IV. SYSTEM DESCRIPTION

A. General Overview

The Celestri LEO System is a low Earth orbiting ("LEO") satellite network that will provide high data rate transmission with minimal transit delays over the populated areas of the Earth's surface. The system will provide Fixed-Satellite Services with a variety of user data rates to small, very small and ultra-small satellite earth terminals. It will also provide high data rate connections to gateway earth terminals that interconnect to the public switched telephone network ("PSTN").

The system is composed of a constellation of 63 satellites; a primary and a backup Mission Operations Control Center ("MOCC"), each of which includes a Satellite Operations Control Center ("SOCC") and a Network Operations Control Center ("NOCC"); one or more Distributed Virtual Network Managers ("DVNM"s); and several types of CPE. The satellites are interconnected through optical intersatellite links ("ISL"s) to provide a global communication network infrastructure. Control of the satellite constellation is provided by the primary MOCC and transferred to the back-up MOCC in the event of a primary failure. There will be six antenna sites that provide telemetry line-of-sight tracking, and command ("TT&C") communications for the control of the satellites. Two of these sites will be co-located with the MOCCs and four of them will be remote antenna facilities ("RAF"s). Service and subscriber management for the system will be controlled by service providers via DVNMs. The system is fully operational with one DVNM, but it is anticipated that a number of service providers will sell access to the system, and each of these providers is expected to have its own DVNM. Access to the Celestri LEO System for subscribers is through several categories of CPE designed to a standard system interface. Figure IV-1 shows a conceptual overview of the Celestri LEO System.

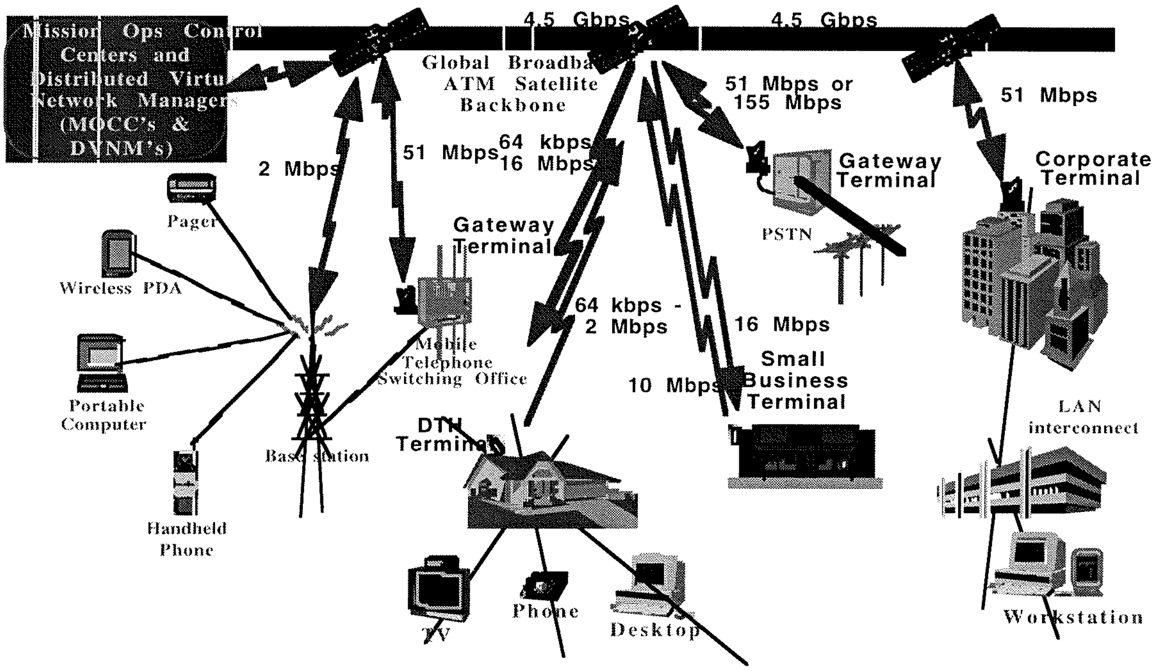

Figure IV-1: Celestri LEO System Architecture

The network architecture for the Celestri LEO System is based on a cell relay routing protocol. Individual cells are routed through ATM switches at network nodes (i.e. satellites), based on information appended to the cells. The individual nodes in the network support peak throughput rates as high as 17.5 Gbps, including uplink and downlink interconnections with subscribers and intersatellite links, to effect high data rate transfers between nodes.

The constellation design for the Celestri LEO System consists of 63 satellites in 7 planes of 9 equally-spaced satellites in each plane. The satellites form a constellation that provides coverage to 99% of the Earth's population. The constellation will be launched starting in 2001, and will be fully operational by the end of 2002.

The payload design for the Celestri LEO System (Figure IV-2) includes phased-array antennas to form service beams that project cells on the Earth's surface, switches to connect antenna beams with the receiver, transmitter, and modem elements, and a dynamic high data rate switch which routes data cells. Interconnections to other satellite nodes to form the satellite network utilize up to 6 optical intersatellite links.

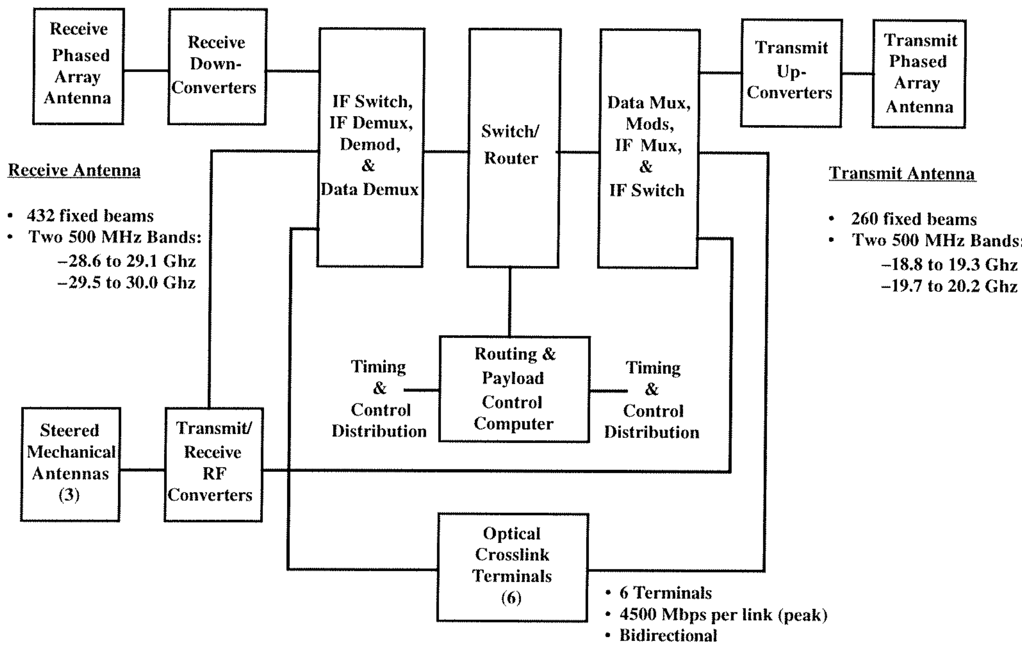

Figure IV-2 Payload Block Diagram

Motorola has selected a LEO constellation for the Celestri LEO System to ensure that the delays experienced by end-users are essentially equivalent to domestic transport systems for global real-time services. The system has been designed to be compatible with the existing global terrestrial infrastructure and with telecommunication standards. Thus, the system will seamlessly integrate with existing networks and provide a quality of service similar to that achieved by terrestrial fiber optic-based networks.

Orbits for the 63 satellites have been chosen to provide double or triple instantaneous satellite coverage for over 99% of anticipated CPE terminal sites. This geometric diversity is employed to maintain the desired quality of service for end-users. Equally important, the geometric diversity provided by multiple satellites in view of CPE sites supports co-existence with other satellite-based systems utilizing the same frequency allocations, provided the designs of such systems permit coordination.

