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Assessment of Candidate Communications Satellites for Developing Countries

FINAL REPORT

December 14, 1977

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Prepared Under Contract No.: AID/TA-C-1426
For
U.S. Agency For International Development
Washington, D.C.

OPERATIONS RESEARCH, Inc.

SILVER SPRING, MARYLAND

ASSESSMENT OF CANDIDATE COMMUNICATIONS SATELLITES FOR DEVELOPING COUNTRIES

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ASSESSMENT OF CANDIDATE COMMUNICATIONS SATELLITE SYSTEMS FOR DEVELOPING COUNTRIES

PART I

OVERVIEW

SUMMARY

PURPOSE: Assess key factors that affect the feasibility of using candidate communications satellites to serve developing countries.

CANDIDATE SATELLITE SYSTEMS:

- INTELSAT IV (Global/Spot beams) and IV-A (Zone beams)
- Symphonie
- Japanese Broadcast Satellite

MAJOR FACTORS:

- Cost of earth terminals
- Cost of transponder lease (INTELSAT)

SECONDARY FACTORS:

- Satellite coverage areas
- Availability for domestic service
- Procedures for use and required approvals
- Regulatory provisions and constraints

SUMMARY

- This study is a technical/economic assessment of the feasibility for using the INTELSAT, Symphonie, and the Japanese Broadcast Satellite for delivery of television, telephony and broadcast radio services to developing countries. Major emphasis was placed on analyzing how each satellite system can be utilized with the least expensive earth terminals for each of the required services.

- A description is presented of each satellite system, noting the candidate satellite's specifications, coverage capabilities, and availability for domestic use. (For the INTELSAT system, the INTELSAT IV global and spot beams were considered in addition to the INTELSAT IV-A zone beams). This is followed by a system analyses which ascertained the least expensive earth terminal that can be utilized with each satellite for the required services.

- Based upon results of the systems analysis, cost are shown for the earth terminals (both master uplink and village sites) using prices of existing terminals that currently are operational with similar satellites and services. In addition, the tariff charges are noted for domestic lease of INTELSAT space segment capacity.

- A review of relevent policies and procedures for use of INTELSAT and Symphonie satellite systems is presented. Of particular importance is INTELSAT acceptance criteria for use of non-standard (small antenna) earth terminals.

- Finally, a discussion is provided on relevant regulatory provisions and constraints. This focuses on current frequency allocations, frequency coordination requirements and problems with some of the allocations and how they may be changed.

RESULTS

VILLAGE SITE EARTH TERMINAL CHARACTERISTICS/COSTS						
SERVICE REQUIREMENT	INTELSAT IV (Global Beam)		INTELSAT IV (Spot Beam)		INTELSAT IV-A (Zone Beam)	
	Antenna Diameter (meters)	Cost 1 Unit	Antenna Diameter (meters)	Cost 1 Unit	Antenna Diameter (meters)	Cost 1 Unit
Television (R/O)	NTP	NTP	4.57 m b)	$28K	10 m b)	$53K
Telephony	4.57 m b)	$40K (1 vc) $6K/addt'l vc	4.57 m b)	$40K (1 vc) $6K/addt'l vc	4.57 m b)	$40K (1 vc) $6K/addt'l ch
Broadcast Radio (R/O)	4.57 m a)	$24K	4.57 m b)	$15K	4.57 m b)	$15K

a) Requires uncooled parametric preamp; noise temperature = $90^{o}K$

b) Requires GaAs FET preamp; noise temperature = $200^{o}K$

NTP - Not Technically Practical

INTELSAT Standard B is assumed for Master Uplink earth terminal.

(R/O) - receive only duplex

(vc) - duplex voice channel

RESULTS

- The current INTELSAT satellites appear technically capable of delivering television, telephony, and broadcast radio services to village sites in developing countries throughout the world.

- The INTELSAT IV Spot Beam has the greatest EIRP (33.7 dBw) of all the INTELSAT antennas. Consequently, it can deliver all three types of services using the small (4.57m) earth terminal antennas and low-cost(GaAS FET) preamplifiers. The INTELSAT IV-A Zone Beam has the next highest EIRP (29.0 dBw) and can deliver telephony and broadcast radio using the same type of small and low-cost earth terminals. However, for television, a larger earth terminal antenna is necessary (10m). Finally, the INTELSAT IV Global Beam, which has the lowest EIRP (22 dBw), is capable of providing only telephony with a small and low-cost earth terminal. Broadcast radio requires a small antenna but an expensive (uncooled parametric) preamplifier. Television service is not possible (even with a 10m antenna).

