
0.040	0.200	7.0×10^{-3}
0.100	0.500	6.0×10^{-4}
0.400	2.000	1.0×10^{-5}
1.000	5.000	5.0×10^{-7}
4.000	20.000	4.5×10^{-9}

Table A-7. Ultraviolet Radiation

Wavelength [Angstrom]	Fraction of Total Energy Below Wavelength [hc/wavelength]	Energy [ergs/sq. cm/yr.]
1	1×10^{-11}	$10^{2} - 10^{3}$
10	1×10^{-8}	$10^{5} - 10^{6}$
100	1×10^{-7}	$10^{7} - 10^{8}$
500	1×10^{-6}	1.0×10^{8}
1000	1×10^{-5}	4.0×10^{8}
1500	6×10^{-5}	2.5×10^{9}
2000	1.5×10^{-4}	6.0×10^{9}
2500	2.1×10^{-3}	9.0×10^{10}
3000	1.2×10^{-2}	5.0×10^{11}
4000	9.0×10^{-2}	4.0×10^{12}
5000	2.4×10^{-1}	1.1×10^{13}

RADIATION ENVIRONMENT FOR SOLAR ARRAY DESIGN

ANNEX B

TO

EXHIBIT B

PERFORMANCE SPECIFICATIONS

RADIATION ENVIRONMENT FOR SOLAR ARRAY DESIGN

1.1 INTRODUCTION

The solar array shall be in compliance with the space environmental conditions set forth in this Annex.

1.2 RADIATION ENVIRONMENT

The solar cells shall be designed using the electron environment defined in Table B-1, the solar flare proton environment defined in Table B-2 and the meteoroid environments defined in Table A-4, Table A-5, and Table A-6. All other components in the solar array, including cover glass for the solar cells, shall be designed using the particle environments defined in Annex A to Exhibit B.

Table B-1. Electron Flux Model for Solar Cell Design

Energy, E [MeV]	Electrons [cm-2 sec-1] (Solar Maximum)
0.04	3.79×10^7
0.10	2.42×10^7
0.50	1.93×10^6
1.00	2.82×10^5
1.50	6.56×10^4
2.00	2.17×10^4
2.50	4.81×10^3
3.00	1.80×10^3
3.50	7.47×10^2
4.00	2.56×10^2
4.5	6.91×10^1
5.00	1.84×10

Table B-2. Solar Flare Proton Model for Solar Cell Design

Energy, E [MeV]	Solar Flare Protons [cm-2 sec-1]
10.0	2.66×10^1
20.0	2.66×10^1
30.0	2.66×10^1
40.0	2.66×10^1
50.0	2.66×10^1
60.0	2.66×10^1
70.0	1.85×10^1
80.0	1.27×10^1
90.0	8.72×10^1
100.0	5.97×10