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SPACEWAY™

Providing Affordable

and

Versatile Communication

Solutions

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For further information, please contact
E. J. Fitzpatrick, Vice President,
Hughes Communications, Inc.
Los Angeles, CA 90009
(310) 364-4840

ABSTRACT

By the end of this decade, Hughes' SPACEWAY™ network will provide the first interactive "bandwidth on demand" communication services for a variety of applications. High quality digital voice, interactive video, global access to multimedia databases, and transborder workgroup computing will make SPACEWAY™ an essential component of the computer-based workplace of the 21st century. With relatively few satellites to construct, insure, and launch -- plus extensive use of cost-effective, tightly focused spot beams on the world's most populated areas -- the high capacity SPACEWAY™ system can pass its significant cost savings onto its customers. The SPACEWAY™ network is different from other proposed global networks in that its geostationary orbit location makes it a truly market driven system: each satellite will make available extensive telecom services to hundreds of millions of people within the continuous view of that satellite, providing immediate capacity within a specific region of the world.

Introduction

This paper presents a summary description of SPACEWAY™, a global network of Ka band satellites being developed by Hughes Communications, Inc., to provide worldwide telecommunication services. The SPACEWAY™ network will utilize state-of-the-art technology to introduce a broad range of innovative and affordable satellite services on a global basis to consumer and commercial end-users. The outline of principal topics addressed in this paper is as follows:

1. System concept
2. Space segment characteristics
3. Ground segment characteristics
4. Link performance objectives and power budgets

1. System Concept

The SPACEWAY™ system[1] is a network of regional systems that will utilize satellites in the geostationary satellite orbit (GSO) to provide cost-effective, two-way voice, medium- and high-speed data, image, video and video telephony communications service to both business and individual users. Direct access to the satellites will be available on demand throughout the world via inexpensive ultra small aperture terminals (USATs). SPACEWAY™ is a high capacity, high quality, yet very versatile system. Figure 1 provides a summary of the performance available with each satellite. A two satellite regional configuration would therefore enable over 230,000 simultaneous telephone calls at 16 Kbps. The all digital 16 Kbps circuits utilized for telephony will ensure consistent high quality voice channels.

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[1] Application filed by Hughes Communications Galaxy, Inc. with the Federal Communications Commission on 26 July 1994.

The high capacity of each SPACEWAY™ satellite is focused through the spot beams on the populated areas of the world thereby creating a significant cost advantage in the delivery of its telecom services. The flexibility of applications available through SPACEWAY™ is achieved through its broad range of data rates and is illustrated in Figure 1A.

The SPACEWAY™ network is different from other proposed global networks in that its geostationary orbit location makes it a truly market driven system: each satellite will make available extensive telecom services to hundreds of millions of people within the continuous view of that satellite, providing immediate capacity within a specific region of the world. SPACEWAY™ will be implemented in a phased, regional approach beginning in 1998, expanding into a network of four interconnected regional systems: (i) North America, (ii) Asia Pacific (iii) Central/South America, and (iv) Europe/Africa. The SPACEWAY™ network will provide in each of these regions the same low-cost, ubiquitous communications services at data rates up to multiple megabits per second, while also providing worldwide connectivity.

In developing countries, SPACEWAY™ will offer essential domestic and international telephone and facsimile services that will be seamlessly integrated into the public switched telephone network ("PSTN"). SPACEWAY™ will offer high bandwidth services for a variety of consumer and business applications, both for countries with existing telecom infrastructures and those with emerging needs for advanced services.

Figure 2 depicts the phased regional implementation of the SPACEWAY™ network. The first satellites in the SPACEWAY™ network will be operational in 1998. Each regional system will include two satellites. Our system plan accommodates the growth for up to four satellites per region. For these reasons, Hughes believes that the SPACEWAY™ network will become an essential element in the establishment of the Global Information Infrastructure (GII) by the turn of the century.

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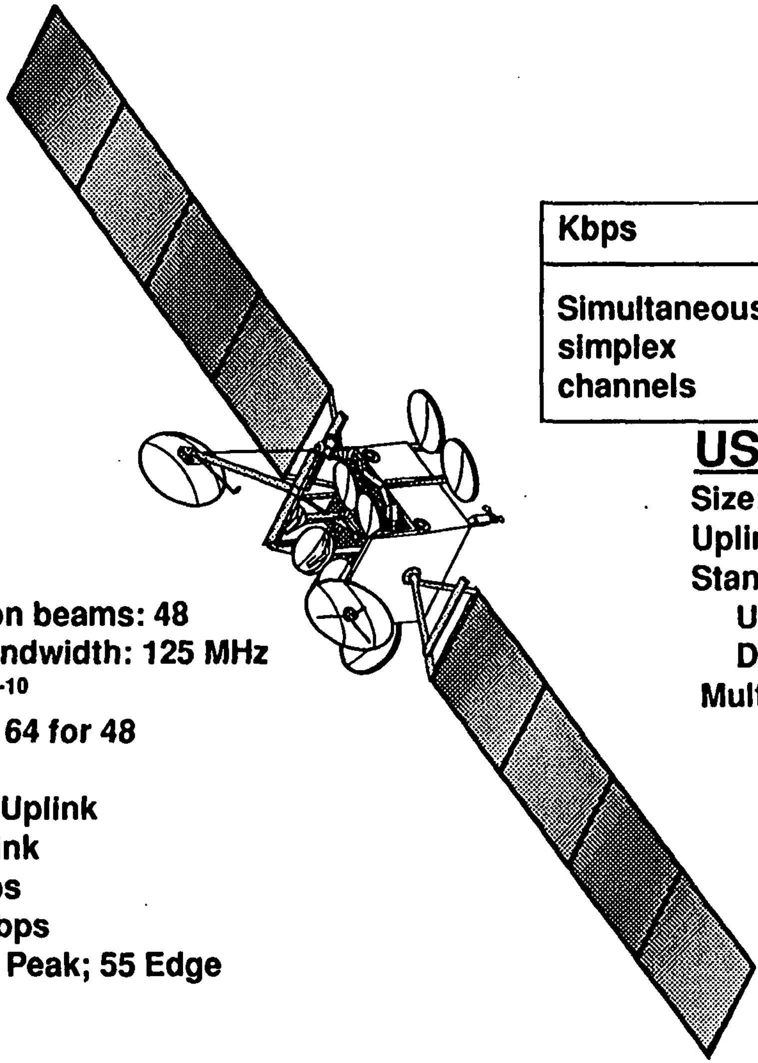
Satellite