The Celestri LEO System requires at least 1 GHz of service bandwidth in each direction in the Ka-band. The distribution of end-users, which is correlated to the population distribution throughout the global coverage area, will naturally create high peak demands on the system. This is a key driver in the overall spectrum requirement and in the design of any practical system. The LEO constellation geometry, in conjunction with a versatile satellite payload design, creates relatively small geographic cell sizes in the coverage footprint. This is instrumental in supporting the highly peaked traffic demands and in achieving spectral efficiency through frequency reuse. In terms of capacity density (i.e., bits/second per square kilometer) in a cell or cluster of cells, the Celestri LEO System can deliver nearly 9 times the stated capacities of GSO systems designed for similar applications. The Celestri LEO System will provide a standard interface definition that will allow manufacturers to develop a broad range of compatible CPE products.

B. Orbit Considerations

The constellation's orbital parameters were selected after careful consideration of many important criteria. First, the constellation must provide the ability to share spectrum with other systems. This criterion places a requirement on the constellation to have multiple satellites in view of subscribers a large percentage of the time to permit the Network Operations Control Center ("NOCC") to assign a serving satellite to the subscriber which will not interfere with external systems' service beams also being used in the same region. Second, the system must provide coverage of the major portion of the populated Earth. Third, the system should provide relatively high elevation angles which normally improve availability to end-users. Fourth, consideration must be given to sharing spectrum with other NGSO and GSO satellite systems.

Fifth, the system must be cost-effective and attempt to minimize the total number of required satellites and launches. Sixth, the capacity of each individual satellite and the ability of the system to deliver that capacity to a specific region of the Earth (such as CONUS) must be in concert with Motorola's business plan.

Analysis of these criteria has led Motorola to select the proposed constellation (Figure IV-3). The technical details of the constellation are given in Table IV-1.

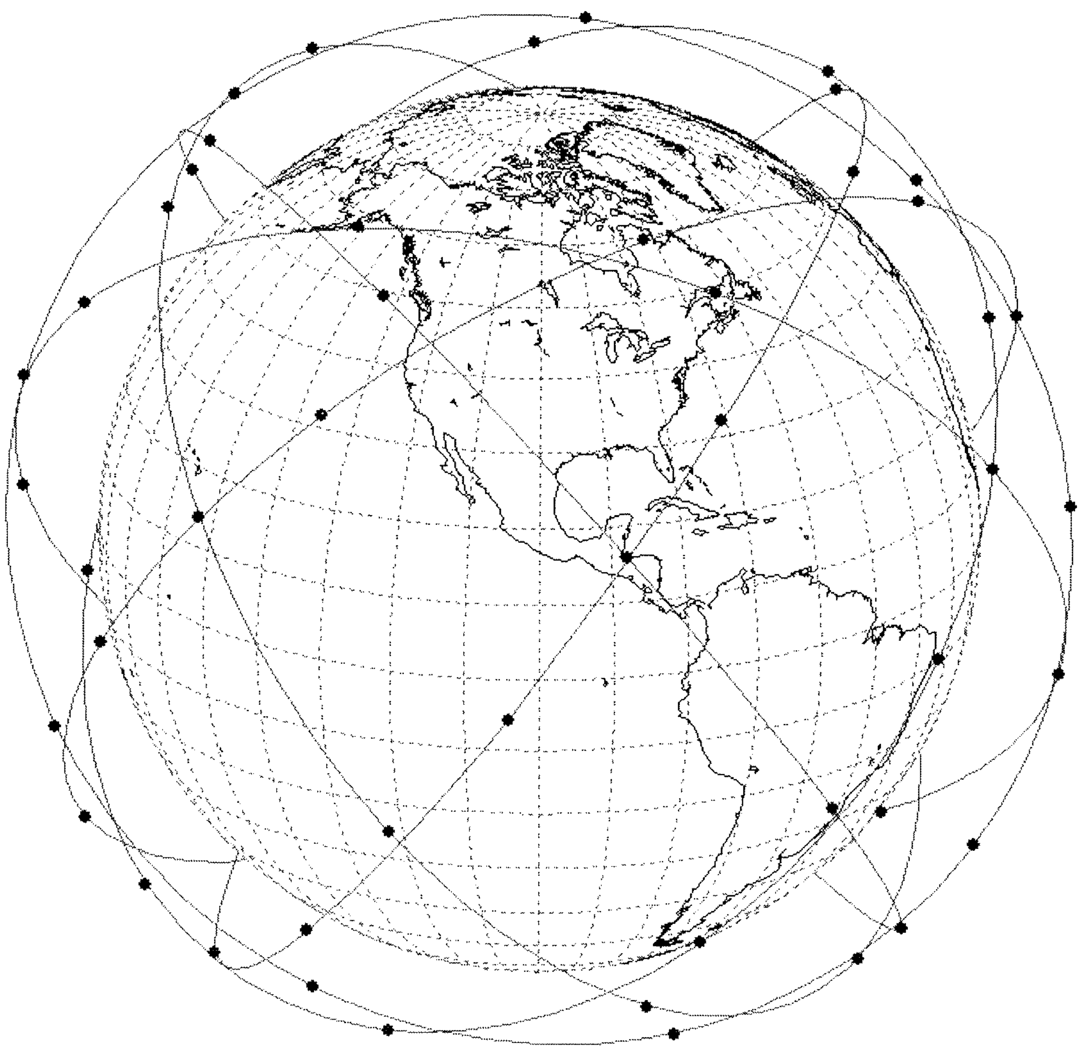

Figure IV-3: Constellation Configuration

Table IV-1: Constellation Technical Parameters

Number of planes	7
Satellites per plane	9
Inclination	48°
Altitude	1400 km
Argument of perigee	0°
Eccentricity	0.0013
Plane spacing at equator	51.43°
Plane phasing	+28.57°
Orbit period	6825 seconds

The constellation is inclined at 48° with respect to the Equator and provides multiple levels of coverage as shown in Figures IV-4 and IV-5. For the Northern or Southern Latitudes between 18° and 48°, which include nearly all of CONUS and most of the population centers in Europe and Asia, double coverage is provided 99% of the time. Three satellites are in view of subscribers within these latitudes more than half of the time. Single coverage of the Earth is provided at elevation angles above 16° between 60° South and 60°North Latitude. The median elevation angle in this range is above 30°. Service can be extended to beyond 70° North and South Latitude by mitigating the effects of low elevation angles.

The booster types being considered for the Celestri LEO System will be capable of placing multiple satellites into a minimum 200 km circular parking orbit. After initial check out, the satellites will be raised to the mission orbit using their on-board propulsion subsystem. Depending on the final mix of boosters selected, up to seven spare satellites may be placed in some (or all) orbital planes. Once a satellite in the mission orbit has exceeded its useful life, sufficient fuel will remain to de-orbit the satellite in a controlled maneuver.

