ORIGINAL

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

Application

for

Authority to Construct, Launch and Operate the

79-SAT-P/L-97(63)

Celestri Multimedia LEO System

A Global Network of Non-Geostationary Communications
Satellites Providing Broadband Services
in the Ka Band

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Executive Summary

Motorola Global Communications, Inc. ("Motorola"), a wholly-owned subsidiary of Motorola, Inc., hereby requests Commission authority to construct, launch and operate the Celestri Multimedia LEO System ("Celestri LEO System"), a non-geostationary orbit ("NGSO") global satellite system, offering a wide range of real-time broadband communication services in the Fixed-Satellite Service ("FSS"). The Celestri LEO System will comprise a total of 63 operational satellites in low-Earth orbit ("LEO") interconnected to virtually all of the populated land masses in the world. The Celestri LEO System will be an integral part of the Celestri System, whose other cornerstones are Motorola's Millennium System and M-Star System

The service and gateway links of the Celestri LEO System will operate in the 18.8-19.3 GHz and 19.7-20.2 GHz bands (space-to-Earth) and the 28.6-29.1 GHz and 29.5-30.0 GHz bands (Earth-to-space).[1] The TT&C high gain links will also operate in the service bands. The system will use optical inter-satellite links to interconnect the satellite network in space.

The Celestri LEO System comprises 63 satellites in 7 inclined orbital planes, up to 7 in-orbit spares, and the associated ground terminal equipment.[2] The satellites in each plane will rotate in circular orbits at an altitude of 1400 kilometers. The constellation is inclined at 48° with respect to the Equator.

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1 Of these bands, the 18.8-19.3 GHz and 28.6-29.1 GHz bands have a primary domestic allocation for NGSO FSS. The 19.7-20.2 GHz and 29.5-30.0 GHz bands have a secondary domestic allocation for NGSO FSS. All bands have a worldwide primary FSS allocation. Motorola is cognizant of the obligations attendant upon system operators providing service pursuant to secondary allocations, and will comply with these obligations.

2 Motorola is not requesting authorization for the ground segment facilities component of the system at this time.

The Celelstri Architecture will allow for the use of relatively small, low power and low cost earth terminals. It will also permit real-time communication capabilities: the delays experienced by end-users will be essentially equivalent to terrestrial communication systems for global real-time services.

Each satellite contains all of the hardware necessary to route communications traffic through the network, including Earth-to-space, space-to-Earth and space-to-space connections. With this architecture, a signal received by a satellite may be transponded directly back to Earth in the same or a different beam, or relayed by optical inter-satellite links through other satellites from which it is then transmitted to Earth. This architecture allows global interconnection for the provision of real-time multimedia, data, video and voice services.

The system is designed to avoid harmful interference with other service operators primarily through the use of space diversity. This technique will allow the Celestri LEO System to share the same spectrum with multiple NGSO and GSO systems, on a co-coverage and co-frequency basis. Implicit in the spectrum sharing approach is the assumption that all NGSO systems will participate in the spectrum sharing responsibility.

The system will utilize multi-beam phased arrays with fixed beams to provide ubiquitous coverage through the satellite footprint. Single or multiple earth terminals will provide access to the satellite constellation. The earth terminals will have equivalent antenna aperture sizes from 0.3 to 1 meter and will support bit rates from 2.048 to 155.52 Mbps.

The Celestri LEO System represents the third cornerstone in Motorola's plan to create the Celestri System global wireless broadband communications infrastructure. It complements the recently licensed GSO FSS Millennium

System and the proposed LEO FSS M-Star System. Each system is optimized for discrete types of broadband FSS offerings aimed at different, yet overlapping market segments.

Together, the three systems will offer an integrated, "total" FSS solution. The Celestri Architecture will comprise LEO and GSO satellites, satellite-to-satellite communications links, space-to-ground interfaces, terrestrial gateways and a family of customer premises equipment designed to deliver a full range of wireless multimedia and other bandwidth-on-demand applications to consumers, small businesses, multinational corporations and telecommunications service providers anywhere in the world.

Motorola believes that this unified and open architecture for the delivery of GSO, LEO and "hybrid" services is an advanced and highly flexible framework for meeting explosive worldwide demand for broadband services as well as an effective approach to spectrum conservation and sharing.

In the Ka-band, services delivered by the LEO system described in this Application and services delivered by the Millennium System will allow a single terminal to receive and send video, data and voice signals that offers the most efficient and cost-effective medium for each application. For applications that require exceptionally large bandwidth, Motorola's proposed M-Star System leverages Ka-band user links into very high-capacity trunking and backhaul applications in the 40/50 GHz band.

Motorola has a proven record of developing and deploying new technologies that create new industries including two-way radio, paging, cellular mobile communications and, most recently, the IRIDIUM® global mobile communications system.[3] As the recognized worldwide leader in wireless communications systems, Motorola believes that the Celestri Architecture will define another new industry -- the global wireless delivery of broadband communications services.

The Celestri Architecture will allow integrated systems to support four classes of service for four segments of the marketplace. These types of service are:

- point-to-point, real-time symmetric connection services ranging from 64 kbps to 155 Mbps;
- point-to-point, bursty asymmetric services, in which each direction of communication uses varying amounts of bandwidth as needed, ranging up to 16 Mbps;
- broadcast and multicast services using variable service areas and communication rates;
- interactive and integrated broadcast and real-time response services.

Combinations of these services will be integrated with applications to serve the following market segments:

- residential consumers purchasing multimedia applications (data, video and voice) for work-at-home, personal productivity, entertainment, education, health care and security purposes;
- small businesses purchasing in the multimedia marketplace;
- large multinational corporations seeking strategic multimedia applications that improve their business processes and customer responsiveness to all corners of the world;

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3 IRIDIUM® is a registered trademark and service mark of Iridium LLC.

- telecommunications carriers and service providers world-wide seeking to extend their reach, control and service quality to areas not presently covered well by their current service offerings.

The Celestri System is ideally suited to rapidly fulfill the Global Information Infrastructure initiative recognized by Vice President Gore because it is capable of providing communications services virtually everywhere in the world without geographic or price discrimination. No other technology can more effectively help close the telecommunications gap between rich and poor countries, alleviating the distinction between information "haves" and "have nots."

While the cost of constructing the Celestri LEO System will be high in absolute terms, the system's global reach makes it possible to spread that cost over a large number of potential users, resulting in a fraction of the per-user cost that would be incurred to build out a terrestrial broadband network, whether nationwide or worldwide. The cost of a comparable terrestrial network infrastructure would be over a trillion dollars.

In addition, Motorola will achieve substantial cost savings through major design reuse of key space and ground-based components of the Millennium, M-Star and Celestri LEO Systems. This approach will dramatically reduce development time and costs, accelerate production of all elements of the architecture, and allow the start of service by the year 2002.

Motorola will operate the Celestri LEO System on a non-common carrier basis. Motorola does not anticipate selling services directly to end users. It intends to offer wholesale space segment capacity to carriers and service providers, who will, in turn, market a variety of services to their customers.

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In re Application of: **MOTOROLA GLOBAL COMMUNICATIONS, INC.** **For Authority to Construct, Launch and Operate the Celestri Multimedia LEO System, a Global Non-Geostationary Orbit Satellite System in the Fixed-Satellite Service.**	)	**File No. ______________**

APPLICATION OF MOTOROLA GLOBAL COMMUNICATIONS, INC.

Pursuant to Sections 308, 309 and 319 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 308, 309, 319, Motorola Global Communications, Inc. ("Motorola"), a wholly-owned subsidiary of Motorola, Inc., hereby requests Commission authority to construct, launch and operate a non-geostationary orbit ("NGSO") global satellite system, offering a wide range of real-time multimedia, data and voice services in the Fixed-Satellite Service ("FSS"). The Celestri Multimedia LEO System ("Celestri LEO System") will comprise a total of 63 operational satellites. The corresponding earth segment will include a System Control Segment ("SCS") for constellation and network operations, and Customer Premises Equipment ("CPE") to provide access to the system for end users.[1]

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1 Motorola is not at this time requesting authorization for ground segment facilities.

The service and control links will operate in frequency bands that have a global allocation for the intended purpose. These links will operate in the 18.8-19.3 GHz and 19.7-20.2 GHz bands (space-to-Earth) and the 28.6-29.1 GHz and 29.5-30.0 GHz bands (Earth-to-space).[2] The TT&C high gain links will also operate in the service bands. The system will use optical inter-satellite links to interconnect the satellites in space.

I. INTRODUCTION

A. General

The Celestri LEO System will essentially complete Motorola's Celestri Architecture for broadband satellite communications. The other cornerstones of the architecture are the Millennium and M-Star Systems. Each of these systems is designed to offer distinct, yet complementary, types of services and to fill different consumer needs. The geostationary ("GSO") Millennium System will primarily provide less delay-sensitive, point-to-multipoint services to the Western Hemisphere;[3] M-Star, a non-geostationary NGSO system, will provide global, broadband backhaul and trunking services for wireless and other providers; the Celestri LEO System will provide primarily gobal point-to-point real-time end-user communications. Motorola will integrate these three systems into a seamless whole. Complete interoperability will allow customers to use the satellite infrastructure that most efficiently meets their bandwidth and service needs.

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[2] Of these bands, the 18.8-19.3 GHz and 28.6-29.1 GHz bands have a primary domestic allocation for NGSO FSS. The 19.7-20.2 GHz and 29.5-30.0 GHz bands have a secondary domestic allocation for NGSO FSS. All bands have a worldwide primary FSS allocation.

[3] Of the various service categories enumerated in the application for the Millennium System, Motorola has decided to place primary emphasis on the point-to-multipoint applications.

The Celestri LEO System comprises 63 satellites in 7 inclined orbital planes, up to 7 in-orbit spares, and the associated ground segment equipment. All of the satellites will revolve in circular orbits at an altitude of 1400 km. The constellation will be inclined at 48° with respect to the Equator.

The system's LEO architecture will allow the use of relatively small, low power and low cost earth terminals for real-time services. End-users will experience delays essentially equivalent to terrestrial communication systems providing global real-time services.

Each satellite contains all the hardware necessary to route communications traffic through the network, including Earth-to-space, space-to-Earth and space-to-space connections. With this architecture, a signal received by a satellite may be transponded directly back to the Earth in the same or a different beam, or relayed by optical inter-satellite links through other satellites from which it is then transmitted to the Earth. This architecture allows global interconnection for the transport of real-time multimedia, data and voice services.

The system is designed to avoid harmful interference with other service operators primarily through the use of space diversity. This technique will allow multiple NGSO and GSO systems to operate co-coverage and co-frequency with the Celestri LEO System. Implicit in the spectrum sharing approach reflected in this Application is the assumption that all NGSO systems, including the Teledesic System, will participate in the spectrum sharing responsibility.

The Celestri LEO System will offer two categories of services. First, through service providers, non-business and consumer end-users will use the system for accessing and retrieving content in real time. Particular applications will include Internet access, video-conferencing, financial transaction processing, home entertainment, distance learning and tele-medicine. This class of service will provide bandwidth-on-demand access to the network at data rates up to 10 Mbps. The second category of service will be interconnection services at up to 155.52 Mbps. This data rate will enable multinational corporations and terrestrial carriers to aggregate voice and data signals.

While the cost of constructing the Celestri LEO System will be high in absolute terms, the system's global reach makes it possible to spread that cost over a large number of potential users, resulting in a fraction of the per-user cost that would need to be incurred to build out a terrestrial broadband network, whether nationwide or worldwide. The cost of a comparable terrestrial network infrastructure would easily be over a trillion dollars.

The Celestri LEO System's ground segment will comprise a System Control Segment ("SCS"), consisting of two Operation Facilities and six antenna sites for constellation and network operations. Each Operation Facility will consist of a Satellite Operations Control Center and Network Operations Center, and will maintain communications with all six antenna sites.

Motorola will operate the Celestri LEO System on a non-common carrier basis. Motorola does not anticipate selling services directly to end users. It intends to offer wholesale space segment capacity to carriers and service providers who in turn, will market a variety of services to their customers.

B. Information Contained in this Application

This Application contains all of the required information for an FSS application as specified in Appendix B of the Commission's 1983 Space Station

Filing Procedures decision,[4] and Part 25 of the Commission's Rules and Regulations to the extent applicable.[5] Motorola will amend or modify this Application, if necessary, after the Commission has adopted its policies and rules for satellite systems in the requested bands. In support of this Application, Motorola provides the following information:

1. Name, Address and Phone Number Of Applicant:

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Attn: Bary Bertiger, President
2501 South Price Road
Chandler, Arizona 85248-2899
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2. Names, Addresses and Phone Numbers of Persons To Be Contacted:

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202-429-3000

3. Type Of Authorization Requested

Motorola requests authority to construct, launch and operate up to 63 non-geostationary orbit satellites, and up to 7 in-orbit spares, to establish a high-

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4 Filing of Applications for New Space Stations in the Domestic Fixed-Satellite Service, Memorandum Opinion and Order, 93 FCC 2d 1265 (1983).

5 See Streamlining the Commission's Rules and Regulations for Satellite Application and Licensing Procedures, FCC 96-425, IB Dkt. No. 95-117 (Dec. 16, 1996).

capacity broadband FSS system. The satellites will be distributed in 7 planes with 9 operational satellites in each plane. The planes will be inclined at 48 degrees with respect to the Equator. Services will be provided on a non-common carrier basis.

II. PUBLIC INTEREST CONSIDERATIONS

The proposed Celestri LEO System worldwide broadband communications system will provide real-time, end-to-end broadband services to consumers' homes, businesses, schools and hospitals. It will facilitate the creation of a global community brought together by the exchange and communication of ideas, images and sounds in real time. It will also introduce competition with other terrestrial and satellite-based providers of broadband services.

The Celestri LEO System is an important component of Motorola's satellite communications vision. It will complement the other satellite systems for which Motorola has licenses from or pending applications with the Commission. Each of these systems -- IRIDIUM®, Millennium, M-Star and now the Celestri LEO System -- addresses a distinct segment of the global satellite communications market. The IRIDIUM® System, with five satellites already in orbit and the remaining constellation scheduled to be launched soon will provide narrowband Mobile-Satellite Services to a universe of mobile users. The Celestri Architecture, on the other hand, will provide broadband Fixed-Satellite Services ("FSS"). Each component of this architecture will target different markets. The Millennium System's four geostationary satellites will provide broadband and multicast services on a regional basis to customers in the Americas. The NGSO M-Star and Celestri LEO Systems will cover the globe. M-Star will be a backbone system, providing backhaul services for terrestrial wireless systems, including third-generation cellular services, and will serve as a conduit for other aggregated signals such as trunking on international private line services. The Celestri LEO System will provide primarily point-to-point broadband offerings for end users -- both businesses and homes -- including Internet access, video-conferencing, financial transaction processing, distance learning and tele-medicine.[6]

Motorola plans to integrate its three broadband FSS systems into a seamless whole. Customers with variable bandwidth and service needs will be able to shift seamlessly from one system to the other and use the infrastructure that most efficiently suits their particular needs. In the Ka-band, a single terminal will be able to receive and send data, video and voice signals over the Millennium or Celestri LEO Systems, depending on geography and efficiency. For applications that require exceptionally large bandwidth, the M-Star System will "leverage" Ka-Band user links into very high-capacity trunking and backhaul applications in the 40/50 GHz band.