Type: HS601
Lifetime: 15 yrs
Dry weight: 3,785 lbs
Eclipse capacity: 100%
Bandwidth: 500 MHz
Number of communication beams: 48
Communication beam bandwidth: 125 MHz
BER performance: 1×10^{-10}
Transmitter redundancy: 64 for 48
Modulation: QPSK
Data stream: FDM/TDMA Uplink
TDM Downlink
Data throughput: 4.6 Gbps
Downlink data rate: 92 Mbps
Downlink EIRP: 60 (dBw) Peak; 55 Edge



Capacity per satellite

Kbps	16	128	384	1,544	2,048
Simultaneous simplex channels	230,400	34,560	11,520	2,880	2,304

USAT

Size: 66 cm to 2 m
Uplink power: 0.1W to 2W
Standard Terminal:
Uplink data rates: 16 kbkps to 1.544 Mbps
Downlink data rates: 16 kbps to 92 Mbps
Multi Mbps with optional terminal

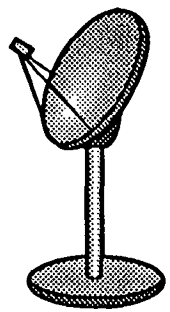


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Fig. 1A. Performance summary.

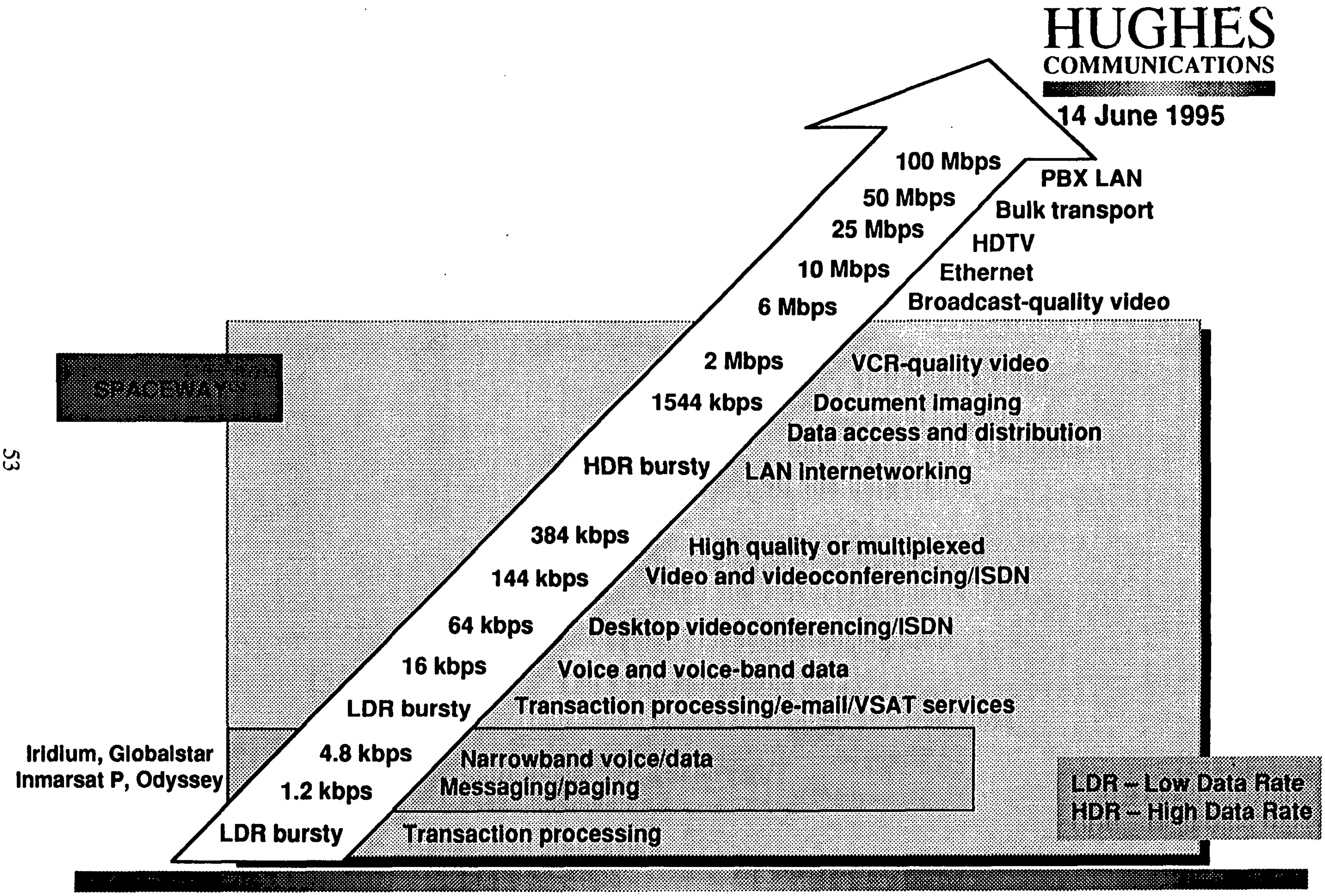

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Fig. 1B. Range of applications.