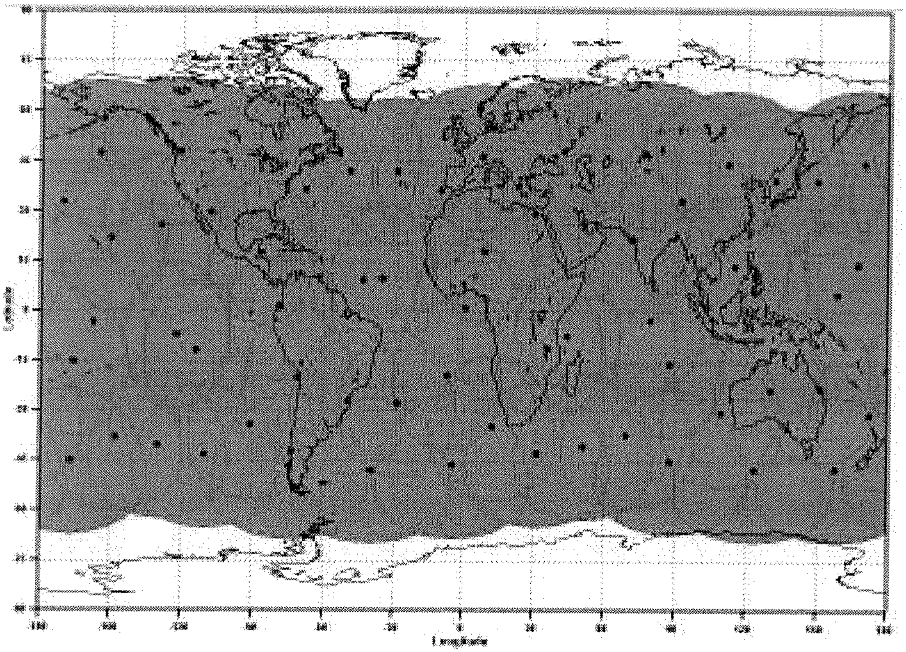

Figure IV-4 Celestri LEO System Coverage Region

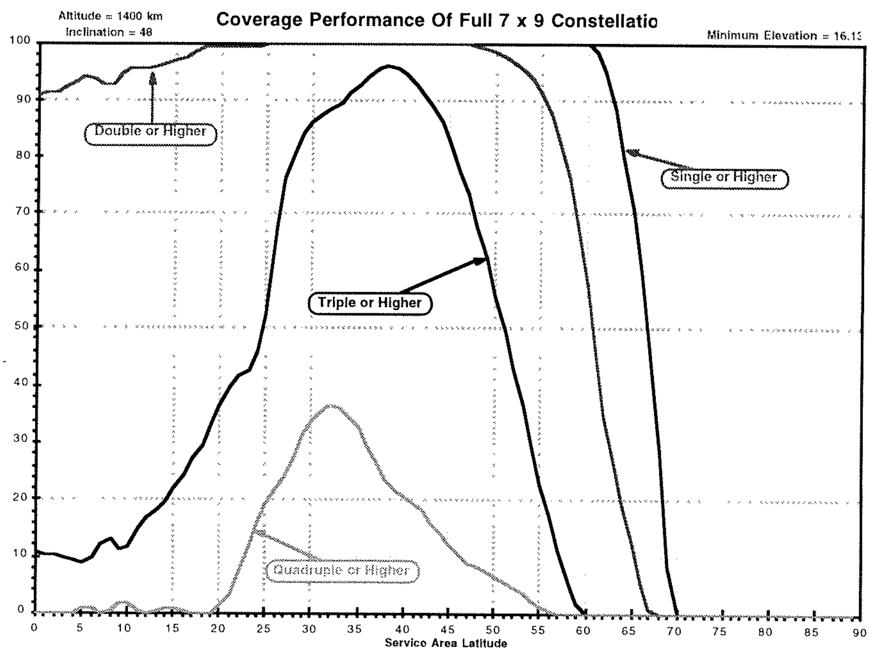

Figure IV-5 Celestri LEO System Multiple Coverage

C. Space Segment - Overview

Figure IV-6 is a conceptual drawing to illustrate the on-orbit configuration for the Celestri LEO System satellite design. (Note that the satellite is depicted in an inverted deployed configuration.) Key objectives in the design are to minimize interfaces and deployment mechanisms, to enhance ease of manufacture, and to mitigate the risk of faulty deployment.

The large flat surface on the nadir end of the satellite provides a mounting surface for the service link antennas. The location on the nadir panel provides an efficient means of interfacing to the payload electronics above the panel.

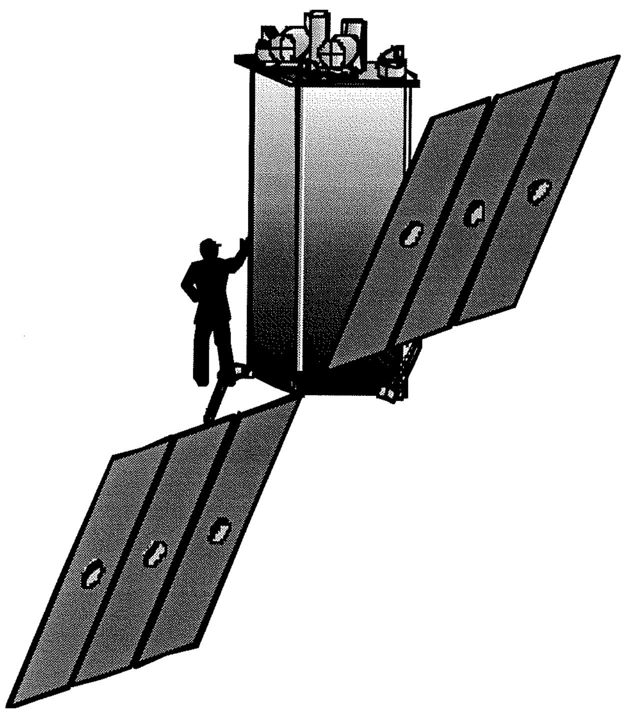

Figure IV-6: Celestri LEO System Satellite Concept

The following table contains a list of key characteristics of the Celestri LEO System satellites:

Table IV-2 General Satellite Characteristics

Peak DC Power	13.6 kW @ End-of-Life
Average DC Power	4.6 kW @ End-of-Life
Mission Life	8 Yrs (Operational Capability) 10 Yrs (Expendables & Decommissioning Functions)
Stabilization	3 Axis Stabilized, Momentum Bias with gyros, Earth and star sensors
Positioning Sensor	GPS
Stationkeeping	1 km
Deployed Length (Overall)	12.7 meters
Total Satellite Wet Mass	3100 kg
Satellite Dry Mass	2500 kg
Propellant	600 kg (Transfer & Stationkeeping)
Telemetry, Tracking and Command (Mission TT&C)	
Wideband Operations	1 TT&C Channel
Frequencies	Service Link Frequencies
Command Link Rate	10 Mbps
Telemetry Link Rate	16.384 Mbps
Satellite Antenna (Cmd & Tlm)	High gain
Telemetry, Tracking and Command (Transfer TT&C)	
Normal Operations	3 TT&C Channels
Frequencies	Service Link Frequencies
Command Link Rate	100 kbps; 2 MHz total BW
Telemetry Link Rate	100 kbps; 2 MHz total BW
Satellite Antenna	Omnidirectional
Communication Beams per Satellite	
-- User Service Beams	260 downlink & 432 uplink
-- Intersatellite Links	6
Antenna Pointing	
-- User Service Beams	Nadir pointing
-- Intersatellite Links	Mechanically steered
Frequencies of Operation	
-- User Uplink	18.8 - 19.3 GHz, 19.7-20.2 GHz
-- User Downlink	28.6 - 29.1 GHz, 29.5-30.0 GHz
-- Intersatellite Link	Optical
Communication Bandwidth	1000 MHz For Subscriber Links
Polarization (Uplink/Downlink)	Circular Right-hand
Peak Receive Flux Density	< -110 $dBW/m^2/MHz$ at 25° Elevation Angle Satisfies Section 25.208(c) of Commission's Rules

1. Radio Frequency and Polarization Plan

a. Service Links

The system design requires 1 GHz for uplink communications (28.6-29.1 GHz, 29.5-30.0 GHz) and 1 GHz for downlink communications (18.8-19.3 GHz, 19.7-20.2 GHz).

The demand for broadband services is expected to grow dramatically in the next few years, imposing new requirements for higher data rate links. Terrestrial broadband networks are expected to utilize OC-3 rates more frequently due to advances in electronics and switching architectures. A natural extension to these terrestrial networks, via a satellite network, will require a flexible allocation of several of these higher data rate links, within a single satellite footprint.

The system architecture for the Celestri LEO System permits considerable flexibility in the channelization within the uplink and downlink bands. In addition to supporting several information rates, the architecture permits subbands to be designated for various data rates and channel types. For example, bandwidth allocated for a 155.52 Mbps channel can alternatively be used for approximately 75 channels at 2.048 Mbps.

The communications links for the Celestri LEO System employ right hand circular polarization and utilize a 7-cell cluster size to achieve the required frequency reuse. This degree of reuse will ensure that the system capacity requirements are met.

b. Intersatellite Links

The system design includes optical intersatellite links.

c. Satellite Footprint and Antenna Contours

Figure IV-7 depicts a representative satellite coverage footprint with 16° minimum elevation angles at ground terminal sites. Also shown in this figure is a sample beam plot for a cell near the satellite nadir point. 432 such beams fill the satellite coverage footprint for uplink communications and 260 such beams fill the satellite coverage footprint for downlink communications. Figures IV-8 and IV-9 show beam plots for uplink cells midway between nadir and the edge of coverage and at the edge of coverage. Figures IV-10 through IV-12 show similar plots for downlink beams.