- Thus, INTELSAT IV Spot Beam and the IV-A Zone Beam offer the best technical capabilities for providing services with the least expensive village site earth terminals.

- The Symphonie satellites have performance characteristics similar to the INTELSAT IV-A Zone Beam. So, the village site earth terminal requirements are basically the same.

- The JBS satellite operates quite well with very small antenna village site earth terminals (1.8m) primarily because of its extremely high 55 db EIRP. However, the cost of each transponder per satellite must be weighed against the low-cost of the accompanying earth terimals.

- Tariff changes for domestic lease of INTELSAT are $1M per year per transponder (preemptible service). Half and quarter transponder segments are priced on a proportional basis.

- Use of small diameter antennas (ie. 4.57m) with INTELSAT satellites will require special approval, but the sidelobe performance of these antennas, (with minor modifications) should meet INTELSAT antenna performance criteria.

- Current regulatory practices require that all C-Band earth terminals (in the United States) be "frequency coordinated." If similar requirements exist in a target developing country, this "clearance" procedure would increase the cost of each earth terminal.

- Ku-Band frequency allocations remain uncertain in Region 2, and so, planning of fixed/broadcast services may be a problem until the 1982 Region 2 WARC. For Regions 1 and 3, allocations were recently defined at the 1979 B/WARC, favoring broadcast services.

ASSESSMENT
OF
CANDIDATE COMMUNICATIONS
SATELLITE SYSTEMS
FOR
DEVELOPING COUNTRIES

PART II

INTRODUCTION

BACKGROUND

AID INVOLVEMENT IN COMMUNICATIONS SATELLITES IS CONSONANT WITH ITS OVERALL DIRECTIVE AS SET FORTH IN SECTION 220 OF THE FOREIGN ASSISTANCE ACT OF 1970.

OFFICE OF EDUCATION AND HUMAN RESOURCES HAS SPONSORED A VARIETY OF ACTIVITIES IN RESPONSE TO OTHER NATIONS DESIRES FOR INFORMATION REGARDING PROJECTS ON SOCIAL SERVICE APPLICATIONS OF COMMUNICATIONS SATELLITE TECHNOLOGY.

FORMER SECRETARY OF STATE KISSINGER EMPHASIZED USE OF SATELLITE TECHNOLOGY TO HELP IMPROVE COOPERATION BETWEEN INDUSTRIALIZED AND DEVELOPING COUNTRIES AND PLEDGED TO FACILITATE TRANSFER OF ADVANCED TECHNOLOGY TO HELP THE ECONOMIES OF THESE COUNTRIES.*

* ADDRESS TO THE UN CONFERENCE ON TRADE AND DEVELOPMENT IN NAIROBI, KENYA, MAY 6, 1976

BACKGROUND

- AID involvement in communications satellites is in accordance with its overall directive, as set forth in Section 220 of the Foreign Assistance Act of 1970, which directs AID to initiate activities for aiding developing countries in use of communications technologies for projects in education, agriculture, health and community community development that strivé to increase social equality and accelerate rural development.

- The Office of Education and Human Resources has sponsored a variety of activities in response to other nations desires for information regarding projects on social service application of communications satellite technology. Some activities involved studies that raised issues pertinent to the needs of system planners in developing countries. Other activities involved conferences/seminars as forums for exchanges among those conducting experiments within the U.S. and other planning experiments or studies in developing countries.

- Former Secretary of State Kissinger emphasized use of satellite technology to help improve cooperation between industralized and developing countries*. Consequently, AID initiated a long-range technology transfer/utilization program with AIDSAT demonstrations to stimulate interest in the applications of space and communications. As a follow-on, long-term demonstations are planned within countries that requested assistance in helping define their use of communication satellites. This follow-on phase may lead to the establishment of experimental operational communication satellite systems in many countries throughout Latin America, Africa, and Asia.

*Address to the UN Conference on Trade and Development in Nairobi, Kenya, May 6, 1976.

PURPOSE

- ASSESS AVAILABILITY OF CANDIDATE COMMUNICATIONS SATELLITES TO SERVE LATIN AMERICA, AFRICA, AND ASIA.
- DESCRIBE THE COVERAGE PATTERNS OF EACH CANDIDATE SATELLITE.
- SPECIFY EARTH TERMINALS CHARACTERISTICS TO PROVIDE A VARIETY OF TELEVISION, TWO-WAY VOICE, AND BROADCAST RADIO SERVICES.
- DETERMINE COSTS OF EARTH TERMINALS AND INTELSAT TRANSPONDER TARIFFS TO PROVIDE EACH SERVICE.
- REVIEW PROCEDURES FOR USE OF INTELSAT AND SYMPHONIE SATELLITE SYSTEMS.
- REVIEW RELEVANT FREQUENCY ALLOCATIONS AND INTERNATIONAL RADIO REGULATIONS.