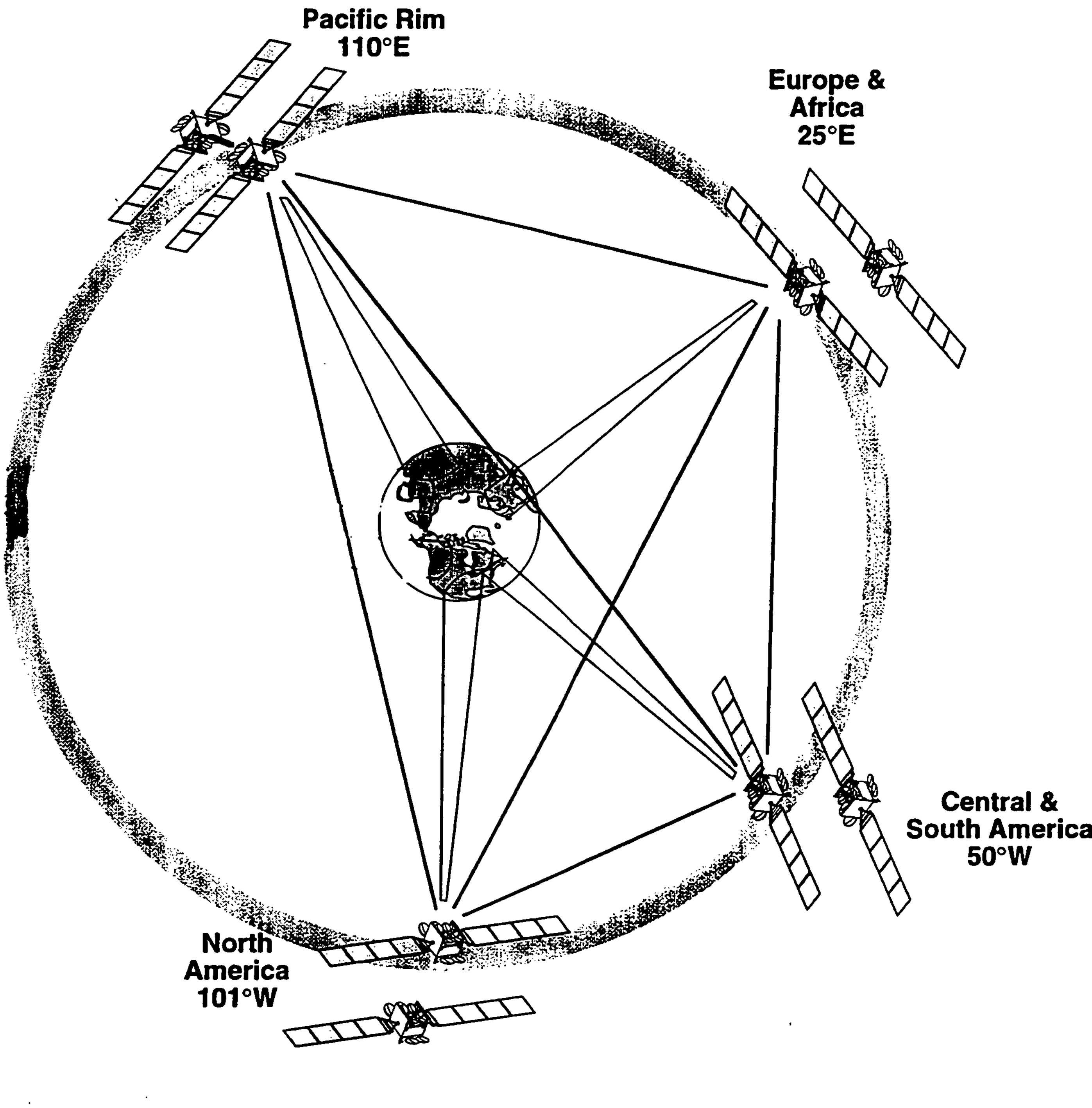


Fig. 2. Spaceway Global Network, Phase 1 (initial operating capability by 2000), showing orbital locations.

This innovative all-digital network will utilize state-of-the-art advances in satellite technology to provide full duplex interactive communications throughout the world. Its features include on-board signal processing, on-board switching, small, easily installed ground terminals, and digital transmissions at a variety of data rates.

A key component of the system architecture is the Ka-band spot beam network. This technology will allow the use of extremely small end user terminals (approximately 66 cm) and provide a high degree of spectrum efficiency. Each spot beam nominally will use 125 MHz of bandwidth. Narrow spot beams (about 1°) with a footprint approximately 650 km. in diameter will cover most of the populated world land mass. The satellite design will permit reuse of frequencies up to twelve times. Thus, the 500 MHz of spectrum utilized by each satellite will result in an effective 6 GHz of useful bandwidth per satellite.

The system allows symmetric and asymmetric data communications at transmission rates from 16 Kbps to 384 kbps, depending upon user requirements with the standard 66 cm terminal. Multi megabit per second applications can be accommodated with the SPACEWAY™ optional broadband terminal.

Each satellite will utilize a state-of-the-art on board switch/processor to provide individual end users with immediate access to the space segment, and to route transmissions within and between appropriate destination spot beams. This "on demand" satellite service will be competitively priced with many basic terrestrial telephone services especially in remote and underserved areas, where basic telephone services are neither economically feasible nor available. In addition, the use of off-the-shelf digital video compression equipment or optional codecs built into the earth terminals will allow end users to utilize a high quality, two-way interactive video telephony service. Availability of such teleconferencing facilities at low cost should help underserved countries improve the delivery of vital services such as health care and education.

SPACEWAY™ will offer a dramatic advancement in the functionality and affordability of business networks relative to today's VSAT capability. For businesses, the SPACEWAY™ USAT both advances the state-of-the-art in VSAT networking, and brings satellite technology to the economic threshold of a greater universe of customers. SPACEWAY™ USATs offer complete mesh connectivity without the need for expensive hubs: in essence a "hubless" network. Thus, through low cost USATs, smaller businesses -- for whom today's VSATs are unaffordable - can take advantage of satellite networking without requiring a large number of sites to amortize hub costs.

SPACEWAY™ will accommodate most conventional VSAT applications, including retail point-of-sale transaction processing, on-line reservations and inventory/pricing information updates. In addition, SPACEWAY™ will offer a variety of wideband services including video telephony and conferencing (allowing multiple meeting sites and interconnection with terrestrial videoconferencing equipment and services), telecommuting (home computer to office LAN connection), medical and technical tele-imaging, and CAD/CAM data and image transmission.

With its small size and low cost, the SPACEWAY™ USAT will make the benefits of satellite communications readily accessible to consumers. It is anticipated that consumers will use SPACEWAY™ for basic telephony and data communications, personal vidotelephony and high speed personal computer access to on-line services (such as Compuserve and Prodigy), as well as two-way interactive access to the wide array of multimedia information and entertainment services currently being developed for the "information superhighway" of tomorrow. The affordability of the SPACEWAY™ terminal will permit advanced telecommunications and media industries to reach an even wider audience.

The SPACEWAY™ network represents a giant stride forward for the transmission of data. The incorporation of on-board satellite switching/processing, multi-spot beam coverage, and advanced ground terminal semiconductor technology, will allow small, inexpensive end user terminals, immediate and on-demand access to space segment and very fast data transmission. For many applications, such as sending medical images (x-rays) to and from remote clinics, short transmission time is critical. The SPACEWAY™ network can dramatically reduce the retransmission time of important data by providing transmission at rates more than 150 times faster than conventional telephone lines. The following chart displays this relationship between time, information content and bandwidth.