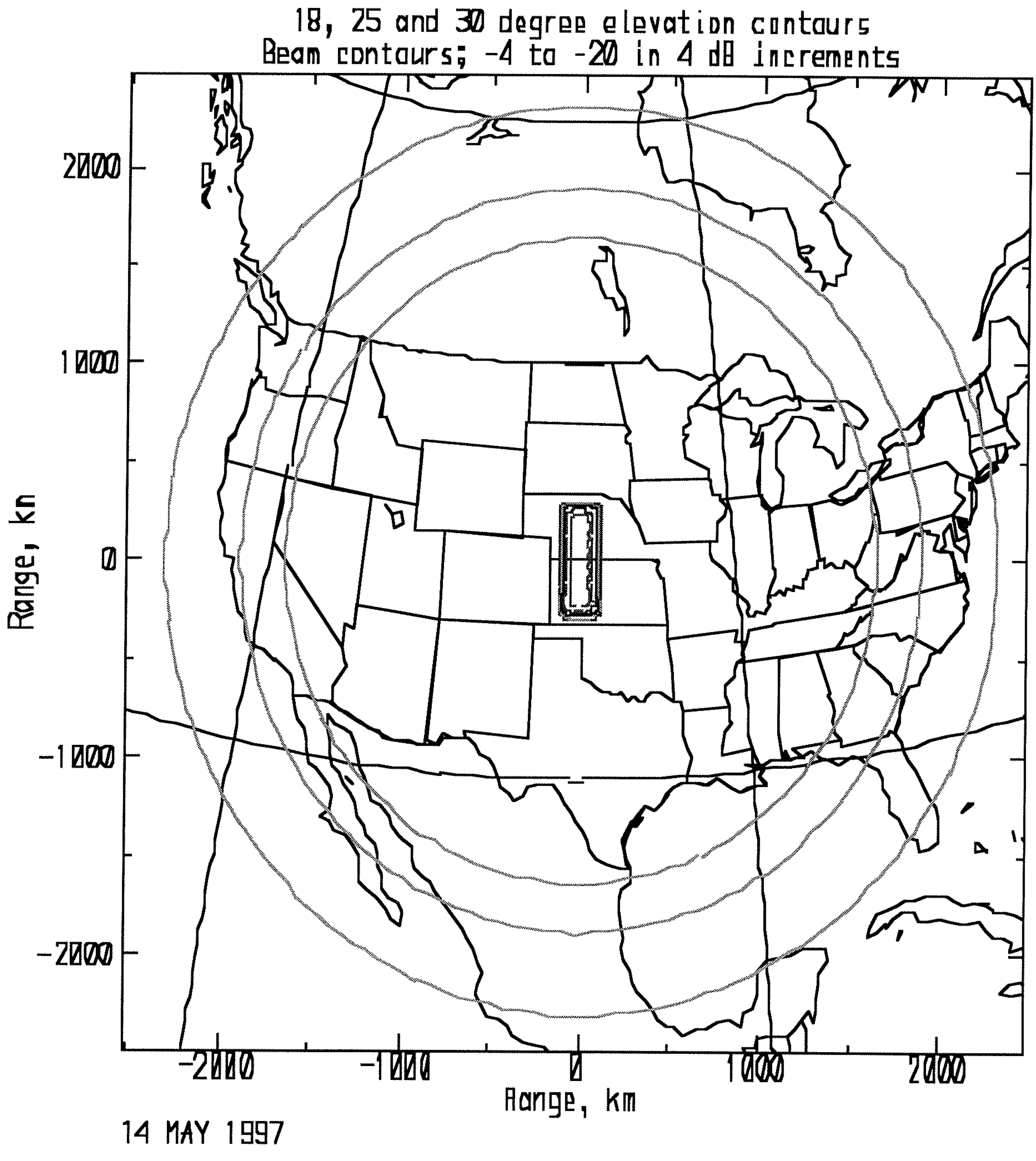

Figure IV-7: Satellite Footprint and Uplink Nadir Beam Plot

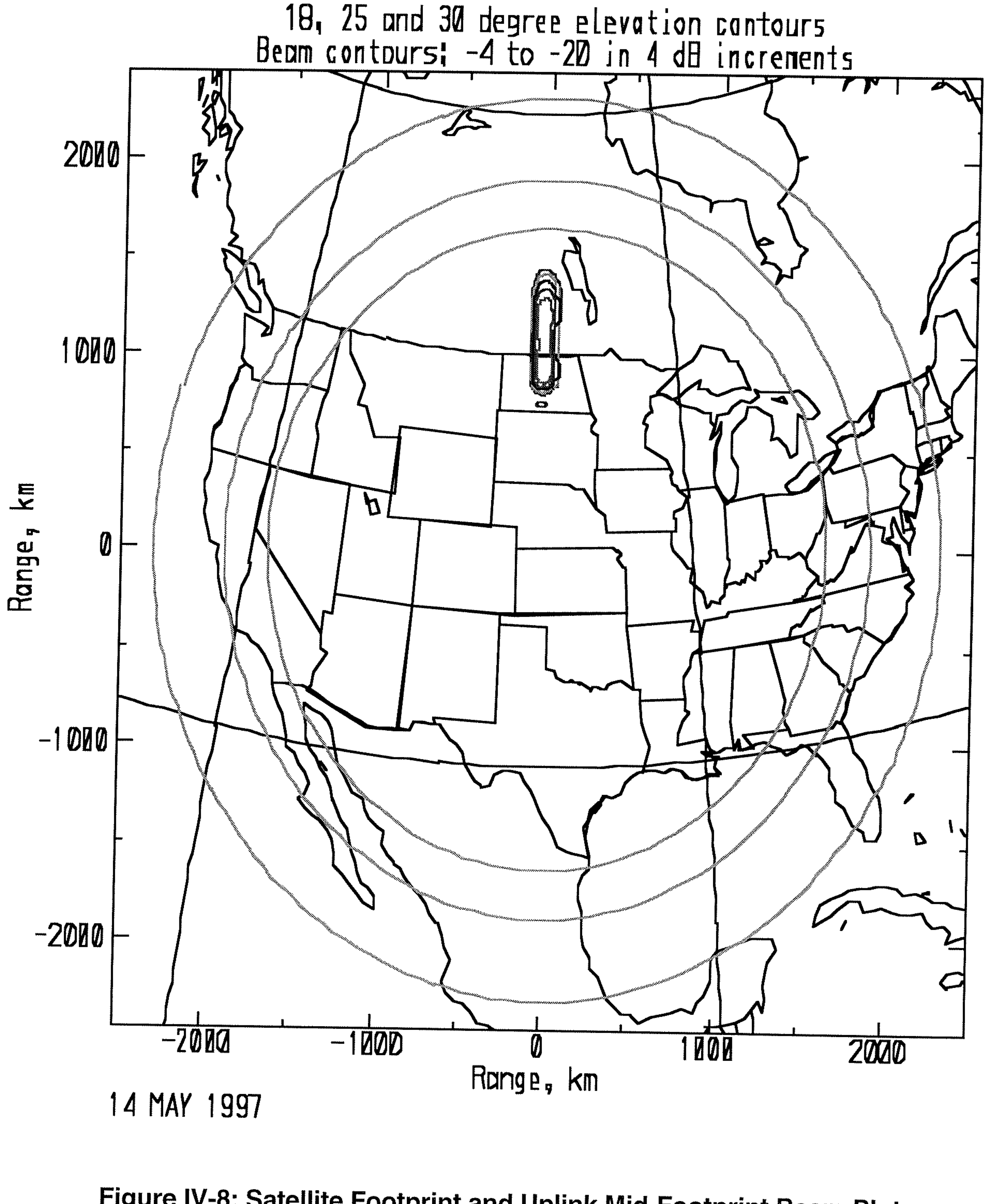

Figure IV-8: Satellite Footprint and Uplink Mid-Footprint Beam Plot

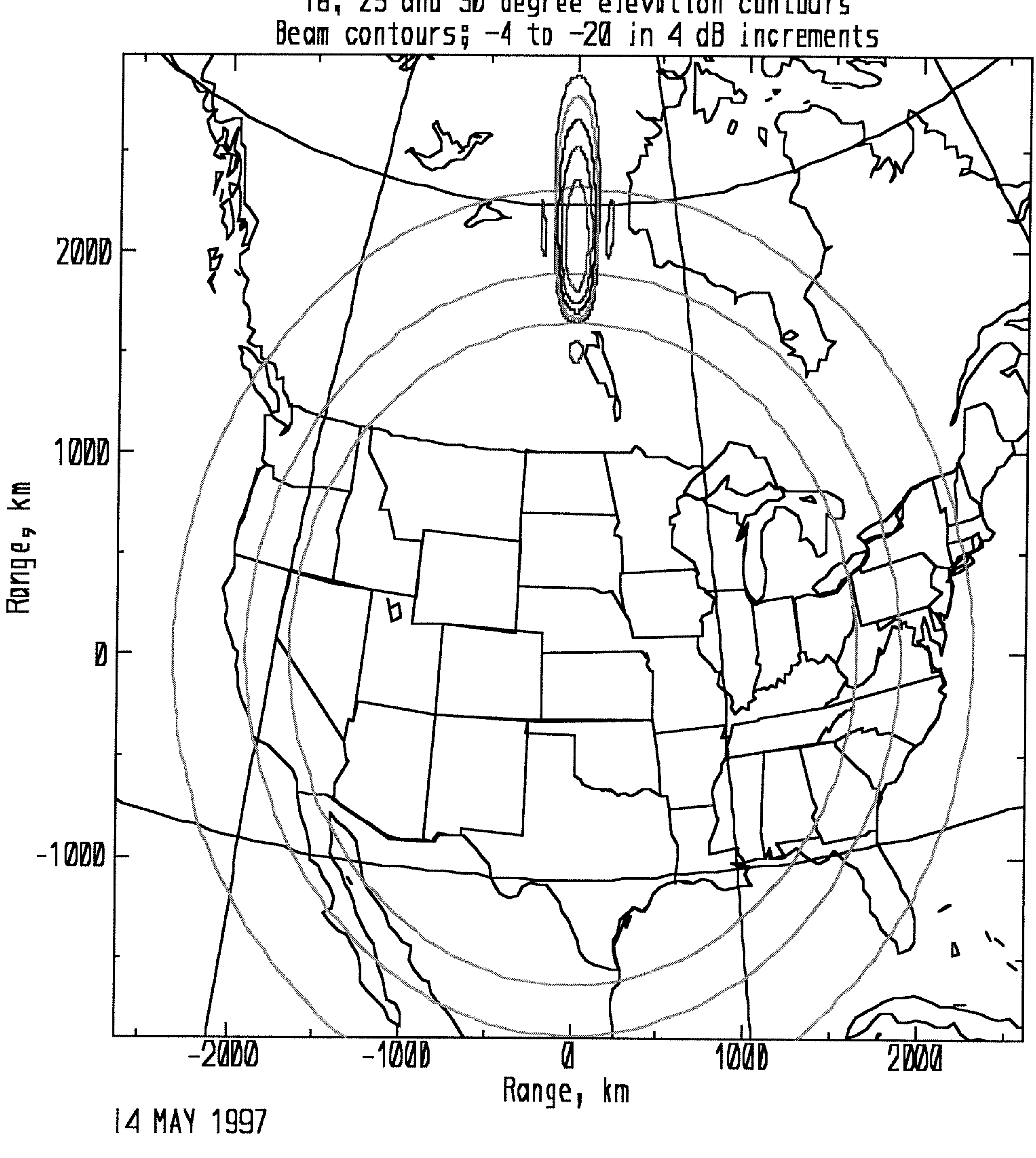

Figure IV-9: Satellite Footprint and Uplink Edge-of-Footprint Beam Plot

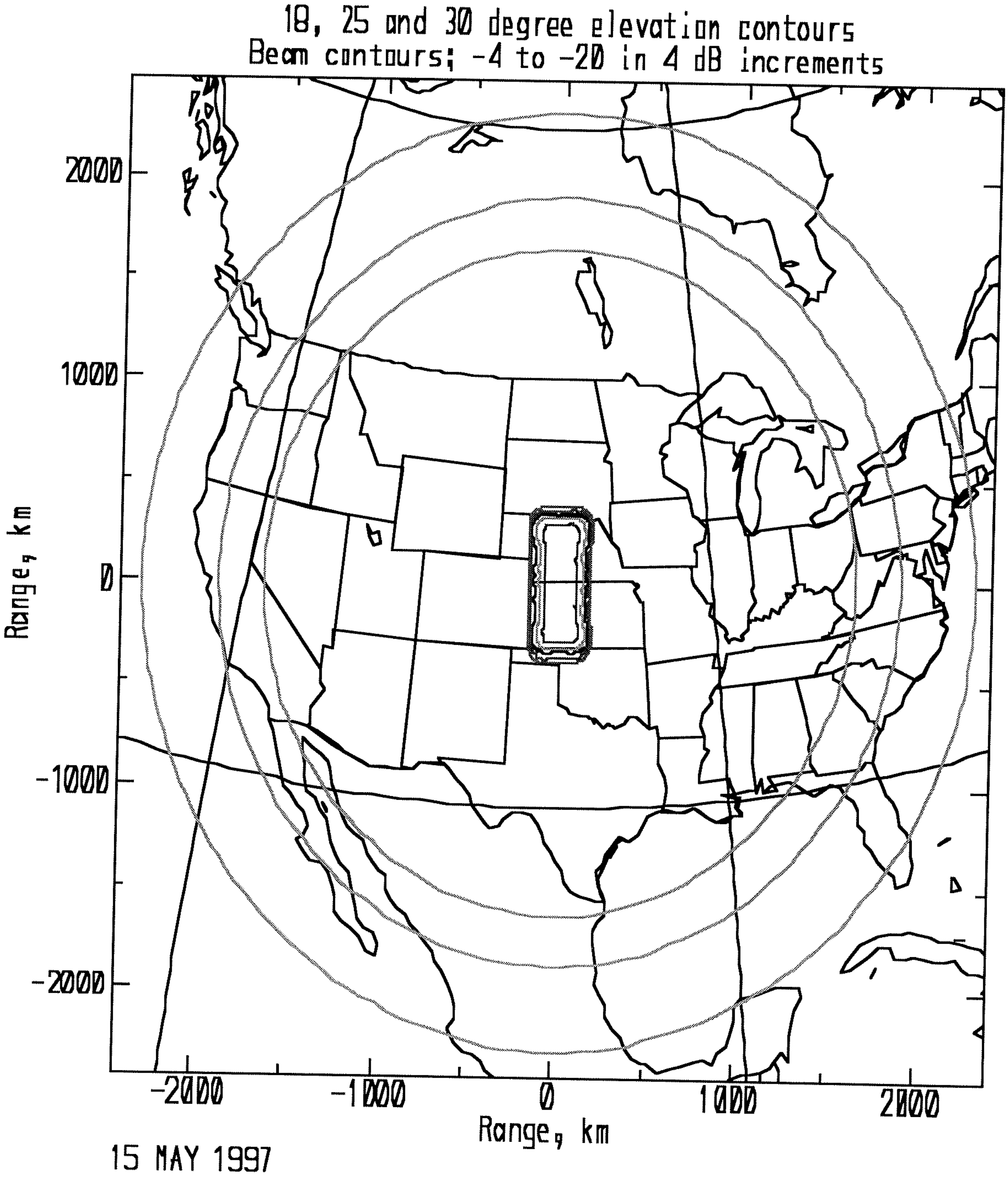

Figure IV-10: Satellite Footprint and Downlink Nadir Beam Plot

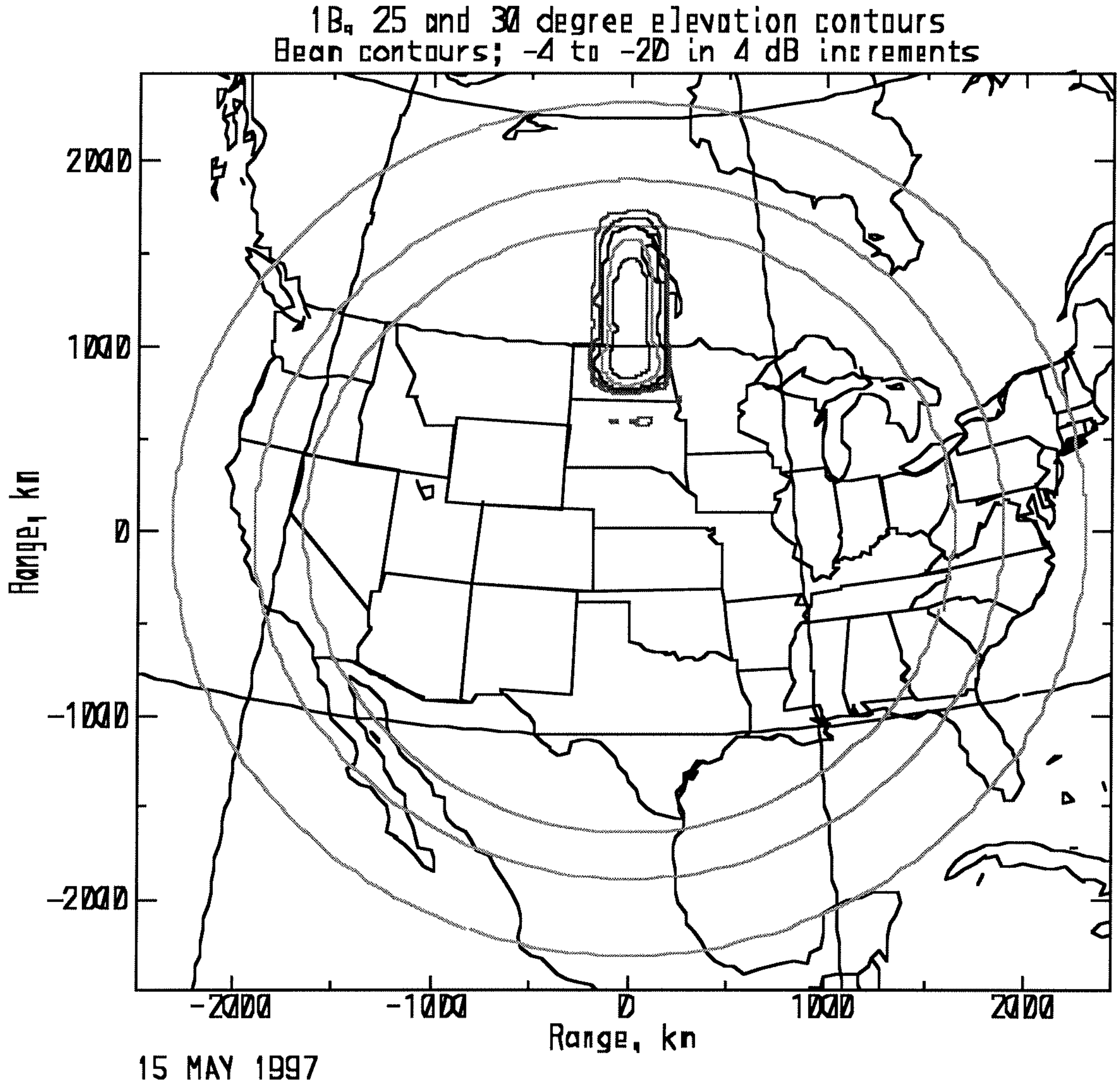

Figure IV-11. Satellite Footprint and Downlink Mid-Footprint Beam Plot

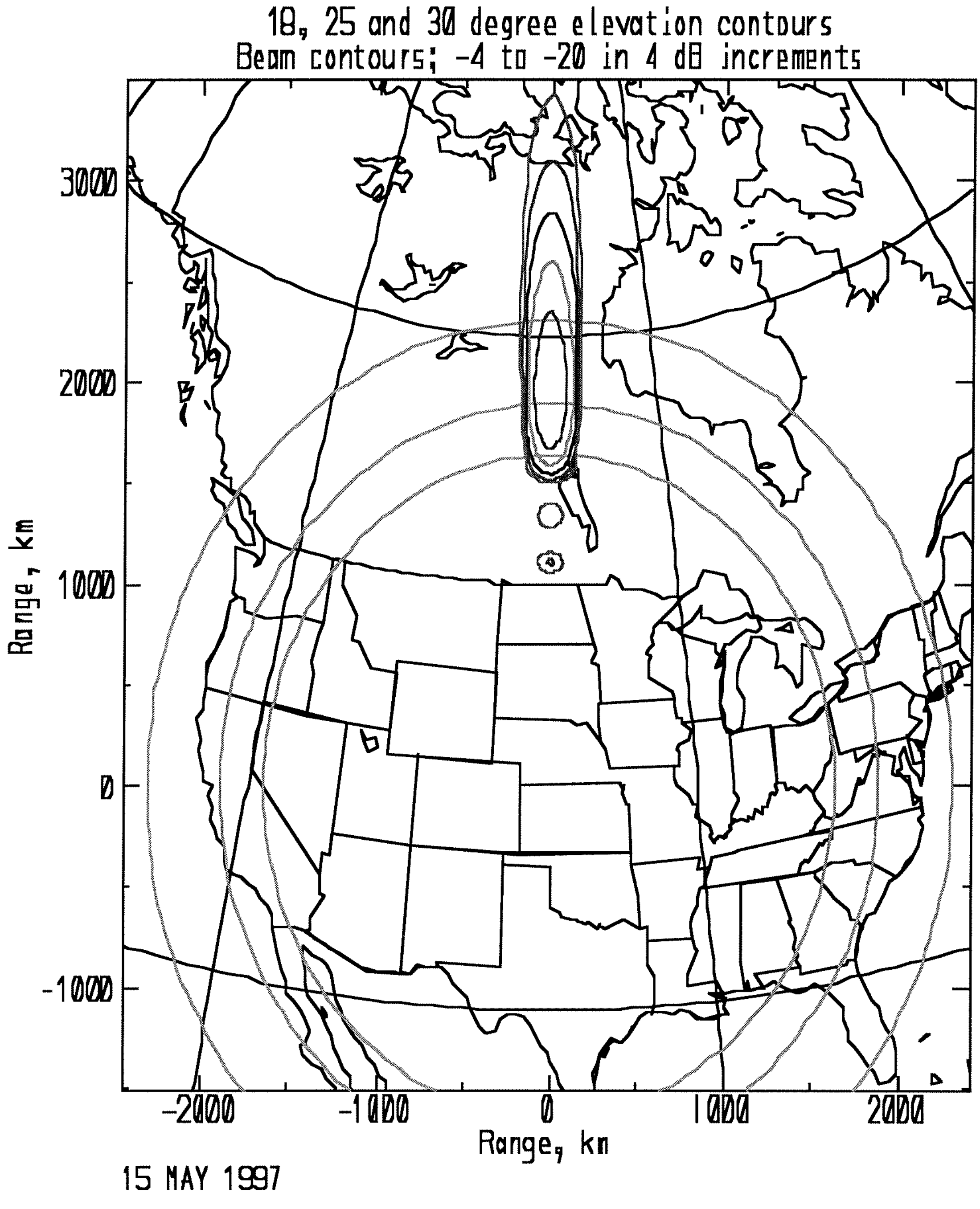