PURPOSE

- In order for AID to properly prepare detailed strategies for the use of communications satellites in its AIDSAT follow-on and experimental/operational phases, detailed data on candidate communications satellite systems must be collected.

- The candidate satellite systems of interest to AID are INTELSAT (IV and IV-A), Symphonie, and the Japanese Broadcast Satellite. The INTELSAT satellites are commercial, available on a leased basis, and capable of providing service to almost all areas of the world. Symphonie is an experimental satellite and can provide service primarily to Africa. The Japanese Broadcast Satellite (JBS) is included in this study to evaluate its potential service capabilities (assuming a duplicate is built).

- Analytical analyses sought to determine the least expensive earth terminal designs to provide the required services (as specified by AID) using each of the candidate satellites.

- The resultant data is contained in the following categories: technical capabilities of each satellite system; minimum costs of earth stations; tariffs for satellite utilization; procedures for use of INTELSAT and Symphonies satellites; and an evaluation of relevant regulatory provisions and constraints.

REQUIREMENTS

SYSTEM

LATIN AMERICA

Sample Country: Columbia
Satellites: INTELSAT IV and IVA
Syncom IV
Japanese Broadcast Satellite
(assumes duplicate is built)

AFRICA

Sample Country: Cameroons
Satellites: INTELSAT IV and IVA
Symphonie

ASIA

Sample Country: Nepal
Satellites: INTELSAT IV and IVA

SERVICES

TELEVISION

Receive-only (1 channel)
Receive-only (1 channel) plus one two-way voice channel
Receive-only (1 channel) plus four two-way voice channels

TELEPHONY

Multiple simultaneous two-way voice channels

BROADCAST RADIO

Receive only (1 channel)
Receive only (1-channel) plus one two-way voice channel

REQUIREMENTS

- The candidate satellite systems of primary interest are the INTELSAT (IV and IVA's) and the Symphonie, in that they are currently available for service. Also of interest is the Japanese Broadcast Satellite (JBS) because it is uniquely capable of providing a variety of services utilizing very low-cost earth terminals. Although the JBS is dedicated only to service in Japan, it is assumed that a duplicate could be built for service elsewhere.

- This study considers three of the world regions (Latin America, Africa, and Asia). A sample country was chosen as a representative of the conditions that typify each region.

- There are 3 categories of service evaluated in this study: television, telephony, and broadcast radio.

- Television can be received by itself at a village site or have incorporated with it two-way voice channels. Since these voice channels are intended for audience feedback, they are simplex (push-to-talk) channels and operate on a common frequency (ie., like a party line) to all participants.

- Telephony channels are primarily intended for two-way private link voice service. They are duplex channels and one or more channels maybe required for any location.

- Broadcast radio channels are for distribution of radio program materials that would be rebroadcast via terrestrial AM or FM systems. A two-way simplex voice channel may be incorporated for interactive programs.

ASSUMPTIONS

SATELLITE CAPABILITIES

Space segment capacities were considered on a full and quarter transponder basis.

Saturated EIRP for a full transponder is in accordance with published values. The available EIRP in a quarter transponder on INTELSAT satellites was assumed from INTELSAT document "Attachment No. 3 to BG-28-7E, M/6/77, BG/T-20-5E, W/5/77." The transfer characteristics of INTELSAT IV and IV-A transponders were provided in a working curve by INTELSAT staff. For the Symphonie and JBS satellites, EIRP for a quarter transponder was assumed to be 11 dB less than the saturated values.

No system optimization was performed to ascertain maximum number of channels within an allotted transponder capacity or to minimize system costs for any required services.

MINIMUM OPERATING CONDITIONS

No signal qualities (S/N) were specified. Each service has a link performance of system C/N) = 12 ± 1db.

MODULATION

All carriers are SCPC-FM and preassigned. Also, VOX operation, threshold extension demodulators (TED), and compandors are assumed.

EARTH TERMINALS

No redundancy of earth terminal equipments was considered in the costing analysis.