IMAGE	INFORMATION CONTENT	ORDINARY PHONE LINE	SPACEWAY™ 384 Kbps	SPACEWAY™ 1.5 MBPS (T1)
Digitized Photo	1.0 megabit	1.7 min.	2.6 sec	0.7 sec
CAD/CAM	2.0 megabits	3.4 min.	5.2 sec	1.4 sec
CT Scan	5.2 megabits	9.0 min.	13.5 sec	3.4 sec
X-Ray	12.0 megabits	21.0 min.	31.3 sec	7.8 sec

In sum, the on-demand high-speed data transmission capability of the SPACEWAY™ network will facilitate an array of applications. In addition to those described above, many others could be made available through third-party service providers.

The SPACEWAY™ network will provide interconnected, bandwidth on demand services to virtually every populated area of the world. In this regard, the service area of the SPACEWAY™ network is similar to that of many of the low earth orbit ("LEO") satellite systems that have been proposed. The SPACEWAY™ network is different from these LEO systems in two significant respects: it is more spectrally efficient and it will not forestall the development of other geostationary satellite systems using the Ka band at other orbital locations. It is a geostationary satellite system that operates from a total of six orbital locations and complies with the United States Federal Communications Commission's 2° spacing policies. Thus, it is anticipated that it will be compatible with any other Ka band FSS system that may operate at any other geostationary orbital location that is at least 2° away. Assuming uniform 2° spacing around the world, making 180 orbital slots available, the 2.5 GHz that has been proposed for SPACEWAY™ could be reused to effectively provide 435 GHz of Ka band spectrum for other satellite services. No LEO system that has been proposed to date has offered this type of an opportunity for frequency reuse. In sum, unlike LEO satellite systems that have been proposed at Ka band, the SPACEWAY™ network supports the entry of multiple service providers at all or part of the 2.5 GHz that is available at Ka band.

2. <u>Space Segment Characteristics</u>

The deployment of the multibeam satellites at geostationary orbit will be accomplished on a phased regional implementation and is illustrated in Figure 2. The proposed assignment of frequencies and polarizations to satellite beams, the geographic coverage provided by these beams, and a description of the other satellite parameters are given below.

2.1 <u>Frequency and Polarization Assignments</u>

The SPACEWAY™ global network will utilize the 17.7 to 20.2 GHz portion of the Ka band for space-to-Earth (downlink) transmissions, and the 27.5 through 30.0 GHz portion of the Ka band for Earth-to-space (uplink) transmissions. This spectrum has been allocated on a worldwide basis for the Fixed-Satellite Service ("FSS").

The frequency plan for the SPACEWAY™ network is presented in Figures 3 and 4.

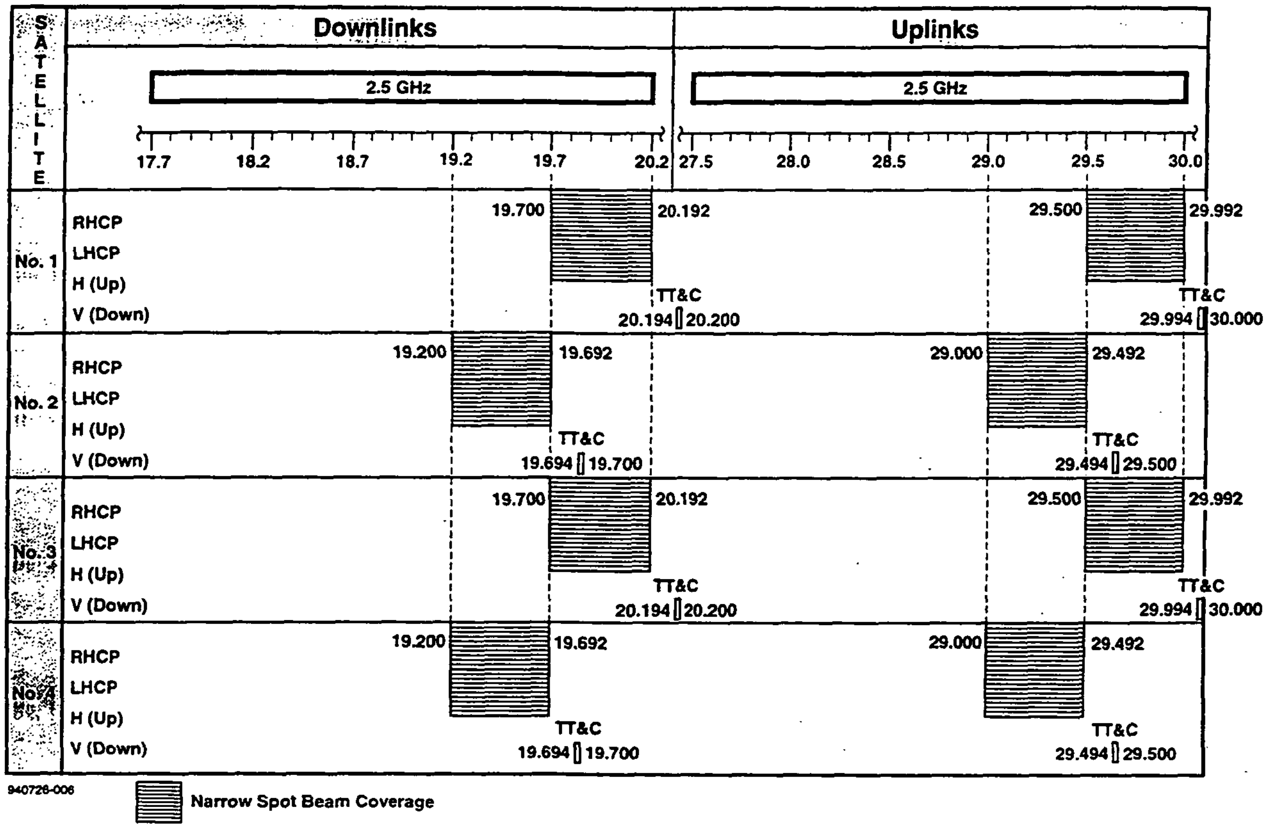


Fig. 3. Spaceway spectrum utilization in North America.