The Celestri LEO System will provide a global broadband infrastructure at a much lower cost than would be possible through a terrestrial fiber optic network. Construction and launch of the Celestri LEO System and the first of four satellites of the Millenium System are estimated to cost $12.9 billion. By contrast, a global broadband fiber optic network to every location in the world would cost over a trillion dollars.[7]

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6 Secondarily, the Celestri LEO System will also offer voice and data aggregation services for terrestrial carriers.

7 The cost of planned fiber-optic backbone networks has been estimated at $550 billion in Japan alone, see Rob Guth, "Down But Not Out," Computerworld, at 9 (Sept. 9, 1996) and $58 billion in Korea, see "In Search of State-of-the-Art Technologies: Korea's Drive to the Information Superhighway," East Asian Executive Reports, at 8 (Sept. 15, 1996). New and upgraded fiber optic networks in the United States will cost several billion dollars per state. See Brian O'Reilly, "First Blood in the Telecom Wars," Fortune (Mar. 4, 1996);

The Celestri LEO System also will provide global broadband services much earlier than comparable terrestrial broadband services will be globally available, particularly in view of the limited success and mixed prospects of current proposals for construction of fiber-based broadband networks providing direct service to end-users.[8] Decisions on whether and where to deploy a terrestrial network may leave populated remote and rural areas where deployment is prohibitively expensive on a per capita basis without broadband services. In contrast, by as early as the year 2002, the Celestri LEO System will be capable of providing economical broadband services to virtually any populated point on Earth through deployment of low-cost Celestri System earth terminals.[9]

The Celestri LEO System also will enhance competition in the broadband telecommunications marketplace. It will compete with terrestrial providers offering "last-mile" fiber or wireless connections, as well as with other announced and planned NGSO and GSO broadband fixed satellite service systems. The

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(Southern New England Telephone Co. network in Connecticut will cost $4.5 billion); "Pacific Bell's California Test Leaves Room for Marketers," Advertising Age, at 19 (Nov. 22, 1993) (upgrade to California network projected to cost $16 billion).

8 The Celestri LEO System will even be available before completion of backbone networks planned in industrialized countries. See Guth, "Down But Not Out" (Japanese fiber backbone network scheduled for completion in 2010); "In Search of State-of-the-Art Technologies" (Korean fiber backbone network scheduled for completion in 2010).

9 See Judith J. Senkevitch Dietmar Wolfram, "Equalizing Access to Electronic Networked Resources: A Model for Rural Libraries in the United States," Library Trends (Mar. 22, 1994) ("satellite transmission could represent an economical way of reaching isolated communities because costs are less distance dependent than for enclose media [such as fiber optics]").

Celestri LEO System's innovative design will provide extensive double coverage and will allow co-frequency sharing between more than one NGSO system by means of interference mitigation techniques such as space diversity.[10] To ensure that the Celestri LEO System is broadly usable, it will be accessible through open interfaces supporting a wide variety of communications protocols. The entry by the Celestri LEO System's use of the Ka-band will validate the Commission's long-standing efforts in the International Telecommunication Union and other international forums to facilitate the use of the Ka-band by multiple NGSO FSS systems.

The services that will be available through the Celestri LEO System will bring to reality virtual person-to-person contact and information exchange, which is now only possible by physical proximity. Communications across countries and between continents will, for the first time, become as effective as face-to-face communication.

The Celestri LEO System and the Celestri Architecture will also provide significant benefits for the U.S. and world economies. First, the widespread availability of broadband communications will increase global productivity.[11] Second, the Celestri LEO System will produce a direct infusion of capital into the United States and other countries. While Motorola will construct the space

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10 Space diversity will also facilitate sharing with GSO satellites using the Ka-band.

11 See, e.g., Stephen R. Rivkin and Jeremy D. Rosner, Shortcut to the Information Superhighway: A Progressive Plan to Speed the Telecommunications Revolution, Progressive Policy Institute (July 1992) at 1 (a nationwide fiber optic network would substantially improve the nation's quality of work and life; according to one study, it could boost U.S. annual productivity growth by 0.4% and add $321 billion to the nation's wealth over 16 years, not including energy and environmental savings) (citing Robert B. Cohen, The Impact of Broadband Communications on the U.S. Economy and on Competitiveness, Economic Strategy Institute (1992).

segment and will manufacture a large portion of the ground segment, Motorola expects that it will employ a multinational team of contractors and subcontractors to help design, build and launch the system and related components. Creations of this system will translate into millions of job person-hours, many of them involving specialized, highly compensated professional work. Third, the Celestri LEO System will promote rural development by providing real-time access to centralized databases, including finance, market, health and other information, not otherwise available locally. Moreover, implementation of the proposed system will add a significant number of jobs and money to the world economy through other direct and indirect economic benefits.

The Celestri LEO System will also play a significant role in global economic development, particularly in less developed countries. Vice President Gore recognized this role when he addressed the first ITU development conference in Buenos Aires on the Global Information Infrastructure ("GII"):

> We now can at last create a planetary information network that transmits messages and images with the speed of light from the largest city to the smallest village on every continent. . . . From these connections, we will derive robust and sustainable economic progress, strong democracies, better solutions to global and local environmental challenges, [and] improved health care . . . . Digital telecommunications technology, fiber optics, and new high-capacity satellite systems are transforming telecommunications.[12]

Global satellite networks like the Celestri LEO System are ideally suited to rapidly fulfilling the GII initiative because they are capable of providing communications services virtually everywhere in the world without geographic or

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[12] Remarks Prepared for Delivery by Vice President Al Gore, International Telecommunications Union (Mar. 21, 1994).

price discrimination. No other telecommunications technology -- including fiber optics -- can make that claim, and none can hope to achieve the promise of geographic universality as soon as global satellite networks.

Satellite services have the potential to help close the telecommunications gap between rich and poor countries is widely recognized.[13] By allowing easy accessibility to vast amounts of information, the Celestri LEO System will help close this gap by alleviating the distinction between information "haves" and "have nots". Its broadband capabilities will provide universal availability to the kinds of economic, telemedicine, distance learning, and teleconferencing services that the GII initiative mandates. With the Celestri LEO System, the promise of the GII and worldwide telecommunications access becomes a reality.

III. MARKET AND DEMAND FOR SERVICES

A. Overview

The future demand for broadband communications services, provided through a global information infrastructure, is presaged today by the enormous growth experienced in the number of Internet host addresses, Internet World Wide Web sites and commercial on-line service subscribers.

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13 See Mobile Satellite News, May 29, 1997, at 7 (quoting statement of ITU Deputy Secretary-General Henry Chasia that satellite-based Internet services can be used "to close . . . the telecommunications gap"); Communications Daily, May 29, 1997, at 10 (quoting statement of Prince Thumbumuzi Dlamini of Swaziland at AFCOM conference that "[u]niversal availability is no longer a dream and it will lead to the rapid acceleration of economic development which has historically been the product of modern telecommunications").

The Celestri Architecture will offer a full range of broadband services for transporting all forms of digital communications (including multimedia) and allocating only the needed portions of a communications channel to do it through bandwidth-on-demand. These broadband applications have the potential to save billions of dollars in health care delivery; enhance the quality and lower the cost of education by bringing remote instructors and new learning opportunities to students; improve the quality of life by fostering effective telecommuting (work at home) environments, place small businesses on a more "even playing field" with large corporations; increase the global competitiveness of all businesses and provide entertaining and personalized information to all consumers.

Providing these benefits to all members of the global community will require the innovative and creative application of satellite technology to complement and extend the reach of terrestrial systems and services. Currently, terrestrial systems offer bandwidth-on-demand services in a limited way and only in the densely populated areas of developed countries. The Celestri Architecture can provide global reach and cost-competitive communications to all regions in all countries, including hard-to-reach rural areas and remote locations.

B. Trends

1. Key Technology Trends

There are a number of technological and economic trends that create a demand for affordable broadband telecommunications services. The Celestri Architecture will satisfy that demand and enhance competition with the terrestrial and satellite providers targeting the same markets.

a. Digital Technology

Over the last few years, the implementation of digital compression techniques has led to widespread availability of video images in digital form. With the ability to handle all popular forms of media (data, video, text, still image and voice) in digital form for storage, transmission and delivery, a global broadband infrastructure becomes more realistic. The Celestri Architecture will not only provide the necessary long-haul transport, but supply "last-mile" connections, making available ubiquitous communicating devices (information appliances), easy-to-use collaborative applications and broadband communications transport, and placing these multimedia formats within everyone's grasp.

b. Computers as Communication Devices

The need for a broadband infrastructure is a direct consequence of the recent revolution in the capabilities and functions of the personal computer. The personal computer has evolved from a sophisticated text processor and calculator to a true multimedia information appliance capable of processing all forms of multimedia, video, data and voice information. Increasingly complex operating systems and software that process images, voice, and video add to the volume of data. The "language" of these computers is broadband digital data, and it is the need to transport these data that generates demand for the services that will be provided by the Celestri System.

Computers are increasingly equipped with digital signal processors that can efficiently and rapidly handle multimedia signals. In 1970, a supercomputer could perform several million operations per second. Supercomputers today are many thousands of times faster, manipulating vastly larger volumes of data and storing information at levels not imagined in 1970. Desktop machines for the office and home have experienced corresponding increases in processing speed. Storage devices with capacities of over 3 gigabytes of data are available today for desktop computers for only a few hundred dollars, a fraction of the cost of much lower capacity storage systems only five years ago. These cost reductions make it affordable for a typical residential or business user to process and store large files associated with data, image and video. The new challenge is to transport this enormous volume of information quickly and efficiently.

c. Local Area Networks

As the ability of computers to process information has increased, the ability of local area networks ("LAN"s) to deliver that information among geographically distributed commercial environments has also increased. Today's Fiber Distributed Data Interface ("FDDI") networks and high speed Ethernet LANs can transport data at rates of up to 100 Mbps. Gigabit LANs are on the near horizon. Especially for businesses, these changes are alleviating the local area bottleneck that has slowed the development of "bandwidth-hungry" multimedia applications and services. These advanced networks have also promoted the development of bandwidth-on-demand technology, which allows a user to utilize only the bandwidth required for a particular application. For a satellite system, this technology providers the added advantage of spectral efficiency. Figure III-1 illustrates projected growth of LAN sites through the year 2002.

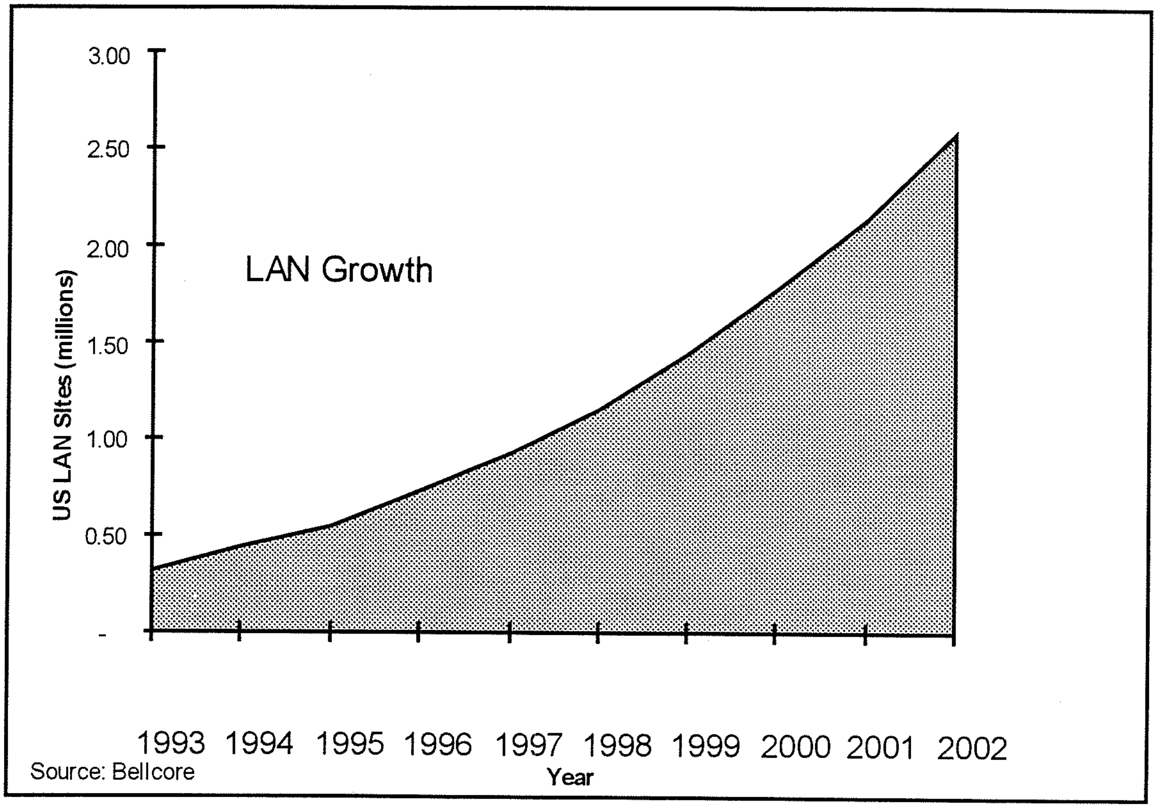

Figure III-1

d. Wide Area Networks

In the past, wide area networks have also been expensive bottlenecks that discouraged users from using high-bandwidth applications over wide geographic areas. However, both local exchange companies and cable operators are deploying high speed digital subscriber lines ("xDSL") and fiber networks that promise to eliminate this bottleneck. By the year 2000, these changes will help spur the development and use of wide area multimedia communications.

In the U.S., the increasing deployment of ISDN by telephone companies will increase the bandwidth available to a typical home user from 33 kbps to 128 kbps (a four fold increase). Several local telephone companies and cable operators have announced plans to lay fiber to the home and provide truly broadband interactive services. Some of these plans appear to have been set back by the realization of the substantial cost and complexity of the enterprise. The progress made so far, as well as the impediments encountered, highlight both the demand for broadband communications and the difficulty of satisfying it in a cost-efficient way through terrestrial technologies.[14]

For business users, fast packet networks (e.g., frame relay) are rapidly growing in the U.S. Further increases will come from the expanding deployment of ATM networks (as illustrated in Figure III-2). These networks should enable businesses to extend their LANs over a wide area without sacrificing performance. While the U.S. is leading in the deployment of these high speed networks, European and Asian demand is also growing rapidly. This suggests that by the end of the decade, initial high speed networks should be a reality in many countries. However, these networks will not be ubiquitous for many decades, if ever.