Figure IV-12: Satellite Footprint and Downlink Edge-of-Footprint Beam Plot

d. Emissions

The emission designators for the Celestri LEO System's communications links, including all uplinks and downlinks as well as intersatellite links, are defined in Table IV-3. Table IV-4 provides a summary of transmitter output power and maximum EIRP for each of these links. Table IV-5 defines the satellite receiver parameters for each of the links. Appendix A contains a more in-depth tabulation of the characteristics of the Celestri LEO System's satellite links.

Table IV-3: Emission Designators

Transmission Description	Emission Designator
16.384 Mbps Downlink	32M8G7W
51.84 Mbps Downlink	104MG7W
10.0 Mbps Downlink	20MOG7W
155.52 Mbps Downlink	311MG7W
2.048 Mbps Uplink	4M10G1W
51.84 Mbps Uplink	104MG1W
155.52 Mbps Uplink	311MG1W
Multicarrier Command Link	300KG7D
Telemetry Downlink	300KG1D
Laser Intersatellite Links	NA

Table IV-4: Satellite Transmitter Output Power and EIRP

Satellite Terminal Link	Peak Transmit Power (W)	Maximum EIRP (dBW)
16.384 Mbps	15.8	44.8
51.84 Mbps	8.7	40.6
155.52 Mbps	5.0	42.9
TT&C Link 100 kpbs	3.5	5.4

(Note: Terminal link numbers reflect performance under rain conditions.)