Prices for C-Band equipments are for existing off-the-shelf hardware, purchased in the U.S., and F.O.B at the manufacturer. Ku-Band earth terminal prices are based upon results from internal ORI studies/workshops performed for NASA and reflect expected prices in the early 1980's when Ku-Band service is commercialized.

Master uplink terminals for C-Band are INTELSAT Standard B types (10m). For Ku-Band, a 5m antenna is used.

Village site terminals are 4.57m for C-Band. (A 10m was required only when the smaller antenna was incapable of achieving the desired performance.) A 1.8m antenna was assumed for Ku-Band village sites.

OPERATING CONDITIONS

Television service is transmitted from a master uplink (large antenna) to a village site (small antenna).

Telephony service is always between a master uplink and a village site; for village site-to-village site link, a double-hop is required via the master uplink.

No intermodulation or spectrum spread analyses were performed. However, engineering estimates were made for the necessary TWT back-off to minimize these problems. Likewise, no intersatellite interference analysis were performed, although potential problems are noted in the study.

ASSUMPTIONS

- This study is intended only as an examination of the feasibility of using 3 candidate satellite systems to deliver a variety of communications services throughout regions of the world. Consequently, many assumptions were made regarding technical analyses of satellite capabilities, earth terminal specifications, performance requirements, and operating conditions. The assumptions, however, are based upon data from current use of each candidate satellite (or use of satellite with similar characteristics). By specifying more detailed system requirements and objectives can a complete and more accurate assessment be performed.

- INTELSAT V is included in this study by virtue that its performance capabilities at C-Band are similiar to those of the INTELSAT IVA. However, the Ku-Band capabilities of the INTELSAT V are intended for operation only with large earth terminals and so this frequency band is not intended nor technically desirable for domestic lease.

- In analyzing the capabilities of each candidate satellite to provide the required services, values derived in this study for RF power at the master uplink and village site represent engineering estimates for utilization of the least expensive earth terminals at the village sites. These values are subject to change through more extensive analyses which may result in minor changes in the link performance and number of two-way voice channels accommodated within an allocated space segment. However, costs of the village site earth terminals are not expected to change significantly as a result of these more extensive analyses.

- The smallest village site antenna was chosen at 4.57m because this is minimum size antenna that will meet CCIR and INTELSAT interference criteria.

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PART III

CAPABILITIES

INTELSAT: SYSTEM DESCRIPTION

TOTAL SPACE SEGMENT

INTELSAT IV: 7 satellites

INTELSAT IVA: 5 satellites*

SATELLITE SERVICES

Half-Circuits:	Full-time lease on a preassigned basis.
Half-Circuits:	Available on demand on a per-minute basis using SPADE
Half-Circuits:	Temporary service
Television:	Regular service and service as needed.
Domestic:	Full-time transponder (or for portions thereof) lease service

*1 satellite remains to be launched in 1978

TOTAL EARTH SEGMENT

157 Antennas

126 Earth Station sites

82 Countries (with earth stations)

EARTH STATION CHARACTERISTICS

All earth stations are owned by individual member countries.

Standard A:	Diameter	= 30 meters
	G/T	= 40.7 dB/^{o}k
	Cost	= $8.54M (approximate)
	Services	= FDM/FM, TV, and SCPC/PSK
Standard B:	Diameter	= 10 meters
	G/T	= 31.7 dB/^{o}k
	Cost	= $2.9M (approximate)
	Services	:= 24 channel FDM/FM, TV, and SCPC/PSK

INTELSAT: SYSTEM DESCRIPTION

- The International Communications Satellite Consortium (INTELSAT) was organized in 1964. Its purpose is to procure, install, manage, and operate a global communications satellite system. While INTELSAT owns and controls the satellites, each member owns its own terminals.

- The permanent structure of INTELSAT was defined in the "Definitive Agreement" that became effective in February 1973.

- Over the past 13 years, INTELSAT has brought five generations of satellites into service, and development of the sixth generation (INTELSAT V) is now in progress.

- INTELSAT currently provides communication services via satellite between 118 countries, with 98 countries as members.

- Almost all terminals conform to a Standard A or B design. Their primary difference is the size and amount of traffic carried by each.

- Telephone is the major portion of the traffic (70-80% of INTELSAT revenues). Television accounts for less than 5%.

- Satellite capacity is allocated to the ground terminals by two methods. One method is on a preassigned basis, where the Operations Center allocates circuits that are requested for long-term use: The other method is on demand assignment, which uses a SPADE technique to provide circuits whenever needed to handle traffic above preassigned capacity or between terminals that have no preassigned circuits.