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[14] See "Fiber Use Continues as Strong as Cable TV Girds for Competition," Fiber Optic News, May 6, 1996 (The cable TV industry will likely surpass its 1995 growth in the deployment of fiber optic lines, as that industry is installing 163 miles of optical fiber every hour daily.); "New SONET Carries Voice, Video and Data," Video Technology News, Apr. 7, 1997 (GI and Fujitsu believe that cable operators are willing to invest in fiber technology enough to spur a booming market.); "TCI Suspends Large Portions of Fiber Upgrade," Fiber Optic News, Nov. 4, 1996 (TCI has decided to suspend large portions of its fiber upgrade, until further notice.). But see "Growth in HFC Seen Buoying Scientific-Atlanta Share Value," Fiber Optic News, Apr. 28, 1997 (One commentator suggests both that TCI will continue its fiber upgrade and that cable operator fiber buildout will be at a 20 percent annual expansion rate). Shira McCarthy, "A Full Meal, Cable Industry Tucks in its Bib for the Western Show," Telephony, Dec. 9, 1996 ("Cable operators have realized the cost inherent in doing telephony over a hybrid fiber/coax architecture today is too great.").

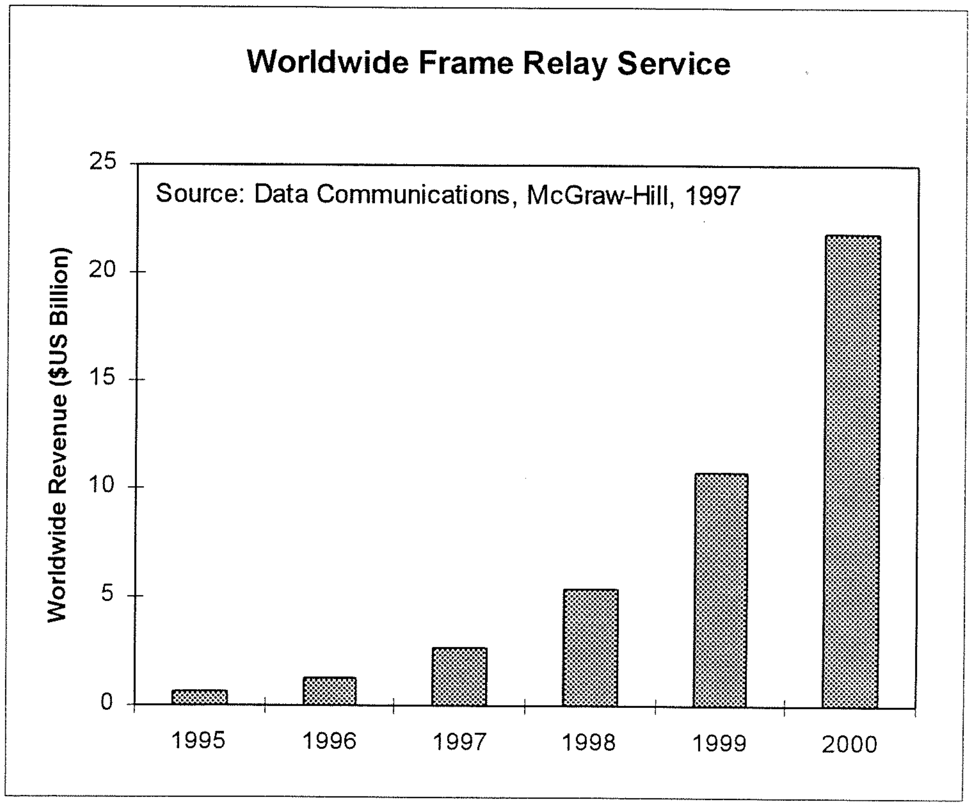

Figure III-2

2. Standards

In recent years, standards organizations and industry forums have defined key compression standards for digitizing images and video communications. By compressing communication streams that require hundreds of megabytes in their uncompressed form, these standards make it possible to store and transmit images and video using today's storage and communication technologies. The Celestri Architecture will be compatible with many world-wide data protocols and formats. Some examples are listed below:

ISDN (Integrated Service Digital Network)
Frame Relay
X.25

TCP/IP (Transmission Control Protocol / Internet Protocol)

ATM (Asynchronous Transfer Mode)

FDDI (Fiber Distributed Data Interface)

3. Economic and Regulatory Trends

A number of economic and regulatory trends are expected to enhance the market for many types of broadband digital communications services. These trends include:

- **Cost reduction pressures on all industry segments.** Businesses have come under increasing pressure to be globally cost competitive, to reduce the cost and improve the quality of education, to improve availability and to reduce overall costs of health care. The drive to efficiency has, in turn, increased the demand for applications such as telecommuting, distance learning and telemedicine.

- **Mobility and wider geographical distribution of work force.** This trend is associated with the increasing globalization of businesses as well as the environmental and quality-of-life pressures to increase the "work at home" population. It is estimated that 30 million households in the US currently have employees that work at home in some form (i.e., after-hours or telecommuting). This figure is expected to double by the year 2000.

- **Strategic importance of information access for large business.** For large business, information processing and communications are becoming a source of strategic advantage. They are used to increase efficiency and productivity as well as to propel expansion into the global marketplace.

- **Growth in number of small businesses.** Small businesses in the U.S. represent nearly 7 million establishments and are growing at 2% per year, according to estimates from IDC/Link Resources. They are using communications technology to "level the playing field" with large corporations. Information technologies such as interactive advertising on the World Wide Web allow them to inform vast audiences of their goods and services at a fraction of the cost of advertising through the traditional mass media.

- **Liberalization of international telecommunications.** Throughout the world, an increasing number of state-controlled public telephone companies are in the process of privatization. Access to the local network is gradually opening to support competition. It is expected that this liberalization will facilitate development of broadband applications and services. A significant milestone in the liberalization process is the February 15, 1997 agreement in the World Trade Organization Group on Basic Telecommunications. This agreement involved sixty-nine countries, most of which made significant commitments to open their markets for basic telecommunications services, including voice and data transmission by satellite, beginning as early as January 1, 1998.

- **Internet growth.** Internet continues to grow at a phenomenal rate is increasingly used for commercial transaction and interactive services. The Internet growth rate exceeds 25 to 50% per month, demonstrating a dramatic pent-up demand for information access in a personalized fashion. An Internet Society analysis shows that World Wide Web traffic currently constitutes about 30% of all Internet traffic, but is growing at more than 25% per month. Figure III-3 illustrates this growth in data volume.

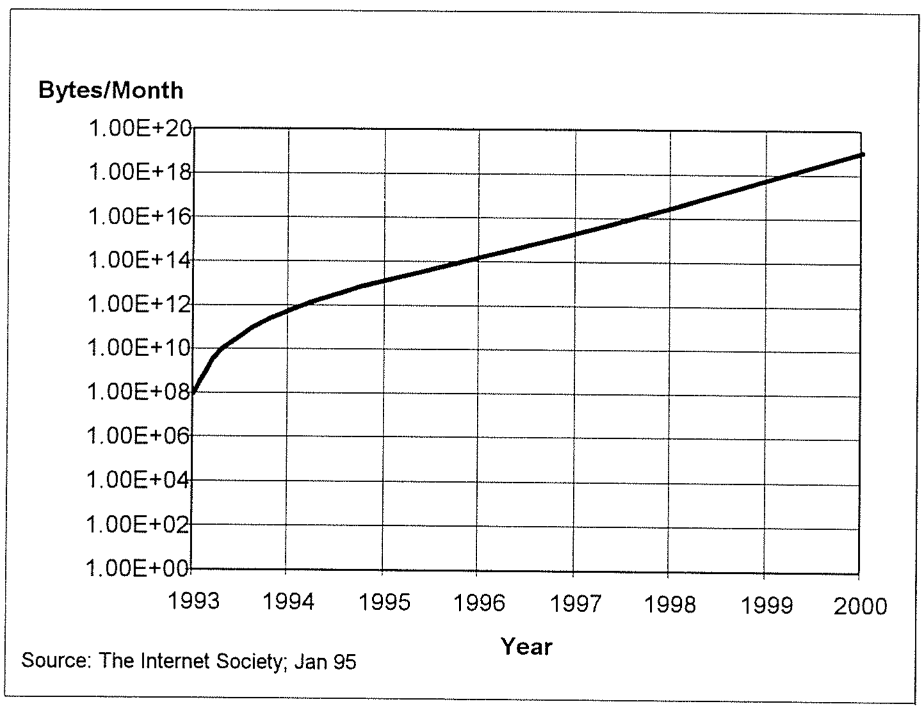

Figure III-3

- **Communications partnerships and alliances.** Communications and computer firms are forming alliances to offer end-to-end services by exploiting the synergies made possible by convergence of their industries.

- **Cost reductions in broadband equipment.** As equipment for broadband networks comes down in price and as a larger number of firms develop this equipment, it is becoming less difficult for new entrants to develop and offer broadband networks at affordable prices to consumers. For example, initial frame relay service networks in the U.S. use switches that cost less than 10% of the price of a typical central office voice switch. ATM switch prices begin at under $50,000.[15]

C. Proposed Services

The broadband communications market includes consumer and business users of high and often variable bit rate data and media (voice, text, data, image and video). Typical data rates are in the 128 kbps to 51.84 Mbps range. In the case of voice-only transmission, data rates range from 16 kbps to 64 kbps. In cases where multiple sources of input are aggregated, the resultant bandwidth demands range from 51.84 Mbps to over 155.52 Mbps. The baseline design for the Celestri LEO System will serve the low (to 2.048 Mbps, E-1) and medium (to 155.5 Mbps, OC-3) data rate markets.

End users will access the system to retrieve information. Content can be user-created (as in the case of a video-conference or a home page on the World Wide Web) or can be more formally created (as in the case of film or magazines). The business plan for the Celestri LEO System focuses primarily on point-to-point applications. In some cases, content is multiplexed from many sources. Examples include LAN-to-LAN interconnections and access from local

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[15] Of course, the start-up costs for deploying a broadband network remain high, particularly for terrestrial technologies.

PCS service providers to a service collection point into the public switched telephone network ("PSTN").

Content users are coming to expect:

- Fast access to content;
- Low access and retrieval costs;
- Reliable retrieval of content;
- Support and ease of use in identifying and accessing the desired content;
- Support for collaboration among several users in the access, viewing and interpretation of content;
- Sophisticated and pleasing displays of content involving the incorporation of multiple representations of media (voice, image, sound, video, etc.).

The Celestri System will meet these consumer demands.

1. Service and Application Characteristics

The Celestri LEO System will offer two categories of broadband services. The first category involves data and video services that enable residential and business customers to communicate at data rates ranging from 64 kbps to 10 Mbps on a bandwidth-on-demand basis. While voice may be part of the communication (as in the case of video-conferencing), it is not the primary ingredient of these services. It is assumed that *pure* voice communications will be served by a variety of wireless and wireline networks.

The second category of broadband services involves interconnection services that enable multinational corporations and terrestrial carriers to aggregate and transmit voice, data and video signals together. These services will primarily use the 51.84 Mbps (OC-1) and 155.52 Mbps (OC-3) data rates.

a. Residential and Business Broadband Services to End-Users

Internet Access. This service enables a personal computer to connect to the Internet. It may offer service to the user at home or to small businesses throughout the world. In the case of home usage, such access will comprise not only entertainment or news type services, but also cost effective data access for such services as self-care. The bulk of these services is handled by a relatively low speed uplink from the home or office (64 - 2048 kbps) and a fluctuating but fairly large downlink into the home or office (2.048 Mbps to more than 10 Mbps).

Video-conferencing. This service can be used in either business or residential environments through a personal computer. The video conference can be conducted between two computers or between several users at different locations. A higher-quality link can be used to establish a video conference with another person by linking a video-equipped computer or room to the satellite network. Such applications have characteristics similar to telephone calls but with higher bit rates. It is expected that such services will require symmetric links of 128 kbps to 1.544 Mbps.

Telecommuting. This service enables a telecommuting worker to connect to an office computer for the purpose of accessing work-in-progress, collaboration with co-workers, corporate information and databases, e-mail, etc. The capacity requirements are similar to those for Internet access.

Small Business Transaction Services. This service supports transaction data access for credit validation on credit/debit card sales as well as electronic data interchange access ("EDI") for order and invoicing by small businesses. Traffic demands are low for both uplink and downlink. The equivalent of a 64 kbps channel is adequate for this service.

Home Entertainment. This service includes satellite-delivered programming plus interactive services such as movies on demand, games, news and information services, and home shopping. The bulk of these services is handled by a relatively low speed uplink from the home (64 kbps or lower) and a bursty but fairly large downlink into the home (384 kbps up to 16.384 Mbps for some video services).

Telemedicine. This service uses the satellite system to transmit multimedia patient records (text records, high-quality images, video and voice annotations) between institutions. By using telemedicine, doctors and other care givers can consult with specialists thousands of miles away; continually upgrade their education and skills; and share medical records and x-rays. Telemedicine is projected to reduce health care costs while enhancing efficiency and accessibility to health care services. For example, in Texas, over 70 hospitals, primarily in rural areas, have been forced to close since 1984. Texas offers interactive video consultation to primary care physicians in rural hospitals as a way of alleviating the shortage of specialists in these areas. This trial is increasing the quality of care in rural areas and is providing at least 14 percent savings by cutting patient transfer costs and provider travel. Such services require symmetric links of 128 to 384 kpbs. Tele-radiology used for primary diagnosis requires data rates of 1.544 to 50 Mbps (for mammography images). In addition to the telemedicine applications described above, the Celestri Architecture can achieve savings of several billions of dollars in U.S. health care expenditures by promoting self-care. The National Telecommunications & Information Administration ("NTIA") has identified a savings of $40 to $60 billion from use of personal health information systems, even if such systems were used only 25 to 35 percent of the time.[16]

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[16] See NTIA, "The National Information Infrastructure: An Agenda for Action" (1993).

Distance Learning and University Education. This service enables a student or teacher to connect to a school's computer for the purpose of accessing homework, reference materials, and/or communicating with other students or teachers. The bulk of these services is handled by a relatively low speed uplink from the home or school site (64 kbps or lower) and a bursty but fairly large downlink in return (64 kbps up to 16.384 Mbps for some video and image services). This service also allows live instruction provided between two or more classroom locations, using one or two-way video, video-conferencing, collaborative applications and/or multimedia. Characteristics of this service are very similar to video-conferencing; such services require symmetric links of 128 to 384 kbps.

b. Aggregated Broadband Services

PCS Backhaul. This service will allow islands of PCS systems to interconnect with the rest of the world, even if they are remote to the global telephone network. In this application, the Celestri Architecture would provide communications services for use by the PCS service provider, not the end user. Estimates show that service cells of up to 5,000 subscribers can be handled with a symmetric uplink/downlink of from 128 to 384 kbps. This service would allow universal access to PCS service providers anywhere in the world.