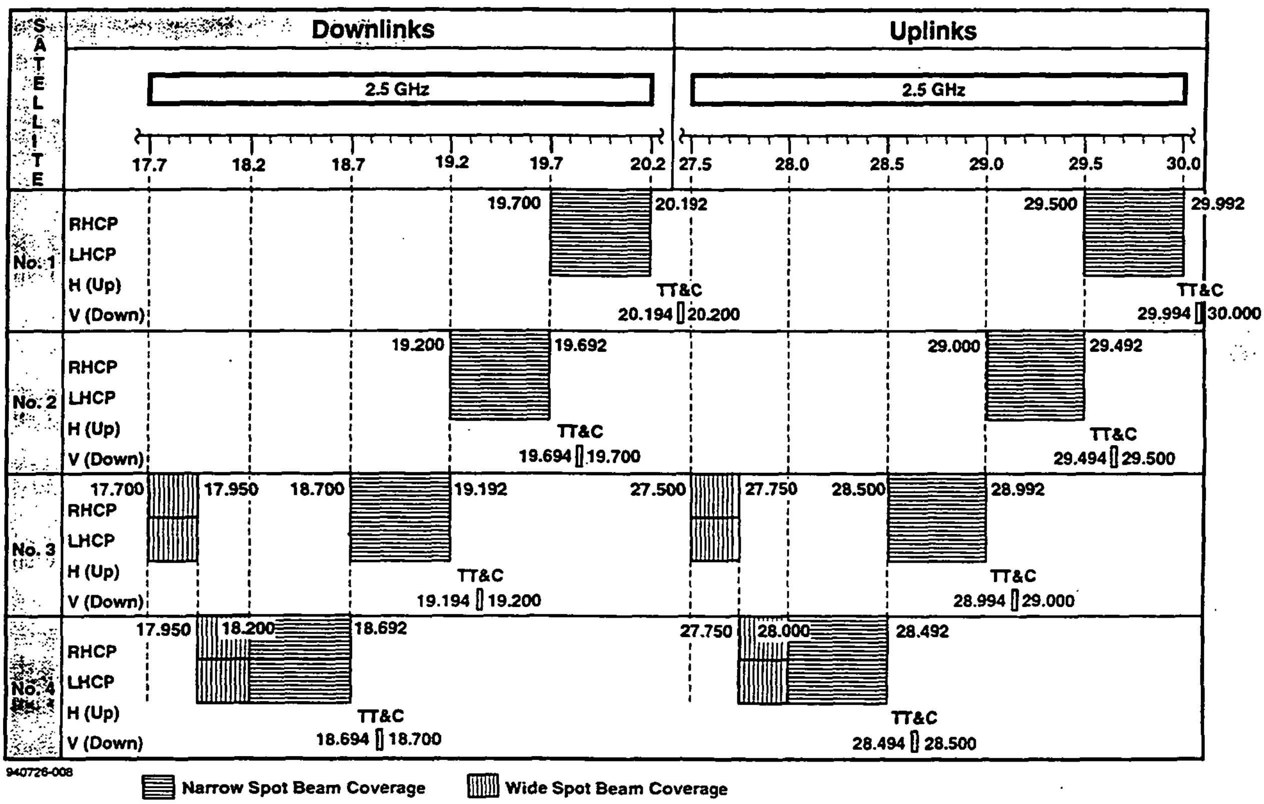


Fig. 4. Spaceway spectrum utilization in Central and South America, Europe, Africa, and Asia Pacific.

The plan for the four satellites serving the North America region is depicted in Figure 3. Satellites 1 and 2 will occupy the 101° W.L. position and will each employ 500 MHz of bandwidth. North American satellites 3 and 4 will be located 2° away at 99° W.L. and will employ precisely the same spectrum as North American satellites 1 and 2. North American coverage is provided by two satellites at each of 101° W.L. and 99° W.L. By placing two satellites at each of these locations, and using the same 1000 MHz of spectrum at each location, the system will have sufficient capacity to provide the full range of proposed satellite services.

Each of the four North American satellites will provide a total of forty-eight 125 MHz spot beams (24 beams used on opposite circular polarizations) for uplink and downlink transmission. In this way, each satellite effectively reuses the 500 MHz of spectrum assigned to it about 12 times.

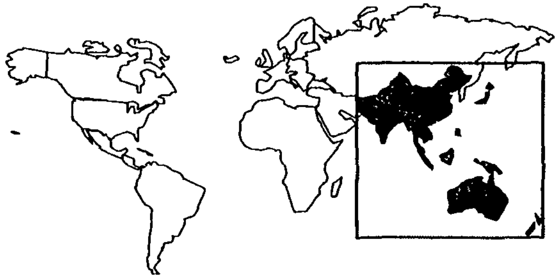
Each of the other three regions is supported by a constellation of four satellites that will use the full 2.5 GHz of spectrum at a common orbit position as illustrated in Figure 4. This will allow any subscriber within any of these regions to use a single earth terminal to access capacity on any of the four satellites at that orbital position. In each region, satellites 1 and 2 are identical in frequency plan to their counterparts in North America and divide their 500 MHz into forty-eight 125 MHz spot beams in a manner similar to that shown in Table 1. However, satellites 3 and 4 in each region are assigned two different 500 MHz band segments so that they may be co-located with satellites 1 and 2.

2.2 Beam Coverage Areas

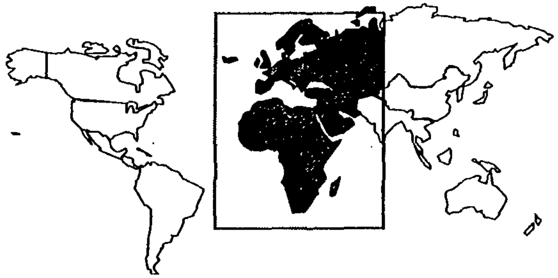
The proposed system will provide spot beam coverage of all inhabited land areas of the world. An eight satellite constellation provides service to 90% of the world's population. Figure 5 depicts the four regions of coverage by the SPACEWAY™ system. The two satellites per region provide high EIRP and G/T coverage to allow the use of small inexpensive earth terminals.