Table IV-5: Satellite Receiver Parameters

Satellite Terminal Link	G/T (dB/K)
2.048 Mbps	7.16
10 Mbps	7.16
51.84 Mbps	7.16
155.52 Mbps	12.77

(Note: G/T numbers vary over the satellite footprint.)

2. Communications Subsystem

The Celestri LEO System is capable of providing subscribers with flexible data rates, bandwidth, and modulation formats on a per-beam basis. Various traffic demand patterns and channel conditions can be handled using bandwidth and power efficient modulation techniques, dynamic channel allocation, and dynamic power control.

The satellites will use the latest phased array antenna technologies, on-board processing, and switching technologies to achieve a high degree of spectrum efficiency and system flexibility. Isolation between antenna beams and spatial separation between satellites covering the same region will permit reusing the available spectrum more than 35 times within one footprint. In order to utilize on-board resources efficiently, minimize interference, and provide protection against rain, dynamic power control will be used.

The phased-array antennas used on board the spacecraft will generate hundreds of beams to cover a satellite footprint. In addition, the use of phased-array antennas at Ka-band will obviate the need for traveling wave tube amplifiers ("TWTA"s) and provide soft-failure capabilities, thereby increasing system reliability.

Satellites in the Celestri LEO System will be capable of dynamically configuring receiver resources and switches to handle the various (2.048 Mbps, 10 Mbps, 51.84 Mbps and 155.52 Mbps) data rates, depending on the bandwidth requirements of the subscriber. The flexible Demand Assignment Multiple Access ("DAMA") protocol permits extremely efficient use of the allocated spectrum by sharing channels among multiple users. Downlink transmissions will use either QPSK or 8PSK depending on terminal type. Powerful forward error correcting codes will be used to achieve bit error rates of 10^{-9} or better.

Overall network interconnectivity is achieved by optical intersatellite links, which will provide interconnections to six neighboring satellites.

a. Uplink and Downlink Communications Parameters

Communication links will operate at rates of 2.048 Mbps (E-1), 10.0 Mbps, 16.384 Mbps, 51.84 Mbps (OC-1), and 155.52 (OC-3) Mbps. CPE terminals will operate with 0.3 m to 1 m aperture antennas and up to 5 W transmit RF power for small terminals and up to 20 W for larger terminals. To reduce self-interference and interference to other systems, and to provide robustness against rain, dynamic power control will be incorporated into the system design. A summary of the communication link parameters is included in Table IV-6.

Table IV-6: Summary - Uplink & Downlink Communications Parameters

Parameter Description	Specification
Modulation Format	QPSK, 8PSK
Target Bit Error Rate	10^{-9}
Downlink Data Rates (information) (Mbps)	16.384, 51.84, 155.52
Uplink Data Rates (information) (Mbps)	2.048, 10.0, 51.84, 155.52
Downlink Bandwidth	1 GHz
Uplink Bandwidth	1 GHz
Eb/No Requirement	5.9 dB (QPSK) 11dB (8PSK)
Ground Station RF Power Amplifier	up to 5 W (small terminals) up to 20 W (large terminals)
Ground Terminal Effective Aperture	0.3 to 1 m
Ground Terminal Figure of Merit G/T	7.3 dB/K (large terminals)

b. Intersatellite Links

Intersatellite links will employ optical technology.

c. TT&C Links

All functions necessary for monitoring and controlling the spacecraft will be performed by the TT&C subsystem. The Satellite Operations Control Center ("SOCC") will be sized and will employ sufficient antenna diversity to maintain highly reliable TT&C links with the satellite constellation under all operating conditions. Command signaling will include authentication codes to prevent malicious or unintentional access to the spacecraft command functions.

3. Transmission Characteristics

This section provides a general overview of the transmission characteristics for the uplinks, downlinks, and intersatellite links for the Celestri LEO System. More extensive tabulations of link performance and power flux density are provided in Appendix A.

a. Service Uplinks and Downlinks

FDM/TDM transmissions are used for service downlinks, with a variety of alternatives for data rates and modulation formats as summarized in Table IV-7. Forward error correcting codes will be used to achieve the required low bit error rate of 10^{-9}. In order to achieve the desired capacity in 1 GHz of spectrum, a reuse cell cluster of 7 beams will be used for all the service links other than the gateway links, which reuse their allotted spectrum in each of two beams per spacecraft.

The service uplinks will use demand-assigned FDM/TDMA as summarized in Table IV-8. As with the service downlinks, various alternatives are supported in order to provide flexibility in system operation within the architectural constraints of the communications subsystem.

Table IV-7: Summary of Downlink Data Rates and Modulation Alternatives

Downlink Information Rate (Mbps)	Modulation Format	Bandwidth Per Channel (MHz)
16.384	QPSK	32.512
51.84	QPSK	97.421
155.52	8PSK	205.67

Table IV-8: Summary of Uplink Data Rates and Modulation Alternatives

Uplink Information Rate (Mbps)	Modulation Format	Bandwidth Per Channel (MHz)
2.048	QPSK	4.244
10	QPSK	20.31
51.84	QPSK	97.421
155.52	8PSK	205.67

b. Intersatellite Links

Network connectivity is provided by optical intersatellite links. Six inter-satellite links are established between any given satellite and its neighbors. In-plane links are maintained between satellites fore and aft, while four additional links are maintained with two satellites in each of the two adjacent planes of the constellation.

4. Power Flux Density

The estimated power flux densities have been calculated for worst case conditions at cell centers within the coverage footprint (i.e., angles at and above 25°) and found to be less than -110 dBW/m^2/MHz. The results of these calculations are tabulated in Appendix A.

5. Traffic Capacity

The distribution of end-users, which is correlated to the population distribution throughout the global coverage area, will create high peak demands on the system, a key determinant of the overall spectrum requirement and of the design of any practical system. The LEO constellation geometry, in conjunction with a versatile satellite payload design, create relatively small cell sizes in the coverage footprint, which is instrumental in supporting the highly peaked traffic demands. The capacity for a 7-cell cluster will vary from 3600 to 5300 equivalent 64 kbps channels depending on the mix of terminals. The capacity can be concentrated in a single urban area or spread over an area about the size of California. This peak capacity is increased by the number of satellites available to illuminate the arc. Over CONUS, this number varies from 3 to 5 depending on the area and time.

Over CONUS, it is projected, with conservative de-rating factors, that the system can support nearly 395,000 simultaneous equivalent 64 kbps service channels. In the global coverage area, the Celestri LEO System is designed to support over 1,800,000 equivalent 64 kbps service channels.

D. Major Spacecraft Subsystems

1. Antenna Subsystem

a. Uplink and Downlink Antenna Subsystem

The satellite antenna subsystem for communication with CPE terminals is a set of phased array antennas. One transmit array forms a field of 260 downlink beams which cover the satellite footprint. One receive array forms a field of 432 uplink beams which cover the satellite footprint. The beams are fixed with respect to the satellite. When a CPE terminal enters the field-of-view of a beam, a portion of the 1 GHz spectrum will be assigned to the beam to support the services associated with that CPE and is maintained as the CPE moves from beam to beam.

Figures IV-7 through IV-12 set forth the antenna gain contours for the uplink and downlink antenna subsystem.

b. TT&C Antenna Subsystem

TT&C data is transferred between ground and satellite nodes utilizing the normal user communication band. The command uplink uses a 3 meter reflector-type antenna at the ground site to provide reliable communications. For normal TT&C operation, the spacecraft will use a near-omnidirectional antenna. For periods when wide-band TT&C data is to be sent to the spacecraft, the normal mission antennas aboard the spacecraft will be used.

c. Intersatellite Antenna Subsystem

Intersatellite links will utilize optical technology. Each link will use a set of co-boresighted gimbaled telescopes for transmission and reception.

2. Thermal Control Subsystem

The thermal control subsystem provides active and passive controls for maintaining the thermal environments of each of the spacecraft subsystems within the ranges necessary for reliable operation over the satellite's 8-year mission life.

3. Attitude and Orbit Control Subsystem

The attitude and orbit control subsystem provides 3-axis attitude control to maintain ground coverage and intersatellite links throughout all mission phases. This subsystem provides the pointing for the maneuvering capability to transfer from either the parking or the sparing orbits into mission formation, and maintaining the constellation formation in accordance with orbit requirements.