LAN-to-LAN. This service enables a LAN-to-LAN communication by connecting routers at remote locations through a satellite channel. It would also allow remote branch locations access to corporate headquarters' data services. This service uses a symmetrical link running between 384 kbps and 51.84 Mbps. The bandwidth in use would be determined by the traffic demand at any point in time. Most LANs are expected to require up to 2.048 Mbps in service bandwidth.

Interexchange Carrier Backhaul. This service enables telecommunications carriers to aggregate voice long distance traffic for both domestic and international delivery. It takes advantage of the switching capabilities of the satellite to deliver data to numerous points from a single collection point. This service requires symmetric uplink and downlink channels that run from 51.84 Mbps to over 155.52 Mbps. The tremendous value of this service to carriers is the ability to reconfigure capacity to where it is needed, when it is needed.

2. Customer Premises Equipment

Motorola expects that the Celestri System will be accessed by end users through four categories of customer premises equipment ("CPE"): direct-to-home ("DTH") terminals that support information rates up to 2.048 Mbps, business terminals supporting information rates up to 10.0 Mbps, corporate terminals that support an information rate of 51.84 Mbps, and gateway terminals supporting an information rate of 155.52 Mbps.

D. Demand Analysis

1. Markets and Estimated Demand

Through the broadband offerings described above, the Celestri System will target several markets or market segments, including:

- Residential;
- Corporate customers (large businesses);
- Small businesses;
- Education;
- Terrestrial carriers;
- Government and Military;
- Health care.

The total size of the communication provider market in the first decade of the new millennium, as projected by Bellcore, is expected to approach $1.5 trillion in worldwide annual service revenue. This reflects end-user willingness to pay for delivery of, and access to, content; it does not include the value of content itself to the user. Motorola conservatively estimates that approximately 70-80% of this market will be served by terrestrial systems such as fiber and cable. This leaves an unserved global market of at least $300 billion. Rapid growth in demand is projected on the basis of data and estimates applicable to the discrete categories of broadband services described above. The following are some examples:

a. Video Demand

- Business Video-conferencing;
- University Education;
- Telemedicine;
- Telecommuting;
- Home Entertainment.

Frost & Sullivan, Inc.[17] project that equipment used for desktop and room-based video-conferencing is selling at a compound annual growth rate of 45%.

b. Data Demand

- Distance Learning;
- Internet Access;
- Telecommuting;
- Small Business Transaction Services;
- LAN-to-LAN.

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17 Frost & Sullivan, Inc., "U.S. Desktop Video Product Market: The First Definitive Business and Technology Assessment" (1993).

Data growth rates are best represented by World Wide Web usage as shown in Figure III-3. This reflects a 25% increase per month. Additional indicators are LAN and WAN growth trends shown in Figures III-1 and III-2.

c. Voice Aggregated Demand

- PCS Access;
- Interexchange Carrier Backhaul.

International voice traffic is growing at over 12% per year. PCS growth projections from Bellcore[18] show a worldwide market of over 80 million subscribers by the year 2000.

2. Geographic Coverage

As detailed below, the Celestri LEO System constellation will provide around-the-clock coverage of all points between 60° Northern and 60° Southern Latitudes at elevation angles that exceed or equal 16°. Coverage can be extended beyond 70° Latitude by mitigating the effects of low elevation angles. With respect to the United States, the system will be capable of continuous 24-hour-a-day service to any point in the contiguous United States ("CONUS"), Alaska, Hawaii, the Commonwealth of Puerto Rico, the U.S. Virgin Islands and all U.S. territories. It will also provide double coverage of all points in the 48 contiguous states (i.e. coverage by two satellites at elevation angles of at least

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18 Private study prepared for Motorola (1995).

16° 99% of the time) as well as between 18° and 48° Northern and Southern Latitudes.[19] Further, all points in the contiguous U.S. will enjoy triple coverage for more than 50% of the time. Double and triple coverage will be important to allow for sharing spectrum with other systems by means of satellite diversity.

E. Key Advantages Over Terrestrial Services

In all cases, the services addressed by this analysis have counterparts in terrestrial networks. Delivery through NGSO satellite system, however, has several critical advantages. The primary advantage is global reach. While terrestrial broadband networks are typically restricted to a confined geographical area, the Celestri System can serve virtually any point in the world where people live or work. Moreover, terrestrial broadband networks are likely to serve only large concentrations of customers such as those found in major metropolitan areas. In contrast, the Celestri System can serve virtually any customer no matter how geographically isolated the customer may be. To appreciate this point, it is instructive to consider that although telephony services are over 100 years old, fewer than 5% of potential customers in parts of Asia and Africa have basic telephony service. Although terrestrial broadband services and technologies have been available for decades, they are expensive and cannot be readily obtained by consumers even in the United States and other highly developed countries.

A second advantage is interoperability. A communication solution over a large geographic area (e.g., multiple countries) will often involve multiple terrestrial carriers. Each carrier will offer different service features, and the

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[19] Beyond CONUS, all points between 55° Northern and 55° Southern Latitudes will enjoy double coverage for 90% of the time.

services of the carriers may not inter-operate. In contrast, the Celestri Architecture can link two or more locations anywhere in the world and offer the customer a single network with a common set of features and interfaces. Interoperability is guaranteed. Another key feature of the Celestri Architecture is its adherence to international standards and data formats.

A third advantage is speed of service activation. A customer who is not already connected to a terrestrial network may have to wait weeks (possibly years in some areas of the world) to obtain service. In contrast, that customer can receive satellite-based service as soon as a satellite terminal can be delivered.

F. Information Concerning Sales of Communications Services -- Regulatory Classification as Non-Common Carrier

Motorola intends to operate the Celestri LEO System as a non-common carrier with respect to all of the foregoing services. It will not provide services directly to the public. Rather, Motorola will market the Celestri LEO System's space segment capacity on a wholesale basis to a small number of service providers, each of which will offer the services to end-users. Motorola will make individualized decisions with respect to the choice of each provider and the terms of its relationship with each such provider, and will enter into long-term relationships with those providers. Consequently, neither Motorola nor the Celestri LEO System will hold itself out indiscriminately to serve the public, nor should there be any legal compulsion to regulate the space segment provider as a common carrier. See National Association of Regulatory Utility Commissioners v. FCC, 525 F.2d 630, 642 (D.C. Cir.), cert. denied, 425 U.S. 999 (1976) (NARUC I). In substantially the same circumstances, the Commission has held that the sale of FSS capacity on a wholesale basis does not constitute common carriage. See Domestic Fixed-Satellite Transponder Sales, 90 F.C.C.2d 1238, 1256-57 (1982), aff'd, World Communications Inc. v. FCC, 735 F.2d 1465 (D.C. Cir. 1984), modified Martin Marietta Communications, Memorandum Opinion and Order, 60 Rad. Reg. (P&F) 2d 779 (1986). Therefore, in accordance with the Commission's DISCO I Report and Order, Motorola elects to offer services on a non-common carrier basis.[20]

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[20] Amendment to the Commission's Regulatory Policies Governing Domestic Fixed Satellites and Separate International Satellite Systems, Report and Order, 11 FCC Rcd. 2429, 2436 (1996) ("DISCO 1 Report and Order"). See also In the Matter of Teledesic Corporation Application for Authority to Construct, Launch, and Operate a Low Earth Orbit Satellite System in the Domestic and International Fixed Satellite Service, 12 FCC Rcd. 3154, ¶¶ 25-27 (International Bureau March 14, 1997).

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.

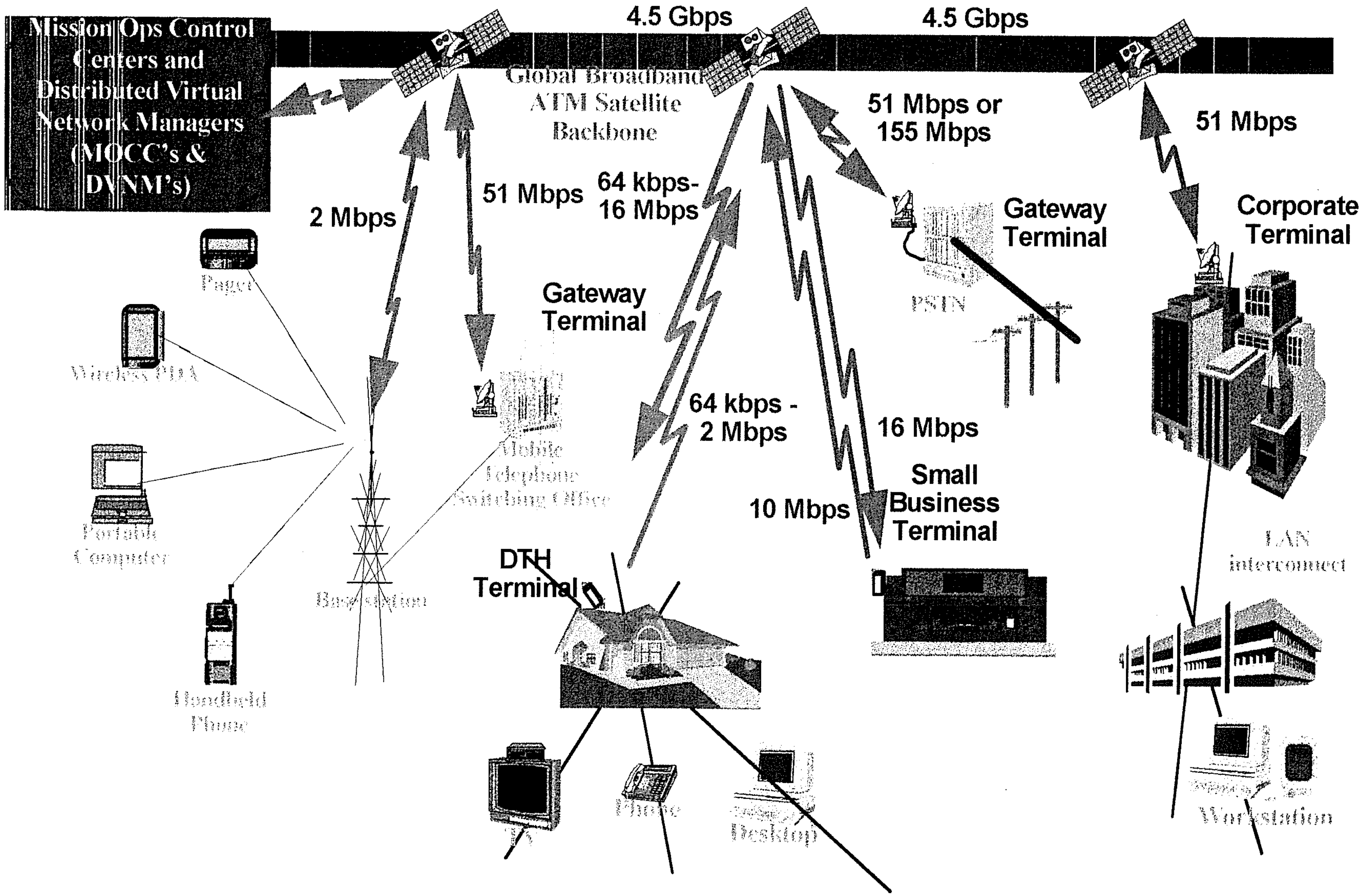

Figure IV-1: Celestri LEO System Architecture

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.

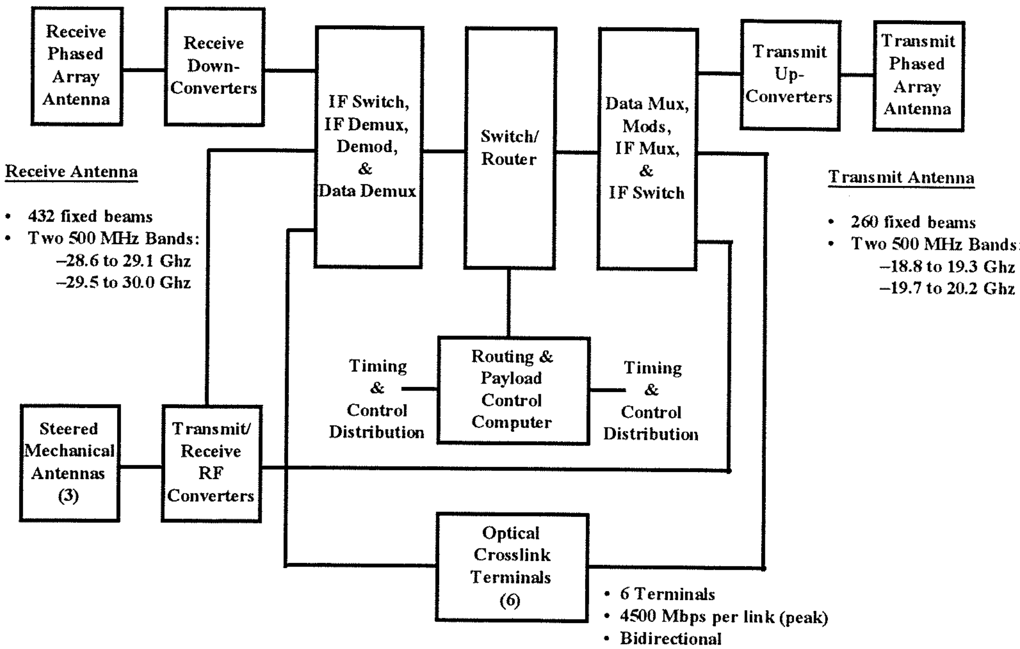

Figure IV-2 Payload Block Diagram

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.