The system comprises two satellites per region:

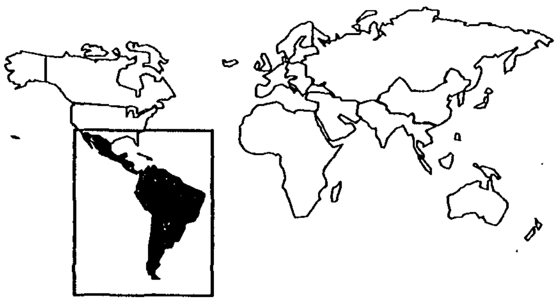
Asia Pacific



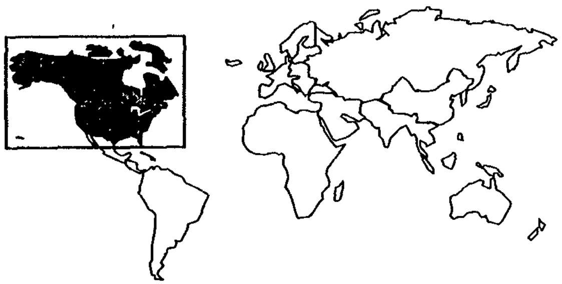
Europe, Africa, and Middle East



Central and South America



North America



High Capacity per Satellite

	Voice	Data
KBPS	16	1,544
Simultaneous Circuits	115,200	1,440

Rapid Transmission Times

	Telephone Modem	T1 Circuit
KBPS	9.6	1,544
X-Ray	21.0 Mins.	7.8 Secs.
Newspaper	28.0 Mins.	10.4 Secs.

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Hughes Proprietary

Fig. 5. An eight-satellite system provides service to 90% of the world's population.

2.3 Satellite Characteristics

The on-orbit configuration of the satellites is illustrated in Figure 6, and the major spacecraft characteristics are given in Table 1. The launch weight budget is presented in Table 2. The satellite receiver and transmitter parameters are given in Tables 3 and 4.

Table 1: Major Spacecraft Characteristics

General	
Spacecraft bus	HS-601
Stabilization	
Transfer orbit	Spin stabilization
On-station	3 axis. momentum bias
Mission life	15 years
Eclipse capability	100 percent
Station keeping	
North-South (orbital inclination)	±0.05°
East-West (longitudinal)	±0.05°
Antenna pointing	
Normal (Precision two-axis RF beacon tracking)	±0.1° N-S and E-W
Backup (Earth sensor)	±0.2° N-S and E-W
Beam rotation (antenna axis attitude)	±0.25°
Communications	
Number of communications beams (Satellites 1 and 2 over each region)[3]	48
Communications beam bandwidth	125 MHz
Transmitter redundancy	64 for 48
Communications channel receive flux density per Hz (narrow beams, edge of coverage)	-182.6 dBW/(m^2Hz)
Communications channel receive flux density per Hz (wide beams, edge of coverage)	-194.1 dBW/(m^2Hz)
Emission Limitations	
(Spurious level below unmodulated power)	
Frequency offset by 50% - 100% of BW	≤ -65 dBc
Frequency offset by 100% - 250% of BW	≤ -65 dBc
Frequency offset by > 250% of BW	≤ -65 dBc

3 Satellites 3 and 4 in each region will have additional narrow spot beams and as many as five wide spot beams. However, only 48 beams in total, either narrow or wide, will be addressable at any time.

Table 2 Launch Weight Budget

Category	Weight, Lb.
Spacecraft dry	3785
10 year orbit sustenance propellant	883
Beginning of life (subtotal)	4668
Transfer orbit	3159
Total separated weight	7827

Table 3 Satellite Uplink G/T Budget

	Narrow Spot Beam	
	Peak	Edge of Cov.
Antenna gain (db)	46.50	41.50
System noise temperature (dB K)	27.60	27.60
G/T (dB/K)	18.90	13.90

Table 4 Satellite Downlink EIRP Budget

	Narrow Spot Beam	
	Peak	Edge of Cov.
Amplifier output power (db)	13.01	13.01
Repeater output losses (dB)	0.50	0.50
Antenna gain (dB)	46.50	41.50
EIRP (dBw)	59.01	54.01

3. Ground Segment Characteristics

3.1 SPACEWAY™ USATs

The SPACEWAY™ ground terminal will cover the range of communications required by the late 1990's; namely efficient and low cost telephony for areas of the world with emerging telecom infrastructure requirements as well as broad bandwidth multi-media requirements.

The SPACEWAY™ ground terminal is a multi-media ultra small aperture terminal (USAT) configured to enable direct exchange of packets with ATM type devices. Packets from video, voice and data inputs are assembled and transmitted in data bursts of up to 384 KBPS and received at TDM packet rates of up to 92 MBPS. The system with optional uplink terminals enables efficient transmission of both on-demand circuit-switched services such as ISDN, T1, and fractional T1, and packet-switched services such as frame relay and X.25.

The SPACEWAY™ system will incorporate two types of ground communications equipment: (i) end user USAT terminals and (ii) terrestrial network interfaces or gateways. The terminals will accommodate bi-directional transmissions from 16 Kbps up to 1.5 Mbps (T1) rates, using antennas ranging from 66 centimeters to 2 meters in diameter. However, virtually all mass market subscribers will utilize the 66 cm USATs which will be mass produced and easily installed.

Larger SPACEWAY™ ground terminals, or gateways, can support multiple carriers for much higher transmission throughout. Gateways are intended to provide interconnection between the global satellite system and the terrestrial public switched telephone network (PSTN), and will be strategically located to interface with inter-exchange and local exchange common carriers in the U.S. and telecommunications operators in various countries throughout the world.

Through on-board satellite switching and gateway earth stations that provide terrestrial interconnection, the system architecture will allow end users the greatest possible flexibility in making connections to each other. The system will allow both "private" network and "open" network communications. Private networks can be created where end-user terminals in a pre-defined "community" communicate with each other directly via a SPACEWAY™ satellite, with or without connection to the PSTN. Open networks allow system subscribers to connect with any other subscriber or with any other person or entity served by the PSTN through a SPACEWAY™ gateway.

The vast majority of the transmit/receive earth stations used to communicate with the global system will be owned by the end users of the service. It is anticipated that when fully deployed, the network will serve more than five million subscribers around the world, each of whom will own an earth terminal.