4. Propulsion Subsystem

The propulsion subsystem is responsible for orbit raising, stationkeeping, orbit repositioning, and deboost maneuvers throughout mission life.

5. Electrical Power Subsystem

The electrical power subsystem is capable of supporting payload and bus power requirements under maximum traffic loads and worst case environmental conditions, through the end of mission life. In sunlight, the power needs are met by solar arrays, whereas, batteries supply power during eclipse conditions.

6. TT&C Subsystem

The satellite design uses the Ka-band for receiving commands and transmitting telemetry. This enables on-station satellite, constellation, and network operations with a high availability from one of six antenna sites in the coverage area connected to a MOCC.

The TT&C subsystem utilizes a near omni-directional antenna on board each spacecraft to receive and transmit command and telemetry communications during normal operations, launch operations, deployment operations, parking and storage orbit operations, orbit transfers, and anomalous conditions on station that cause the satellite to drop out of the network. This narrow-band communications subsystem will operate at a command information rate of 100 kbps and a telemetry rate of 100 kbps. For periods when broadband TT&C data is to be sent to the spacecraft, the normal mission antennas aboard the spacecraft will be used. In order to accommodate simultaneous communications with the multiple satellites launched on each of the planned launch vehicles, the Celestri LEO System will need three separate TT&C

transmit and receive channels. When necessary, high data rate TT&C communications can be established using the service link frequencies and formats. This capability will be used during initial system deployment integration and test as well as for anomaly resolution and software upgrades.

7. Number of Satellites

The satellite system comprises sixty-three operational communications satellites and up to seven in-orbit spare satellites.

8. Satellite Operational Lifetime

The satellite operational lifetime is 8 years.

E. Earth Segment.

1. Ground Segment

The System Control Segment consists of two Mission Operations Control Centers ("MOCC"s), which control the overall operation of the Celestri LEO System, two Antenna Facilities co-located at the MOCC sites and another four Remote Antenna Facilities ("RAF"s). Each MOCC contains a Satellite Operations Control Center ("SOCC") and a Network Operations Control Center ("NOCC"). The SOCCs monitor and manage the technical operation, health and status of the satellites, assuring orbit compliance and overall satellite hardware and software integrity. The NOCCs control the overall performance of the telecommunications network, including network management and failure detection and recovery operations.

The MOCCs can be configured so that one functions as the primary control center and the other operates as the back-up, or both can share designated components of the overall control function. This capability, coupled with the two co-located Antenna Facilities, provides ground segment redundancy and assures operational reliability.

Each MOCC is co-located with an Antenna Facility to provide communications with the satellites from the MOCCs, an approach that has both financial and technical advantages in the operation of the Celestri LEO System.

Each MOCC will maintain communications with all RAF sites. The antenna sites will be located to provide line of sight contact with every satellite multiple times each orbit as well as to provide coverage during launch and initial on-orbit operations. The RAF sites will be apportioned between the Northern and Southern Hemispheres. All of these facilities will have nearby access to international communications hubs, which will allow them to share data and manage the entire system.

2. Customer Premises Equipment

The Celestri Architecture will provide a standard interface definition that will allow manufacturers to develop a broad range of compatible CPE products.

The lower data-rate CPE terminals support "bandwidth-on-demand" through use of a Time-Division Multiplexed ("TDM") Demand Assigned Multiple Access ("DAMA") protocol and fractional allocations of the peak information rates. The higher data-rate terminals are intended as central hubs. These terminals will provide all required multiple access functions internally and will connect to the constellation using a straightforward TDM DAMA format.

The Celestri Architecture is designed to interface seamlessly to existing networks and equipment. The CPE is the major system element that will support this interconnection capability. Therefore, a major function of the CPE is protocol interworking between existing standards and the Celestri System. Examples of interworking functions include ATM, TCP/IP and frame relay interfaces. CPE products will provide support for applications such as e-mail, compressed video, home shopping and electronic banking. Some CPE terminals will be equipped to provide activation by smart card subscriber identity modules (SIMs). This will allow public access to the network as well as limited subscriber mobility.

At this time, Motorola expects that the following four types of CPE terminals will be developed by manufacturers.

Gateway Terminal :

The gateway terminal provides an interface to the PSTN. It is expected that gateway terminals will be available to connect at OC-1 rates (51.84 Mbps) and at OC-3 rates (155.52 Mbps). By appropriately placing distributed antenna facilities, a gateway terminal can have an availability of 99.99% or greater.

Corporate Terminal:

The corporate terminal provides access for enterprise networking and provisioned private lines at an OC-1 rate. The terminal will provide 99.9% availability in rain region K with the nominal antenna size and without the use of antenna site diversity. As an option, the availability can be improved by larger antennas or site diversity.

Small Business Terminal :

The small business terminal is a Very Small Aperture Terminal ("VSAT") class terminal designed to provide a variety of services for small businesses. The terminal provides an availability of 99.9% in rain region K with a nominal 0.75 m mechanically steered antenna. This availability can be improved with a larger antenna.

Direct-to-Home Terminal :

The direct-to-home terminal is a VSAT designed to provide multimedia and telecommuting services to the home. This terminal provides 99.5% availability with a small electronically scanned array antenna. Availability can be increased with a larger mechanically steered antenna.

All terminals use directional antennas to maintain contact with the space constellation, with at least two independent antenna beams per terminal to support make-before-break hand-offs.

A variety of customer-selected options are anticipated within the basic CPE categories, depending on the end-user services being supported by the terminal. Fundamental to the CPE design, for example, are customer-specified service converters (e.g., protocol adapters) that provide access to the Celestri System in a manner that is transparent to the end-users (see Figures IV-13 and IV-14). Other CPE options include configurations to support the asymmetric transmission rates anticipated for particular types of services, and configurations to expand a service provider's capacity beyond the specified data rates by using multiple channel frequencies.

The smaller CPE terminals support "bandwidth-on-demand" through use of a TDM DAMA protocol, which uses fractional allocations of the peak information rates.

3. Virtual Network Segment

The Virtual Network segment is responsible for service and subscriber management functions. This segment consists of one or more Distributed Virtual Network Managers ("DVNM"s) which include a Virtual Network Control Center and a Virtual Network Antenna Facility. Communication between the space system and the DVNMs will use the standard service link frequencies and formats.

F. System Link Availability

1. Estimated Link Availabilities

Estimated small business terminal availabilities for various cities are included in Table IV-9. These estimated availabilities were used in the link budget calculations of Tables A-1 through A-4 in Appendix A. These values do not take into account potential improvements due to satellite diversity, nor do they include the effects of sun outages.

Table IV-9: User Link Availability Estimates

City	DTH Terminal	Small Business Terminal	Corporate Terminal	Gateway Terminal
Berlin	99.87	99.97	99.97	99.999
Lisbon	99.55	99.88	99.88	99.999
London	99.90	99.98	99.98	99.999
Los Angeles	99.93	99.99	99.99	99.999
Madrid	99.75	99.94	99.94	99.999
Miami	98.76	99.66	99.66	99.999
Moscow	99.96	99.99	99.99	99.999
New York	99.55	99.88	99.88	99.999
Paris	99.95	99.99	99.99	99.999
Philadelphia	99.55	99.88	99.88	99.999
Rome	99.55	99.88	99.88	99.999
San Diego	99.86	99.99	99.99	99.999
Seoul	99.49	99.91	99.91	99.999
Sydney	98.76	99.68	99.68	99.999
Tokyo	99.49	99.91	99.91	99.999

G. Launch Segment

The launch segment consists of the vehicles and facilities necessary to place the Celestri LEO System satellites into their parking orbits. The satellite has been sized so that multiple satellites can be launched on several existing launch vehicles as well as some planned future vehicles. Election of the types and quantities of launch vehicles required to launch the constellation will include consideration of various factors, including the number of satellites which can be launched using each vehicle type, constellation fill and sparing strategies, launch sites, shroud and dispenser design, system control sites, launch cost, and failure risk.

In order to support the Celestri LEO System satellite deployment plan, selected launch vehicles will be required to deliver multiple satellites to a circular parking orbit at an altitude of 200 km. After drop-off and deployment of appendages at this altitude, the satellites will use on-board thrusters to attain mission or sparing orbits at the intended operating altitude of 1,400 km.