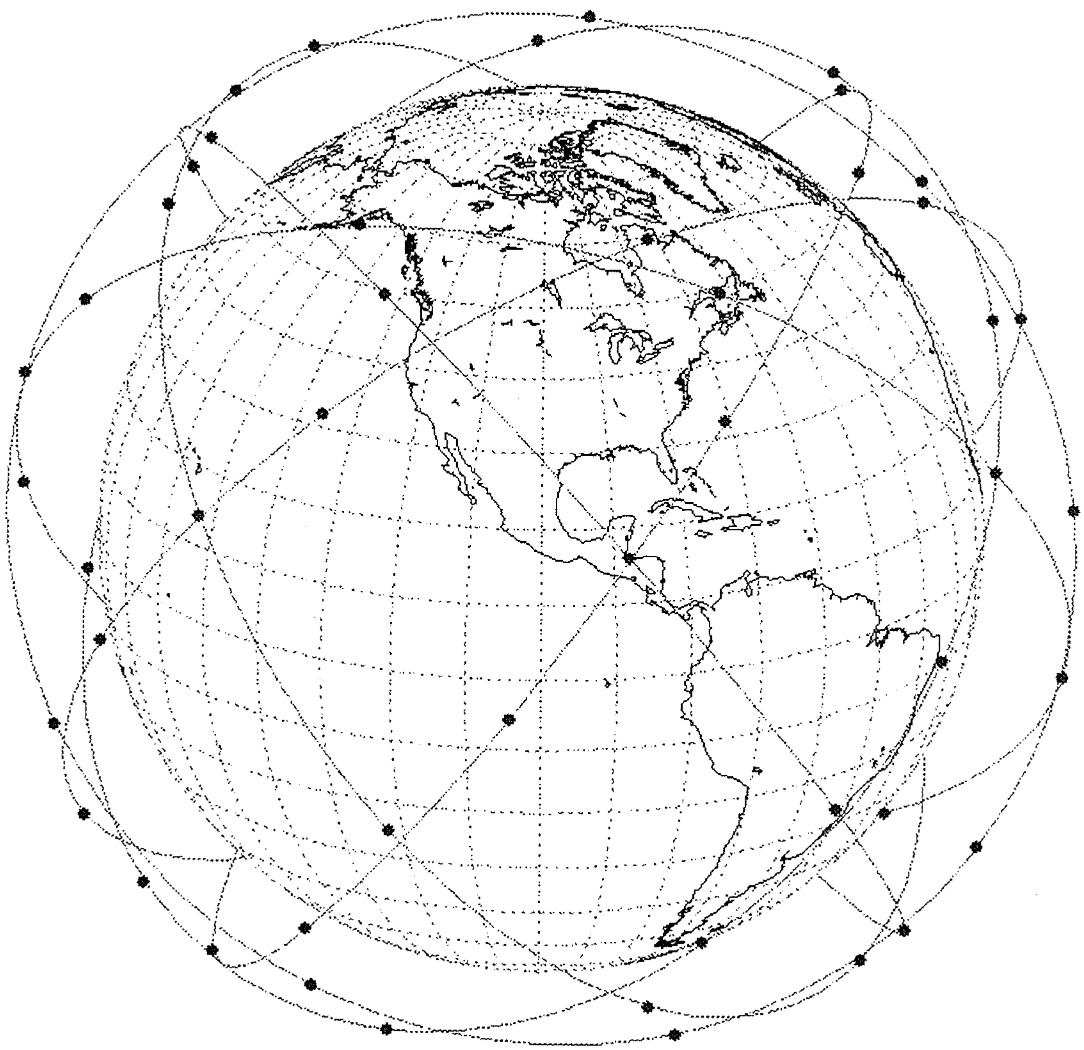

Figure IV-3: Constellation Configuration

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.

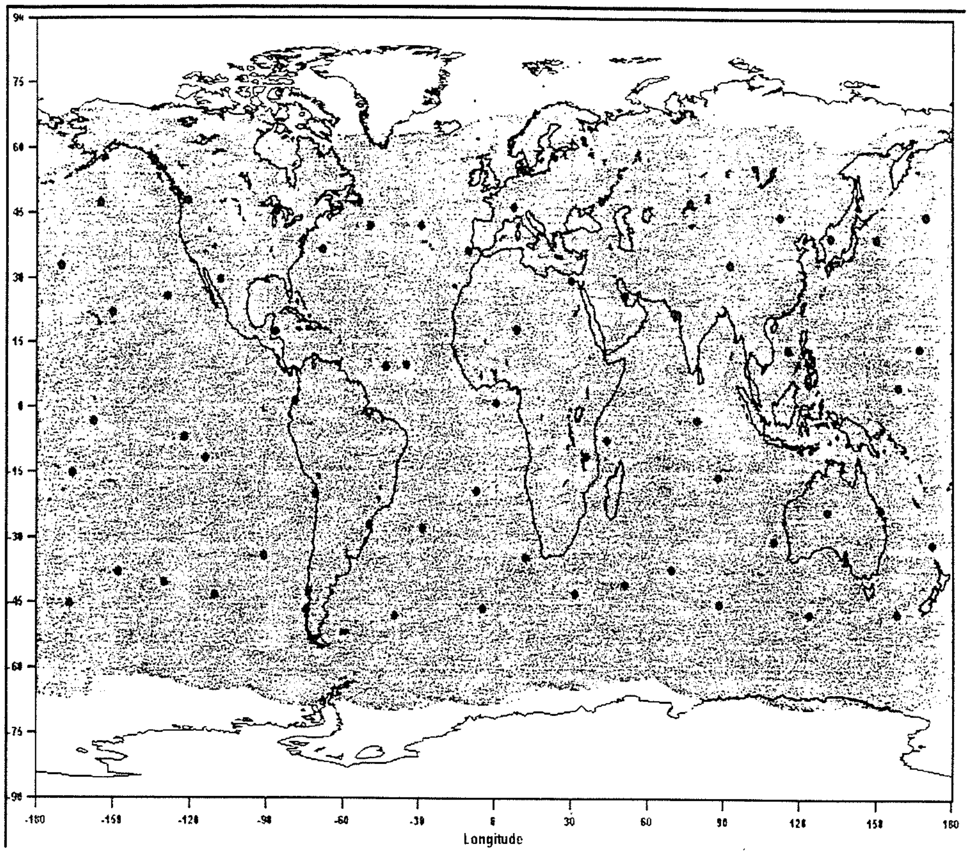

Figure IV-4 Celestri LEO System Coverage Region

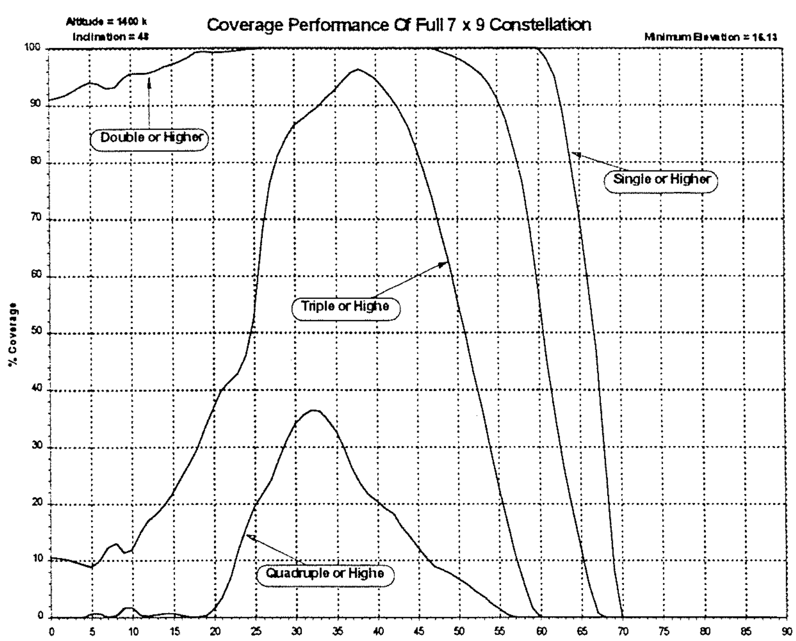

Figure IV-5 Celestri LEO System Multiple Coverage

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.

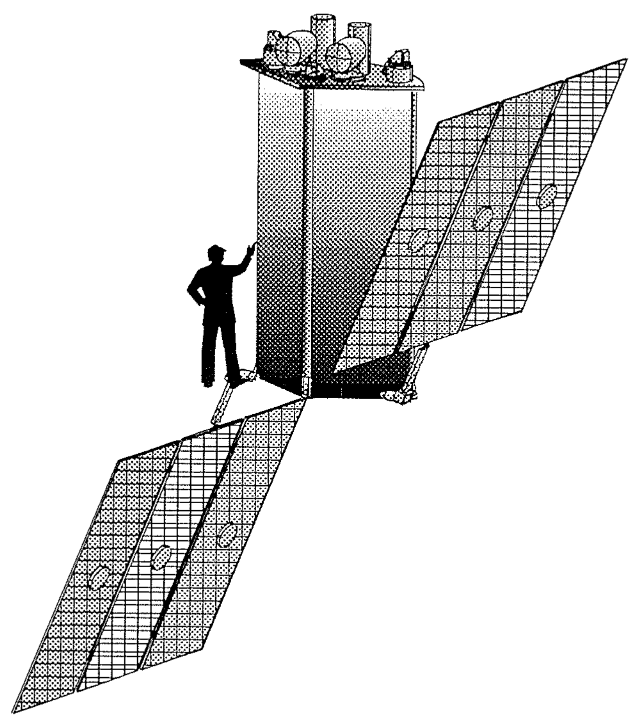

Figure IV-6: Celestri LEO System Satellite Concept

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.