3.2 Availability and Rain Attenuation

In almost all areas,of the world SPACEWAY™ provides availabilities greater than 99 % with a standard ultra small aperture terminal (USAT) that includes a compact 66 cm antenna operating at a burst rate of 384 kbps. The SPACEWAY™ system offers a range of terminal options that achieve availability $\geq$ 99.5 % anywhere in the world. SPACEWAY™ incorporates uplink power control to maintain continuous service through moderate rain.

Ka-band is susceptible to rain fades that reduce availability statistics, but rain fades have a time character that is unlike an outage due to equipment failure or cable damage - which is the normal model for outages in terrestrial networks. NASA data on Ka-band propagation shows that rain fades are typically a few minutes due to the passage of a 'rain cell'. (Rain cells, which span about a kilometer, are bursts of heavy rain in a thunderstorm.) A few minutes of outage, after which service resumes unaffected, has very different consequences on an operating enterprise than the potential for hours of outage to carry out repairs normally associated with outages of terrestrial systems.

The SPACEWAY™ system availability has been evaluated over a wide range of geographical locations using the Crane[2] Rain model. In the United States the predicted link availability ranges from 99.1 % in Miami to 99.97% in Denver. The results from analyses for selected cities in the Asia Pacific region are summarized in Figure 6. The SPACEWAY™ availabilities shown in this figure. include both the standard USAT with a 66 cm antenna and availability improvements possible by using either a higher power uplink amplifier or slightly larger antenna. SPACEWAY™ will offer these optional USAT configurations so that users in the heavy rainfall areas of the world may have access to availability of at least 99.5%.

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2 Robert K. Crane, Predictions of Attenuation by Rain, IEEE Transactions on Communications, vol. COM-28, no 9, September 1980, pp. 1717-33.

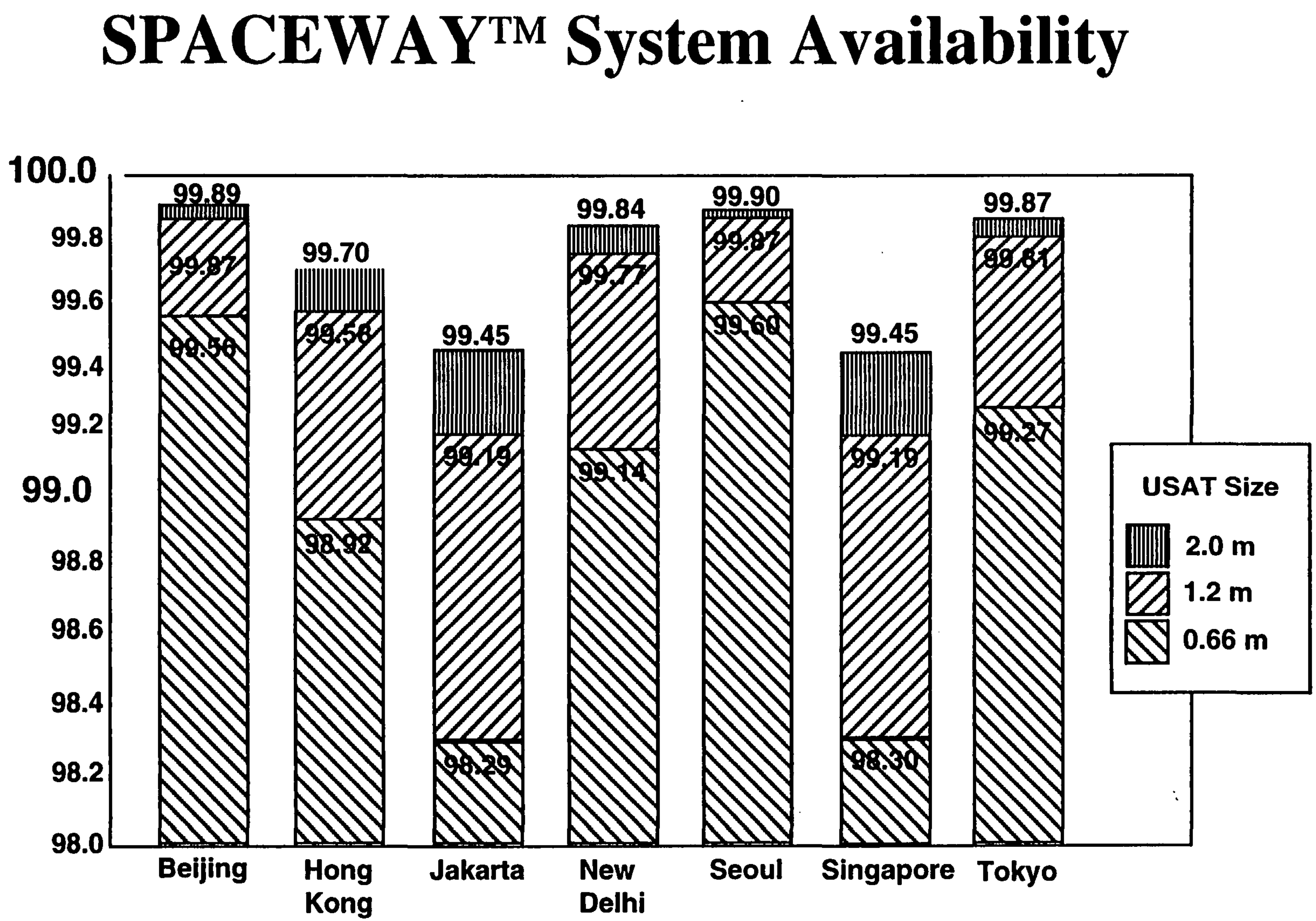

Fig. 6. Spaceway system availability in selected cities in the Asia Pacific region.

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4. Link Performance Objectives and Power Budgets

4.1 Communication Links

Communication services will be provided at rates from 16 Kbps to 1.544 Mbps (T1). User terminals will have the capability to transmit and receive via 66 cm to 2 m aperture antennas with transmit powers that range from 0.1W to 2.0 W transmit power, depending on data rate and the amount of uplink power control used to compensate for rain attenuation. Up to 240 simultaneous 384 Kbps uplink signals may be supported in each beam for a data throughput of 92 Mbps per polarization per beam per satellite. With twelve-fold frequency reuse, the total data throughput is 4.4 Gbps per satellite.