INTELSAT: SATELLITE SPECIFICATIONS

INTELSAT IV

FREQUENCY:	C-band
LIFETIME:	7 years
TRANSPONDERS:	12
SATURATED EIRP:	(-3 db beam edge)
• Global Beam:	22.0 dbw
• Spot Beam:	33.7 dbw
G/T:	-17.2 db/^{o}K
BEAMWIDTH	
• Transmit Antennas	
Global Beam:	17°
Spot Beam	4.5^{o}
(steerable in 17° earth coverage cone)	
• Receive Antennas	
Global Beam	17°

INTELSAT IVA

FREQUENCY:	C-band
LIFETIME:	7 years
TRANSPONDERS:	20
SATURATED EIRP:	(-3 db beam edge)
• Global Beam:	22.0 dbw
• Hemispheric Beam:	26.0 dbw
• Zone Beam:	29.0 dbw
G/T:	
• Global Beam:	-17.6 db/^{o}K
• Hemispheric Beam:	-11.6 db/^{o}K
BEAMWIDTH	
• Transmit Antennas	
Global Beam:	17°
Hemispheric Beam:	$17^{o} \times 8^{o}$
Zone Beam:	$5^{o} \times 8^{o}$
• Receive Antennas	
Global Beam:	17°
Hemispheric Beam:	$17^{o} \times 8^{o}$

INTELSAT: SATELLITE SPECIFICATIONS

INTELSAT IV

- The main requirements of the INTELSAT IV satellites were to provide increased capacity and operational flexibility while retaining compatibility with existing earth terminals.

- While previous INTELSAT satellites had only two communications transponders, the INTELSAT IV made full use of the allocated frequency spectrum (500 MHz bandwidth) and utilized 12 separate transponders to achieve efficient spectrum utilization.

- INTELSAT IV was the first satellite to have two narrow-beam transmitting antennas, with up to two repeaters capable of being connected to each spot beam. In addition, it has an earth coverage antenna for receiving and transmitting.

INTELSAT IVA

- The INTELSAT IVA was developed in response to high traffic demands in the North Atlantic area.

- It has the same satellite body and support subsystem as the INTELSAT IV except for more efficient solar cells.

- The satellite features 20 transponders. Sixteen tranponders are for hemispheric coverage and four are devoted to global coverage.

- The hemispheric transponders are divided into 2 groups (A and B) of 8 per group. Each transponder within a group (e.g., 1A, 2A, etc.) uses a separate frequency while the corresponding transponders of the other group (i.e., 1A corresponds to 1B and uses the same frequencies) are transmitted through separate hemispheric (zone) beams to enable frequency resue.

- One satellite transmit antenna radiates four zone beams: northeast and southeast beams (transmitting Group A transponders); and northwest and southwest beams (transmitting Group B transponders). Two zone beams can be interleaved (e.g., northeast and southeast or northwest and southwest) to create a hemispheric beam. Thus, two hemispheric beams are possible (west hemispheric beam and east hemispheric beam).

INTELSAT: SATELLITE STATUS

PACIFIC OCEAN

INTELSAT IV

F-4 (Reserve)
F-8 (Full-time service)

INTESAT IV-A

To Be Determined

ATLANTIC OCEAN

INTELSAT IV

F-2 (Reserve)
F-3 (Spare/Major Path)
F-7 (Leased service)

INTELSAT IV-A

F-1 (Full-time/Primary Path)
F-2 (Full-time/Major Path 1)
F-4 (Intended for full-time/ Major Path 2)

INDIAN OCEAN

INTELSAT IV

F-5 (Reserve)
F-1 (Full-time service)