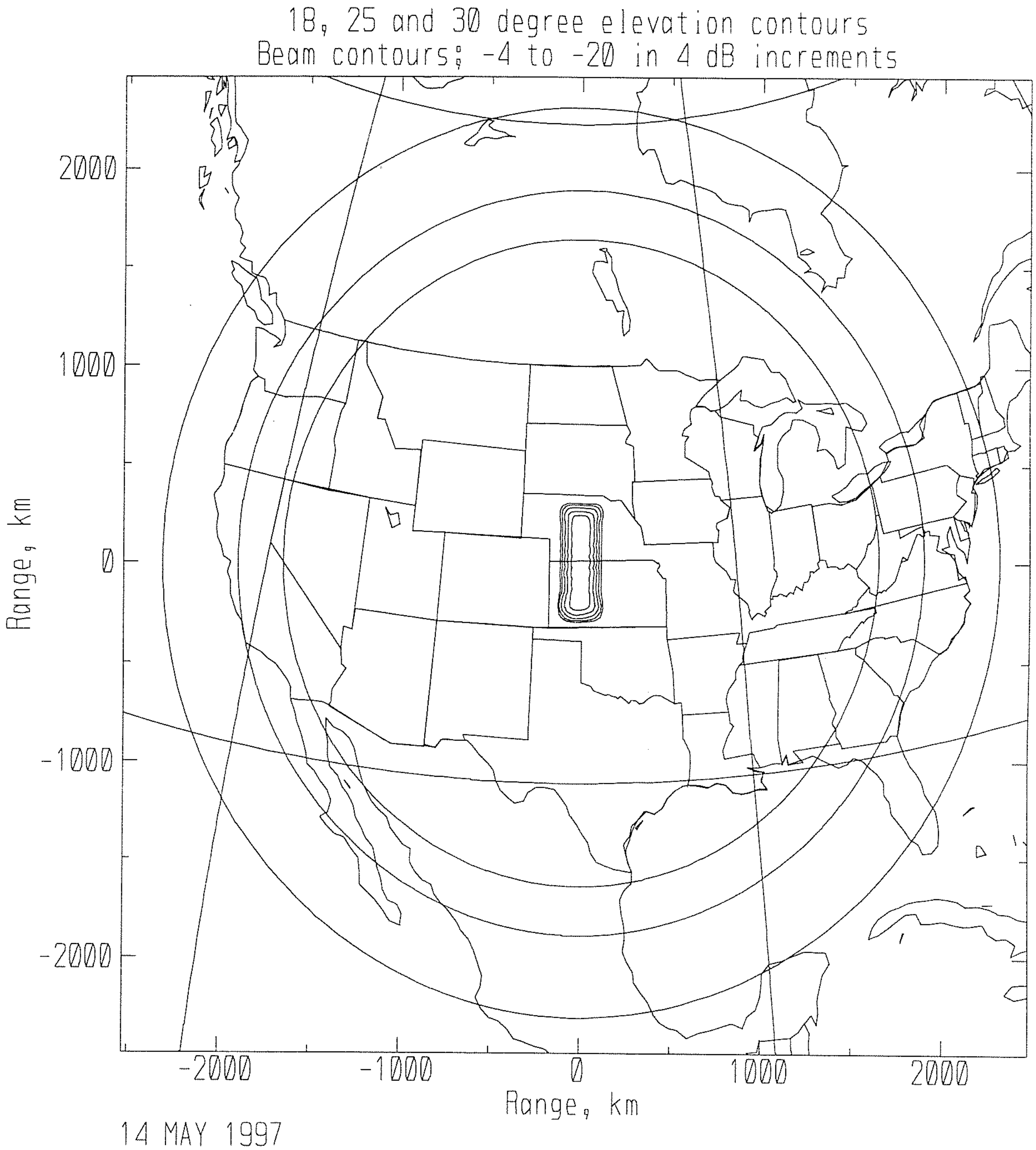

Figure IV-7: Satellite Footprint and Uplink Nadir Beam Plot

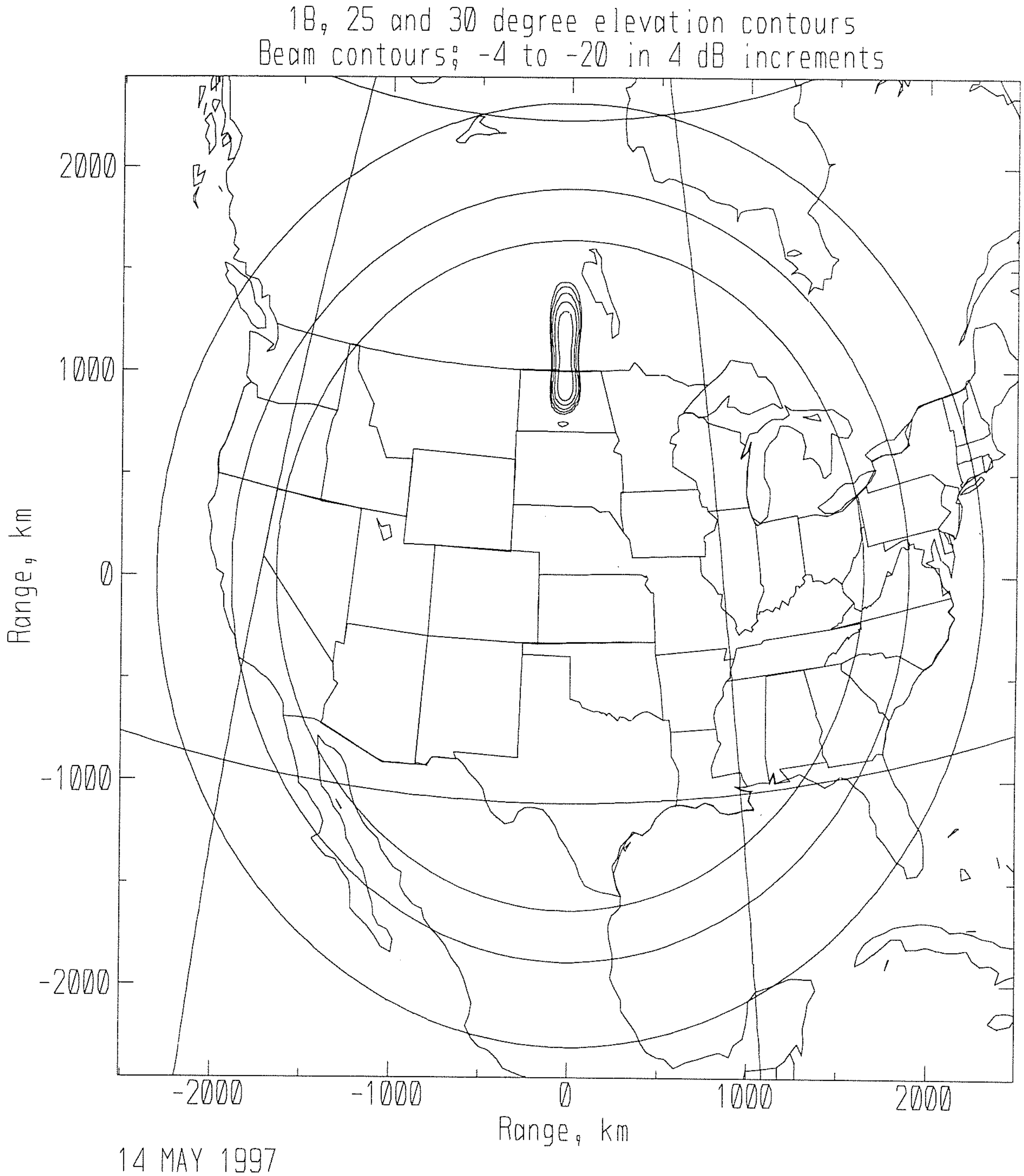

Figure IV-8: Satellite Footprint and Uplink Mid-Footprint Beam Plot

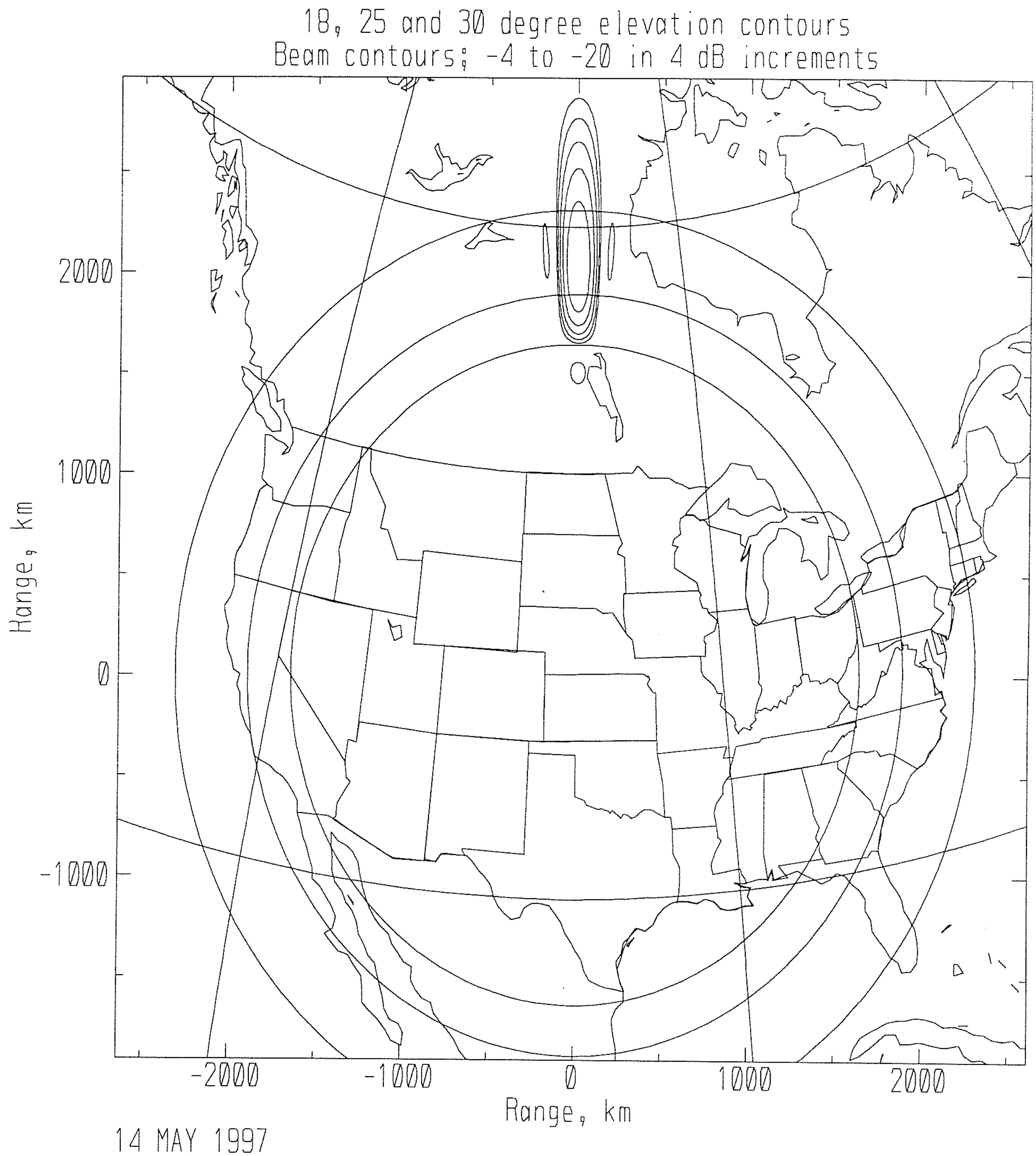

Figure IV-9: Satellite Footprint and Uplink Edge-of-Footprint Beam Plot

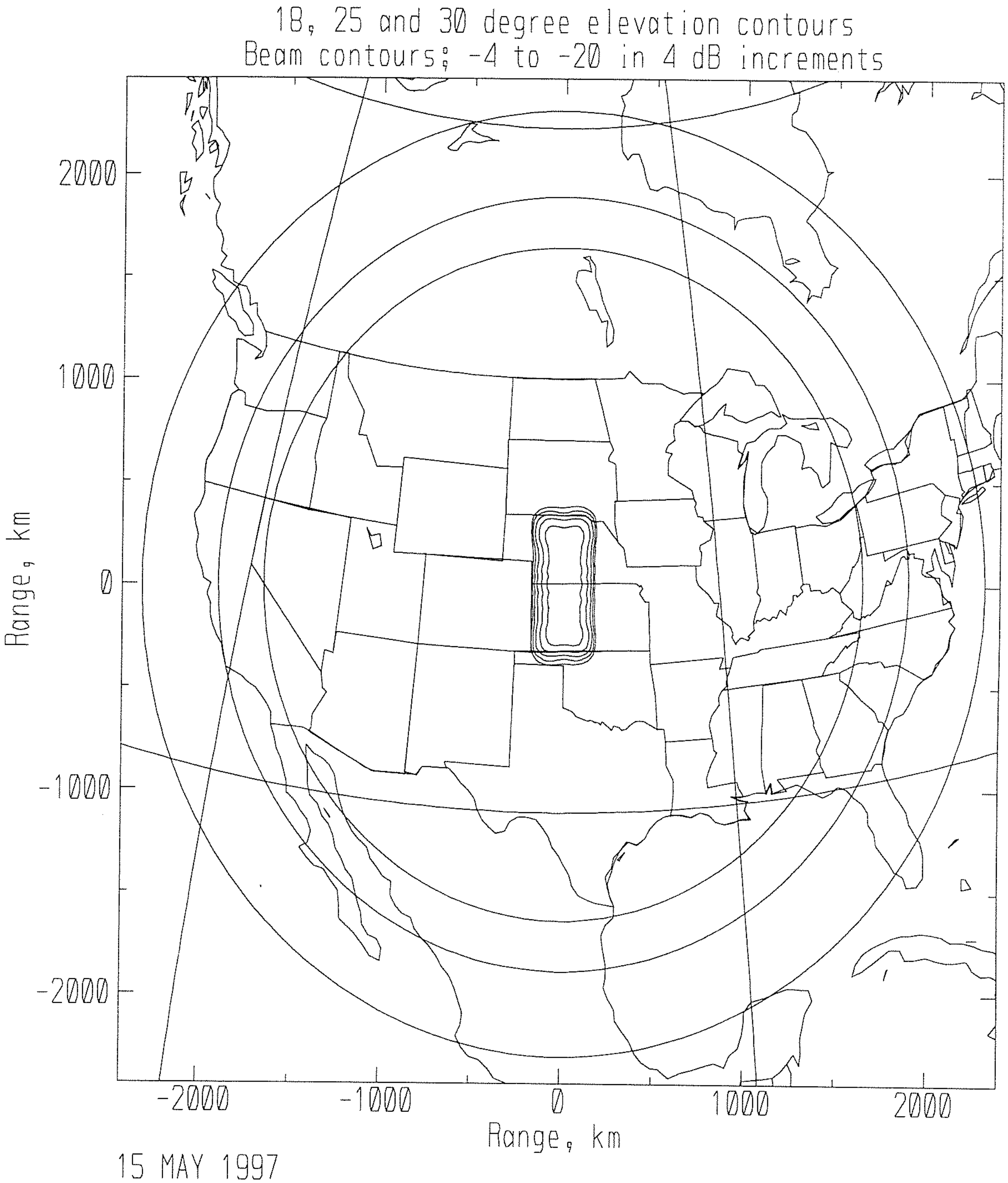

Figure IV-10: Satellite Footprint and Downlink Nadir Beam Plot

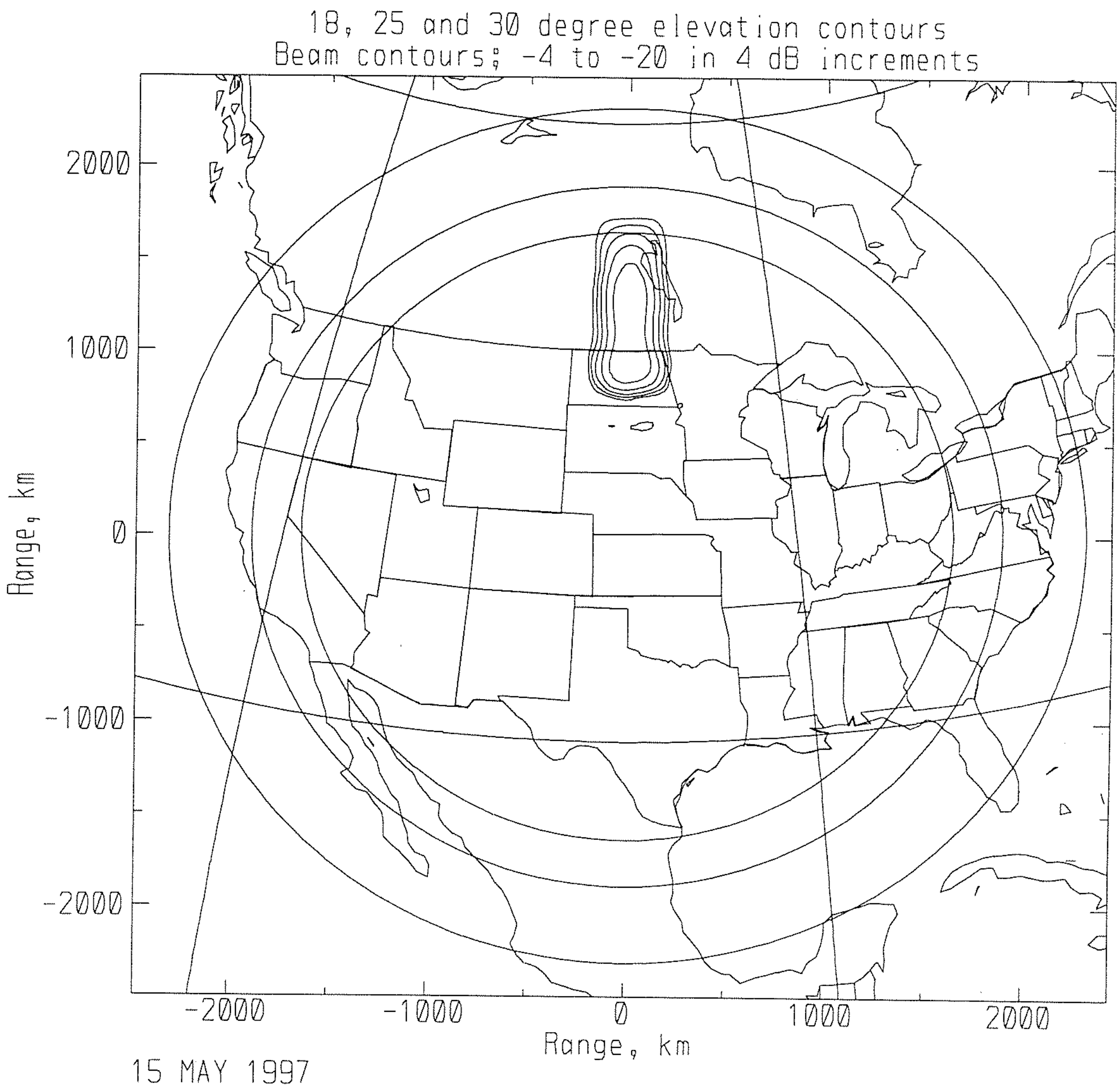

Figure IV-11. Satellite Footprint and Downlink Mid-Footprint Beam Plot

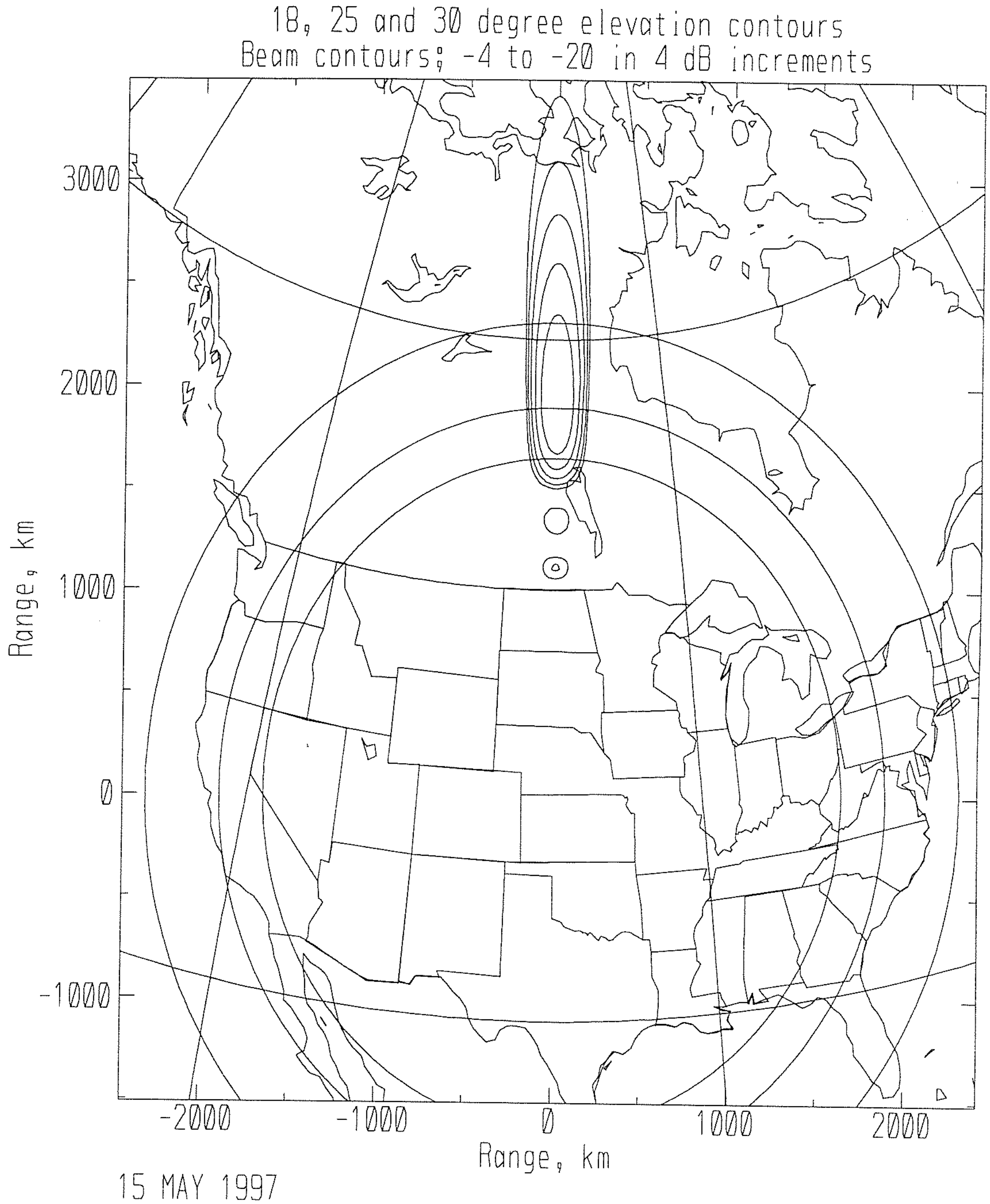

Figure IV-12: Satellite Footprint and Downlink Edge-of-Footprint Beam Plot

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.