The system performance objective is a bit error rate ("BER") of 10^{-10}. Because of on-board demodulation and remodulation of the signal, performance on the uplink and performance on the downlink are independent. Due to the error control coding used, the bit energy levels required of the two links are asymmetric. An E_b/N_0 of 8.0 dB on the uplink and 5.0 dB on the downlink are required to meet the targeted BER. Table 5 is a summary of the spot beam communication performance parameters for a data rate of 384 kbps.

Table 5. Summary of Spot Beam Communication Performance Parameters

Performance requirement	1×10^{-10} BER
Transponder bandwidth	125 MHz
Modulation	QPSK
Uplink data rate	16 to 1,544 Kbps
Uplink channel bandwidth	500 to 2,000 KHz
Required uplink E_b/N_0	8.0 dB
Downlink data rate (per beam per polarization)	92 Mbps
Downlink channel bandwidth	125 MHz
Required downlink E_b/N_0	5.0 dB
Earth station diameter	66 cm to 2 m
Earth station amplifier power	1.0 - 2.0 W
Loss to antenna input	0.5 dB
Earth station receive system noise temperature	24.4 dBK

Tables 6 and 7 provide sample link analysis calculations for uplink peak and edge-of-coverage paths and downlink peak and edge-of-coverage paths, respectively, for the spot beams. Each table illustrates both clear sky and rain conditions. These calculations assume 384 kbps service.

Table 6. Uplink Power Budgets

Peak of Coverage

	Clear	Rain
Transmit power	- 9.73 dBW	- 3.01 dBW
Tramsmit losses	- 0.50 dB	- 0.50 dB
Ground transmit gain	44.45 dB	44.45 dB
Uplink path spreading	- 162.31 dB/M^2	- 162.31 dB/m^2
Uplink effective isotropic area	- 50.85 dB/m^2	- 50.85 dB/m^2
Atmosheric loss	- 0.96 dB	- 0.96 dB
Uplink rain loss	0.00 dB	- 8.77 dB
Satellite G/T (peak)	18.88 dB/K	18.88 dB/K
Bit rate	55.87 dB Hz	55.87 dB Hz
Boltzmann's constant	- 228.60 dBW/K/Hz	- 228.60 dBW/K/Hz
Thermal Eb/No	11.72 dB	9.67 dB
Cross-pol Eb/No	17.45 dB	17.45 dB
Adjacent beam co-pol Eb/I	17.95 dB	17.95 dB
Adjacent system (east) Eb/I	20.85 dB	20.85 dB
Adjacent system (west) Eb/I	20.85 dB	20.85 dB
Total Eb/I	9.29 dB	8.00 dB

Edge of Coverage

	Clear	Rain
Transmit power	- 4.73dBW	- 3.01 dBW
Tramsmit losses	- 0.50 dB	- 0.50 dB
Ground transmit gain (EOC)	44.45 dB	44.45 dB
Uplink path spreading	- 162.31 dB/M^2	- 162.31 dB/m^2
Uplink eff. isotropic area	- 50.85 dB/m^2	- 50.85 dB/m^2
Atmosheric loss	- 0.96 dB	- 0.96 dB
Uplink rain loss	0.00 dB	- 3.77dB
Satellite G/T	13.88 dB/K	13.88 dB/K
Bit rate	55.87 dB Hz	55.87 dB Hz
Boltzmann's constant	- 228.60 dBW/K/Hz	- 228.60 dBW/K/Hz
Thermal Eb/No	12.92 dB	5.66 dB
Cross-pol Eb/No	17.45 dB	17.45 dB
Adjacent beam co-pol Eb/I	17.95 dB	17.95 dB
Adjacent system (east) Eb/I	22.79 dB	22.79 dB
Adjacent system (west) Eb/I	22.79 dB	22.79dB
Total Eb/I	10.20 dB	5.00 dB

Table 7. Downlink Power Budgets
Peak of Coverage

	Clear	Rain
Transmit power	13.01 dBW	13.01 dBW
Tramsmit losses	- 0.50 dB	- 0.50 dB
Satellite transmit gain (peak)	46.50 dB	46.50 dB
Downlink path spreading	- 162.31 dB/M^2	- 162.31 dB/m^2
Uplink eff. isotropic area	- 47.34 dB/m^2	- 47.34 dB/m^2
Atmosheric loss	- 1.10 dB	- 1.10 dB
Downlink rain loss	0.00 dB	- 7.64 dB
Terminal G/T	18.56 dB/K	16.37 dB/K
Bit rate	79.64 dB Hz	79.64 dB Hz
Boltzmann's constant	- 228.60 dBW/K/Hz	- 228.60 dBW/K/Hz
Thermal Eb/No	15.78 dB	5.95 dB
Cross-pol Eb/No	17.45 dB	17.45 dB
Adjacent beam co-pol Eb/I	17.95 dB	17.95 dB
Adjacent system (east) Eb/I	18.50 dB	18.50 dB
Adjacent system (west) Eb/I	18.50 dB	18.50 dB
Total Eb/I	10.52 dB	5.00 dB

Downlink budget calculation SPOT beams

Table E-4 (A)

Edge of Coverage

	Clear	Rain
Transmit power	13.01 dBW	13.01 dBW
Tramsmit losses	- 0.50 dB	- 0.50 dB
Satellite transmit gain (EOC)	41.50 dB	46.50 dB
Downlink path spreading	- 162.31 dB/M^2	- 162.31 dB/m^2
Uplink eff. isotropic area	- 47.34 dB/m^2	- 47.34 dB/m^2
Atmosheric loss	- 1.10 dB	- 1.10 dB
Downlink rain loss	0.00 dB	- 2.64 dB
Terminal G/T	18.56 dB/K	16.37 dB/K
Bit rate	79.64 dB Hz	79.64 dB Hz
Boltzmann's constant	- 228.60 dBW/K/Hz	- 228.60 dBW/K/Hz
Thermal Eb/No	10.78 dB	5.95 dB
Cross-pol Eb/No	17.45 dB	17.45 dB
Adjacent beam co-pol Eb/I	17.95 dB	17.95 dB
Adjacent system (east) Eb/I	18.50 dB	18.50 dB
Adjacent system (west) Eb/I	18.50 dB	18.50 dB
Total Eb/I	8.36 dB	5.00 dB

For 384 Kbps service using narrow beams, the maximum earth station transmitter power is 1.0 W and is reduced to less than 0.1 W under clear sky conditions, as shown in Tables 6 and 7.