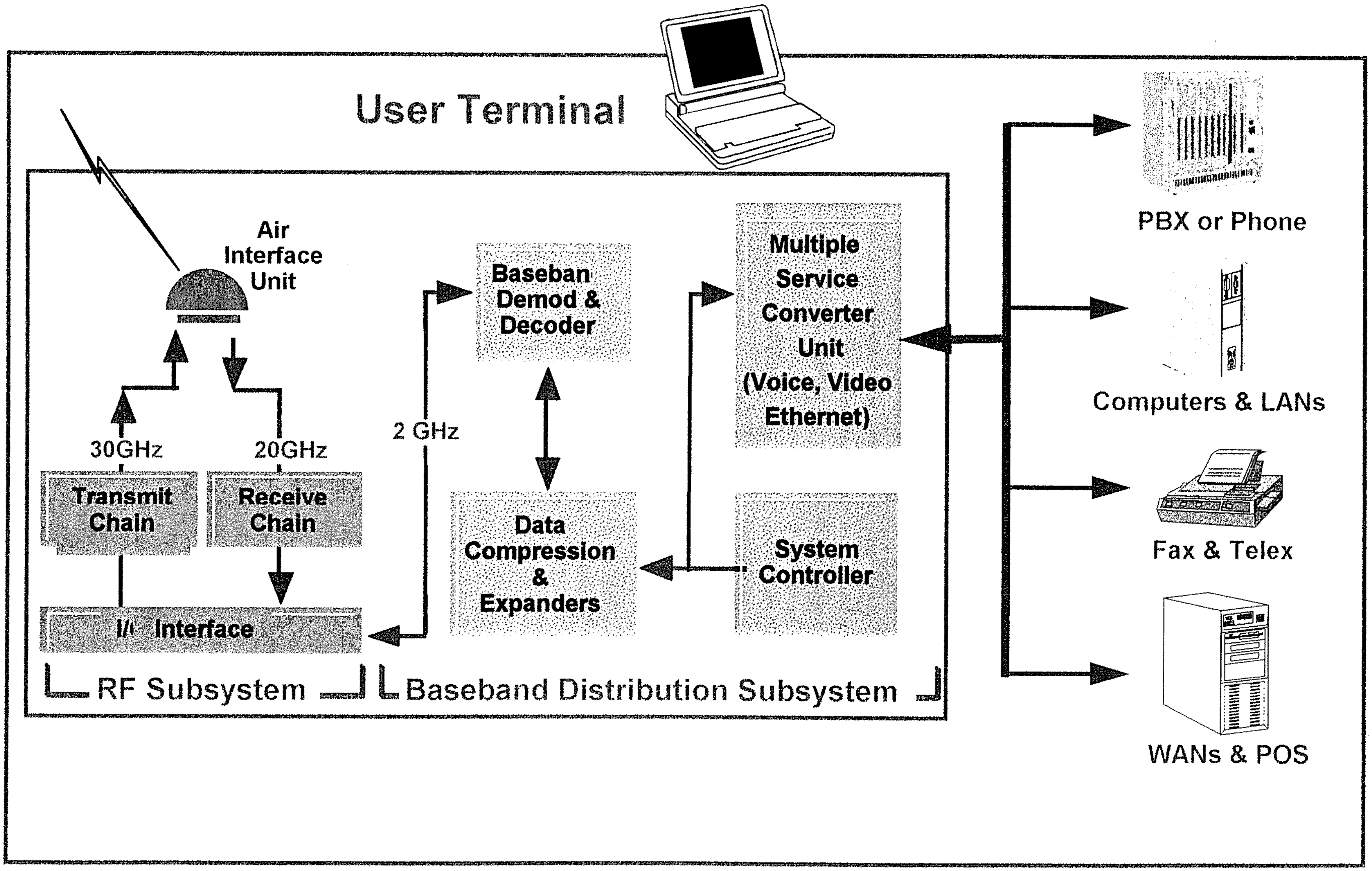

Figure IV - 13: Small Business Terminal Architecture

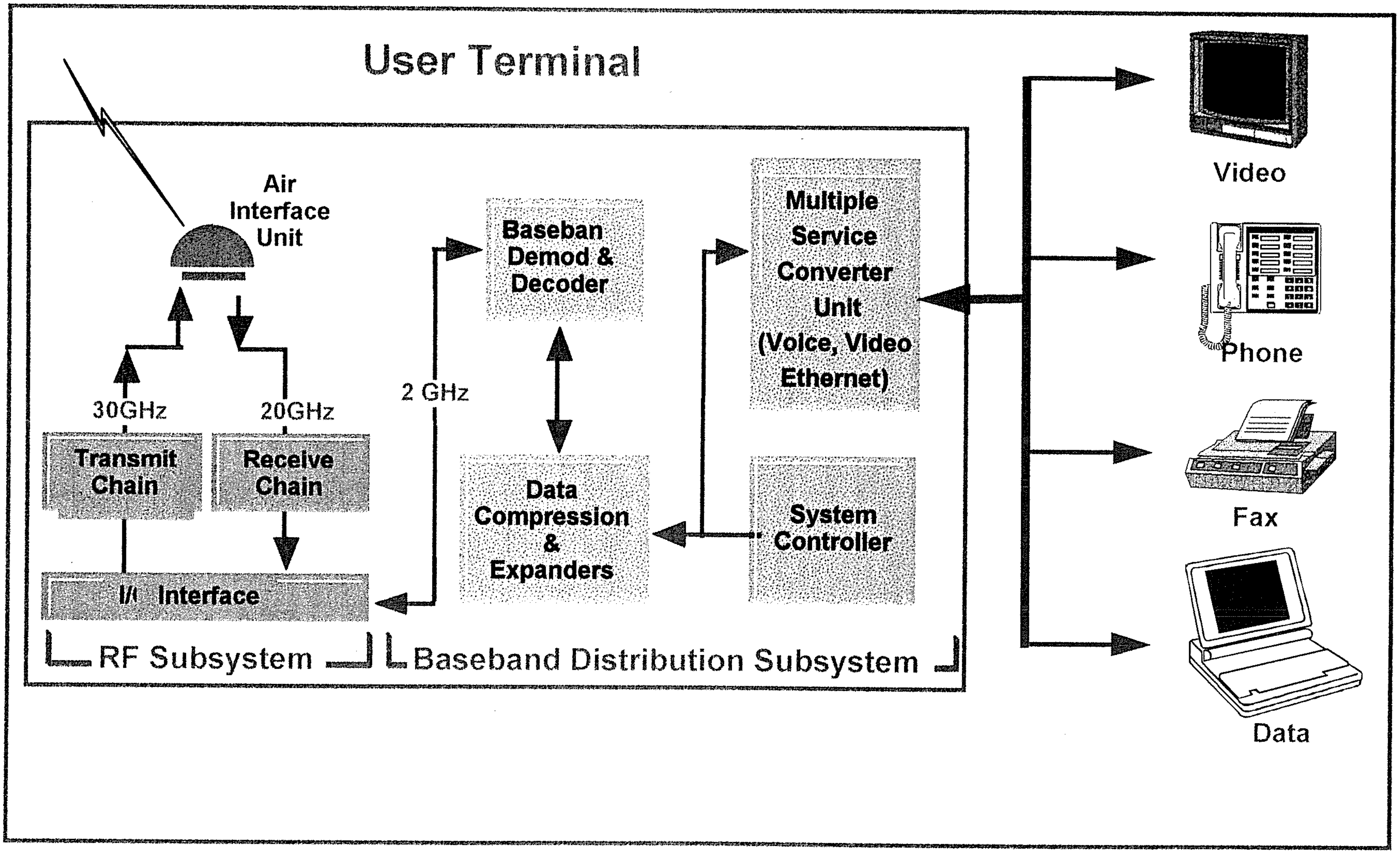

Figure IV-14: DTH Terminal Architecture

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.

V. INTERFERENCE AND SHARING ANALYSIS

Set forth below, and in Appendix B, are the interference and sharing considerations under current ITU and U.S. allocations in the 18.8-19.3 GHz, 19.7-20.2 GHz, 28.6-29.1 GHz, and 29.5-30.0 GHz bands (Ka-band) that apply to the proposed Celestri LEO System.

A. ITU And U.S. Allocations

1. ITU Ka-Band Allocations

In Tables V-1 and V-2, the shaded areas denote the ITU frequency allocations associated with various types of service.

Table V-1: ITU 18 GHz Band Allocation

Service Type	17.7 - 17.8	17.8 - 18.1	18.1 - 18.6	18.6 - 18.8	18.8 - 18.9	18.9 - 19.3	19.3 - 19.7	19.7 - 20.1	20.1 - 20.2
FSS									
Res. 46 for FSS*					To be considered at WRC-97	May be re-considered at WRC-97			
MSS								Region 2 primary	
BSS	Region 2 only								
Fixed Service									
Mobile Service	Region 2 secondary			Except aero					
Earth Exploration Satellite (passive)				Region 2 primary					
Space Research (passive)				Region 2 primary					

Primary Allocation: [shaded] **Secondary Allocation:** [shaded]

* Resolution 46 (WRC-95) allows non-geostationary FSS to be co-primary with geostationary FSS. The ITU has made Radio Regulation 2613 inapplicable where Resolution 46 is applicable

Table V-2: ITU 28 GHz Band Allocation

Service Type	27.5 - 28.5	28.5 - 28.6	28.6 - 28.7	28.7 - 29.1	29.1 - 29.4	29.4 - 29.5	29.5 - 29.9	29.9 - 30.0
FSS								
Res. 46 for FSS			To be considered at WRC-97	May be re-considered at WRC-97				
MSS							Region 2 primary	
Fixed Service								
Mobile Service								
Earth Exploration Satellite								

Primary Allocation: **Secondary Allocation:**

2. U.S. Ka-Band Plan

The U.S. Ka-band designations for the spectrum are set forth in Tables V-3 and V-4, below.[1]

Table V-3: U.S. 18 GHz Band Plan

Service Type	17.7 - 18.8	18.8 - 19.3	19.3 - 19.7	19.7 - 20.2
NGSO/FSS				
GSO/FSS				
Fixed Service				
MSS Feeder Links				

Primary Allocation: **Secondary Allocation:**

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1 See Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services, FCC 96-311, CC Dkt. No. 92-257 (July 22, 1996) (First Report and Fourth Notice of Proposed Rulemaking).

Table V-4: U.S. 28 GHz Band Plan

Service Type	27.5 - 28.35	28.35 - 28.6	28.6 - 29.1	29.1 - 29.25	29.25 - 29.5	29.5 - 30.0
NGSO/FSS	Secondary	Secondary	Primary			Secondary
GSO/FSS	Secondary	Primary	Secondary		Primary	Primary
LMDS	Primary			Primary		
MSS Feeder Links				Primary	Primary	

Primary Allocation: [dark shading] **Secondary Allocation:** [light shading]

B. Celestri LEO System Band Plan

The Celestri LEO System will operate as a global, NGSO system in the Fixed-Satellite Service (NGSO/FSS). The space-to-Earth service links will operate in the 18.8-19.3 GHz and 19.7-20.2 GHz bands and the Earth-to-space service links will operate in the 28.6-29.1 GHz and 29.5-30.0 GHz bands.

C. Interference and Sharing Analysis

The analysis shown in Appendix B addresses the potential for harmful interference between the Celestri LEO System and other systems and services. The analysis shows that the Celestri LEO System can share the same bands on a co-frequency, co-coverage basis with other primary and secondary systems and services. It further shows that it is possible for multiple NGSO/FSS systems to share the same service link bands.

1. Interference and Sharing with Other NGSO Systems

Mutual harmful interference between NGSO systems using overlapping spectrum is avoidable with the use of joint mitigation techniques. The frequency of occurrence and duration of interference events between NGSO systems sharing the same spectrum are a function of the technical parameters of the systems. One approach for mitigating interference events is satellite diversity, which relies on the availability of alternative satellites to provide a particular radio link. Because the Celestri LEO System constellation has been designed so that multiple satellites are in view at any specified Earth location a large percentage of the time, space diversity can be used to share spectrum with other NGSO systems.

A sharing analysis has been completed that evaluates the potential for sharing between the direct-to-home terminals of the Celestri LEO System and the standard terminals of the recently licensed Teledesic NGSO system[2] when satellite diversity is employed. This analysis is included in Appendix B. It shows that the two systems can share the available spectrum by employing satellite diversity mitigation techniques. The Celestri LEO System constellation has been designed to provide double coverage 90% of the time for Earth Latitudes below 60° and more than 99% of the time for Latitudes between 18° and 48°. Thus, by using space diversity, an earth terminal can be assigned to another serving satellite to assure virtually seamless service.

Space diversity incurs a cost in terms of increased system complexity and reduction in system throughput. If both NGSO systems incorporate mitigation techniques such as power control, space diversity and sidelobe control, co-frequency sharing becomes much easier to accomplish.

The potential for sharing with a third NGSO system is a greater challenge because the space capacity available to mitigate interference may be completely allocated for sharing with the other NGSO system. If other NGSO systems were to include provisions for sharing in the design of their systems, however, more than two NSGO systems could use the same spectrum.

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[2] See Teledesic Order, 12 FCC Rcd. 3154 (1997)

While sharing the NGSO portions of the Ka-band can be achieved technically, the operators of the Teledesic network and Celestri LEO System will have to cooperate in the development and implementation of the necessary mitigation techniques if sharing is to work. This will require a joint commitment to make the necessary system changes and to coordinate operational parameters in an equitable fashion.[3]

2. Interference and Sharing with GSO Systems

Recently, the Commission authorized 73 GSO satellites in the 20/30 GHz band, with spacing of 2° or more in the orbital arc ranging from 147° West Longitude to 175.25° East Longitude.[4] In the U.S., these GSO systems are secondary to NGSO systems in the 18.8-19.3 GHz and 28.6-29.1 GHz bands; however, NGSO systems are secondary to GSO systems in the 19.7-20.2 GHz and 29.5-30.0 GHz bands. In the rest of the world, the GSO and NGSO systems are co-primary in these bands.

Mutual interference between NGSO and GSO systems is considered unavoidable if mitigation techniques are not applied. Satellite diversity is even more effective for NGSO-GSO sharing because the portion of the sky where mitigation is required is always fixed relative to any given earth station. There simply are fewer "moving targets" to include in the joint integration implementation. However, satellite diversity as a solution will be limited to the extent that sharing with other NGSO systems is required. Appendix B sets forth this sharing analysis.

The World Radio Conference (WRC-97) Preparatory Meeting (CPM-97) Report identifies interference mitigation techniques to improve sharing

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3 See Teledesic Order, at paras. 28-29.

4 See Assignment of Orbital Locations to Space Stations in the Ka-Band, DA 97-967 (Int'l Bureau, May 9, 1997).

possibilities between GSO FSS and NGSO FSS networks.[5] The following techniques which may reduce the interference between networks operating in the Ka-band are proposed:

1. Satellite diversity;
2. Restricted operational elevation angles;
3. High gain antennas;
4. Adaptive power control;
5. Signal design and network traffic management;
6. GSO arc avoidance;
7. Optimization of the constellation;
8. Satellite footprint shift;
9. Geographical isolation of earth stations;
10. Site diversity;
11. Exclusion zone;
12. Hybrid systems;
13. Residual interference limitation.

The Celestri LEO System will employ mitigation techniques 1 through 7 to enable sharing with GSO/FSS systems.

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[5] CPM Report at Section 4.4.1.1.3.

3. Interference and Sharing with Fixed Services

a. Celestri LEO System Downlink Frequency Band

The Celestri LEO System service downlinks are not expected to cause harmful interference into the Fixed Service ("FS") since they will meet the power flux density limits of Section 25.208(c) of the Commission's Rules and ITU RR S21.16 (Article S21). See Tables IV-4 and IV-5 and Appendices A and B.

The Celestri LEO System earth stations may experience interference from FS in the bands. The only band where this is applicable is 18.8-19.3 GHz in both the U.S. and other parts of the world. In the case where terrestrial microwave stations are located near the low data rate CPE terminals for the Celestri Architecture (e.g., direct-to-home and small business terminals), it may not be practical to coordinate with the FS stations. In this case, interference will be mitigated from the FS stations into the Celestri LEO System low data rate terminals through the use of shielding and other techniques. It is expected that the larger, higher-data-rate terminals in the Celestri LEO System will be coordinated using rules similar to those commonly employed in other co-primary FS and FSS bands.

b. Celestri LEO System Uplink Frequency Band

In the U.S., there are no FS allocations in the Celestri LEO System uplink bands. In other parts of the world where FS is allocated in the uplink bands, interference will be mitigated through coordination, if required. Most likely, such coordination will not be required since the Celestri LEO System will operate at a minimum elevation angle of 16 degrees and will meet the EIRP limits on the horizon. Moreover, the geographic area requiring actual mitigation for each FS installation will be much smaller than the minimum coordination area prescribed in ITU-R Document Rec. IS.847-1.

4. Interference with Mobile Satellite Services and Mobile Services

Due to the ubiquitous nature and mobility of Mobile Service and MSS terminals, it is not expected that sharing is possible with NGSO/FSS systems.

VI. ADVANCE PUBLICATION AND ITU COORDINATION

Motorola is submitting in Appendix C all of the information required to advance publish the Celestri LEO System with the ITU. Motorola respectfully requests that the Commission forward this information to the ITU for publication, subject to any applicable constraints on the timing of such submissions regarding a portion of the spectrum requested for the system. See WRC-95, Resolution PLEN-1.

VII. COMPLIANCE WITH INTELSAT ARTICLE XIV OBLIGATIONS

Motorola recognizes that Article XIV(d) of the INTELSAT Agreement imposes certain consultation requirements on the United States.[6] To the extent this provision is applicable to the Celestri LEO System, Motorola understands that the requested license could be conditioned on the completion of any necessary consultations.

With respect to the economic component of Article XIV(d) consultations, the INTELSAT Assembly of Parties has now determined that a separate satellite system is presumed not to cause economic harm to INTELSAT, regardless of the

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[6] Agreement Relating to the International Telecommunications Satellite Organization, Aug. 20, 1971, Art. XIV(d), 23 U.S.T. 3813, T.I.A.S. No. 7532, 10 I.L.M. 909 (1971).

number of circuits provided by such a system.[7] With respect to the technical component of Article XIV(d) consultations, Motorola assures the Commission that it will provide all information necessary when the consultation process is initiated.

VIII. LEGAL QUALIFICATIONS

Motorola is legally qualified to hold the requested license for the Celestri LEO System. The Commission recently passed upon the qualifications of Motorola, Inc. when it awarded Motorola Satellite Communications, Inc., also a wholly-owned subsidiary of Motorola, Inc., a license to construct, launch and operate the IRIDIUM® System.[8] Appendix E hereto contains an up-to-date FCC Form 430 reflecting all of the information required to find Motorola legally qualified to hold the requested license.

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[7] Report of the Twenty-First Session of the INTELSAT Assembly of Parties, INTELSAT Doc. AP-21-3E FINAL PV/4/97, at 4-5.

[8] Motorola Satellite Communications, Inc., Order and Authorization, 10 FCC Rcd. 2268 (1995), recon. denied FCC 96-279 (1996). See also Application of Comm, Inc. to Construct, Launch, and Operate a Ka-Band Satellite System in the Fixed-Satellite Service, Order and Authorization, DA 97-968 (Int'l. Bureau, May 9, 1997).

IX. FINANCIAL QUALIFICATIONS

A. Milestone Schedule

1. Contract Milestones

Table IX-1 sets forth the Celestri Multimedia LEO System contractual milestones:

Table IX-1: Contract Milestones

Contractual Milestones	Year After Authorization
Spacecraft RFP issued	N/A
Spacecraft contractor selected	N/A
Spacecraft contract executed	1
Launch services contract executed	2
Financing completed	N/A

The financing for the Celestri Multimedia LEO System will be secured from a combination of internal Motorola funds and other potential external sources. As discussed in Section C, below, Motorola satisfies the financial qualification standards set forth in Part 25 of the Rules. See 47 C.F.R. § 25.140.

2. Spacecraft Milestones

Table IX-2 sets forth the Celestri LEO System spacecraft milestones:

Table IX-2: Spacecraft Milestones

Celestri LEO System Spacecraft Milestones	Months After Authorization
Satellite construction begins	6 Months
First satellite constructed	39 Months
First satellite launched	40 Months
Last satellite constructed	50 Months
Last satellite launched	51 Months
Full operational service	54 Months

B. Projected System Costs

The investment required for the Celestri Multimedia LEO System includes the cost to develop and construct satellites, the associated launch services and launch insurance costs, satellite system control costs, network management hardware costs, software development costs, and other pre-operating expenses. Motorola intends to sub-contract appropriate portions of the research and development effort as well as selected segments of the satellite constellation and ground infrastructure construction activities. In addition to the construction costs, the investment costs include the operating expenses through the first year of operations, commencing when the first satellites are launched. Operating costs include service delivery expenses, maintenance expenses, and finance, marketing and other various administrative expenses, but exclude depreciation. Annual operating costs are adjusted by an inflation factor.

The costs projected herein are based primarily on stand-alone development and deployment activities for the Celestri LEO System. In fact, however, Motorola expects the cost of the system to be substantially less than this stand-alone estimate: the joint development of the Celestri Multimedia LEO System described in this Application and Motorola's proposed GSO (Millennium) and LEO (M-Star) Systems will allow substantial synergies and cost savings. Indeed, the $12.9 billion cost estimate already includes the estimated cost of constructing and launching the first of the four satellites of the Millennium System.

End-user terminal equipment is not part of this filing and is not included in the total projected system cost. All necessary subscriber equipment will be purchased by end users.

Table IX-3 shows that the estimated construction and launch costs for the entire system, plus operating expenses (excluding depreciation) through Year 5 (the first year of operation for the system) amount to $12.9 billion.

Table IX-3: Projected System Cost ($ Millions)

	Pre-Auth	Year 1	Year 2	Year 3	Year 4	Year 5
Construction Launch and Launch Insurance Costs	30	960	2,750	4,300	4,300	300
Operations and Maintenance	0	5	5	10	50	190
Annual Totals	30	965	2,755	4,310	4,350	490
Cumulative Total	30	995	3,750	8,060	12,410	**12,900**

C. Projected Revenues

Motorola's estimate of the revenue stream from the Celestri LEO System is illustrated in Table IX-4.

Table IX-4: Projected Revenues ($ Millions)

	Years after Full Operation							
	1-4	5	6	7	8	9	10	Total Revenues
Revenues	0	5,300	13,000	17,900	17,900	17,900	17,900	89,900

The consolidated revenue projections for the Celestri LEO System are sufficient to recover all of the estimated operating expenses over the life of this project. Moreover, these projections represent a rate of return that sufficiently compensates Motorola for the risk associated with this proposed telecommunications venture.

D. Financial Qualifications

Motorola, a wholly-owned subsidiary of Motorola, Inc., has the current financial ability to meet the estimated costs of construction and launch of the proposed system, as well as the estimated expense of operating the entire system for one year after launch. The 1996 audited Consolidated Balance Sheet and Statement of Consolidated Earnings of Motorola, Inc., the applicant's sole corporate parent, are set forth in Appendix D. A declaration signed by Mr. Bary Bertiger, Corporate Vice President of Motorola, Inc., verifies the financial information set forth in the consolidated financial statements. These statements show that Motorola's current assets as of December 31, 1996 amounted to $11,319 billion and its earnings before income taxes for 1996 were $1.775 billion -- a total of $13.094 billion in current assets and operating income -- and thus exceed the $12.9 billion estimated costs of construction, launch, and first-year operating expenses for the entire system.

X. TECHNICAL QUALIFICATIONS

A. System Coverage

The Celestri LEO System is designed to provide high capacity data services between 60° South and 60° North Latitude at elevation angles above 16°. Service can be extended to 70° North and South Latitude by mitigating the effects of low elevation angles. For Latitudes between 18° and 48°, which includes all of the continental U.S. and most of the population centers of Europe and Asia, coverage of all locations by at least two satellites is provided 99% of the time. Three satellites are in view of subscribers within these latitudes more than half of the time.

B. Service in the United States

The Celestri LEO System is designed to provide continuous service to all 50 States of the United States, Puerto Rico, and the U.S. Virgin Islands. Users above 60° North Latitude will require larger antennas to mitigate the effects of low elevation angles.

C. Bandwidth Utilization

The Celestri LEO System satisfies the intent of Section 25.210 of the Commission's Rules by fully utilizing its requested bandwidth and operating in a manner that maximizes spectrum efficiency. Phased array antennas aboard each satellite are used to project relatively narrow beam patterns, which create small cells on the Earth's surface. This design permits efficient reuse of the spectrum, as indicated by a capacity density nearly 9 times greater than proposed GSO Ka-band systems in areas of high demand. Indeed, the same frequency bands can be simultaneously reused in approximately 680 locations over the land areas of the system's global coverage. The spectrum in each reuse area can be allocated to provide high peak capacity where and when needed.

XI. REQUEST FOR WAIVER OF THE COMMISSION'S RULES

Motorola requests that the Commission grant a limited waiver of Section 25.210 of the Commission's Rules. See 47 C.F.R. § 25.210. The Celestri LEO System satisfies the intent of Section 25.210 by using the required bandwidth in the uplink and downlink bands in a manner that maximizes system capacity. The LEO design is inherently incapable of satisfying the explicit requirements of Section 25.210, which was intended to apply to geostationary orbit satellites. Pending a modification of this Rule to meet the design needs of LEO systems, Motorola requests a waiver of Section 25.210 to the extent necessary.

XII. WAIVER PURSUANT TO SECTION 304 OF THE ACT

In accordance with Section 304 of the Communications Act of 1934, as amended, 47 U.S.C. § 304, Motorola hereby waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

ANTI-DRUG ABUSE ACT CERTIFICATION

Pursuant to Section 1.2002 of the Commission's rules, 47 C.F.R. Section 1.2002, Motorola Global Communications, Inc. certifies that neither the Applicant nor any of its shareholders, nor any of its officers or directors, nor any party to this application is subject to a denial of Federal benefits pursuant to authority granted in Section 5301 of the Anti-Drug Abuse Act of 1988.

Motorola Global Communications, Inc.

By: [signature]
Bary R. Bertiger, President

Dated: June 12, 1997

CONCLUSION

For the reasons set forth in this Application, Motorola Global Communications, Inc. requests that the Commission promptly issue it a license to construct, launch and operate the proposed system, allowing Motorola Global Communications, Inc. to deliver to the public the enormous benefits detailed above at the earliest possible time.

The undersigned certifies individually and for Motorola Global Communications, Inc. that all of the statements made in this Application are true, complete and accurate to the best of his information, belief and knowledge, and are made in good faith.

Respectfully submitted,
Motorola Global Communications, Inc.

By: Bary Bertiger
Bary R. Bertiger, President

Dated: June 12, 1997

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this Application, that I am familiar with Part 25 of the Commission's Rules, that I have either prepared or reviewed the engineering information submitted in this application, and that it is complete and accurate to the best of my knowledge and belief.

By: [signature]
Charlie Bucher
Director, Spectrum And Standards
Advanced Systems Division
Space and Systems Technology Group
Motorola, Inc.

Dated: June 12, 1997

DECLARATION OF BARY R. BERTIGER

I, Bary R. Bertiger, hereby declare under penalty of perjury that:

1. I am Corporate Vice President of Motorola, Inc.

2. The foregoing is a true and correct copy of the consolidated financial statements of Motorola, Inc. (the sole parent company of Motorola Global Communications, Inc.) for the year ending December 31, 1996, including the report of KPMG Peat Marwick, the company's independent certified public accountants, as published in the 1996 Annual Report of Motorola, Inc.

Bary R Bertiger

Bary R. Bertiger
President
Motorola, Inc.

Executed on June 12, 1997