INTELSAT IV-A

To Be Determined

NOTE: Status as of July 1977

INTELSAT: SATELLITE STATUS

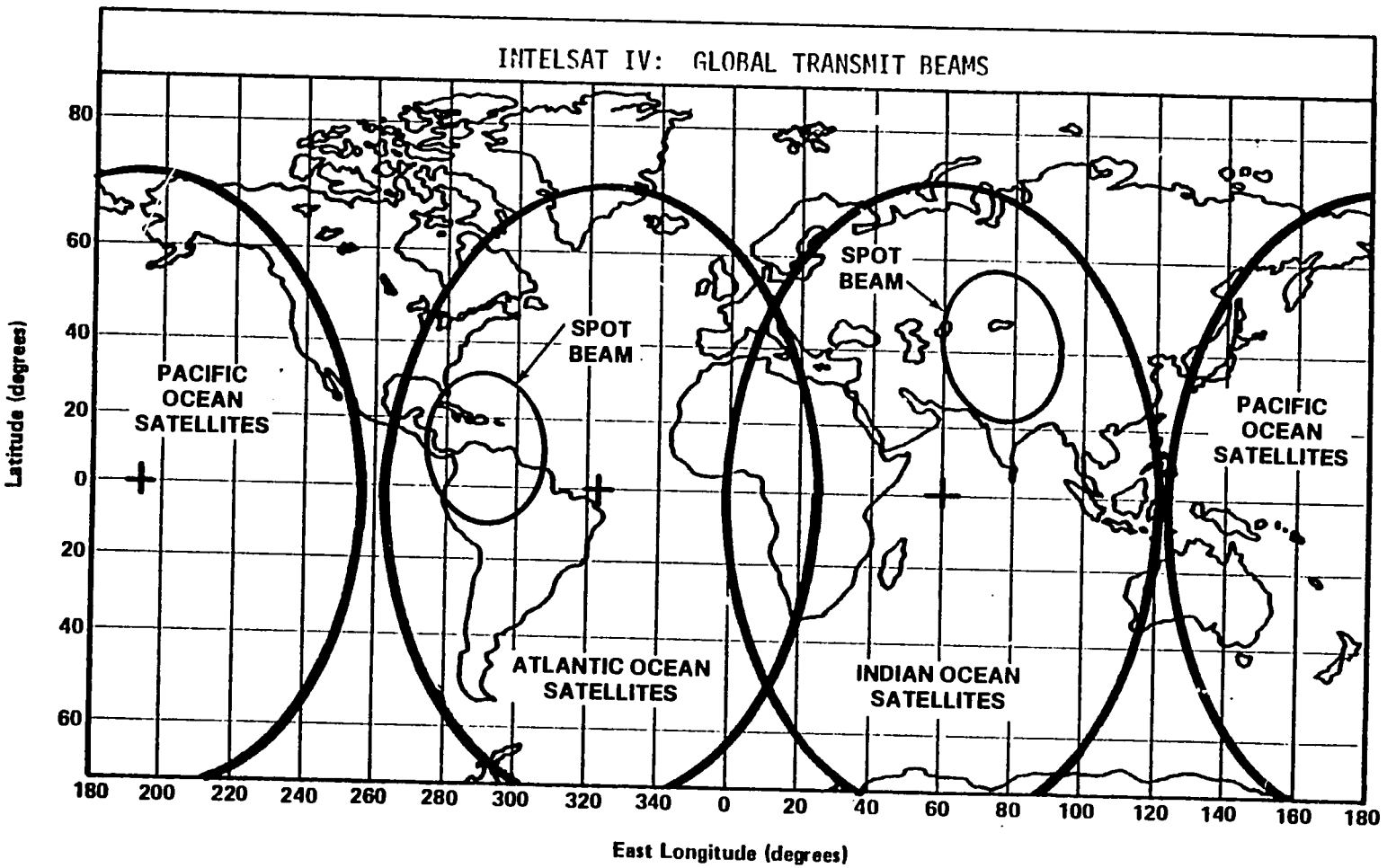
- In requesting lease of space segment capacity on a INTELSAT satellite, one does not specify any particular satellite. Rather, specification is made as to a desired antenna beam from among those that are available on the IV's and IVA's (i.e., global beam, spot beam, zone beam, or hemispheric beam) along with a variety of desired performance criteria. INTELSAT then reviews its satellite and transponder usage plans, and subsequently, determines which satellite and transponder is best suited and available for providing the requested lease service.

- The only satellites not available for domestic service is the Primary satellite over the Atlantic Basin and the Primary satellite over the Pacific Basin.

- Satellites over the Atlantic Basin may be used for domestic service in either Latin America or Africa. Satellites over the Pacific Basin may be used only for domestic service in Asia. Satellites over the Indian Basin may be for service in either Asia or Africa.

- The design life of the INTELSAT IV satellites is soon to expire (some in the late 70's and others in the early '80's). However, these satellites are expected to have a "residual life," implying they can continue to operate except during eclipse periods (which vary from a few minutes to slightly over an hour per day for portions of a year). Thus, continued use of the IV's throughout their "residual life" will be restricted for domestic lease only. This implies the IV satellites over the Atlantic Basin will be operable through 1982 and the satellites over the Pacific Basin operable through 1984.

INTELSAT: SATELLITE COVERAGE AREAS



NOTE: Spot beams are shown at a typical location, but can be repositioned by ground command anywhere within the global service area.

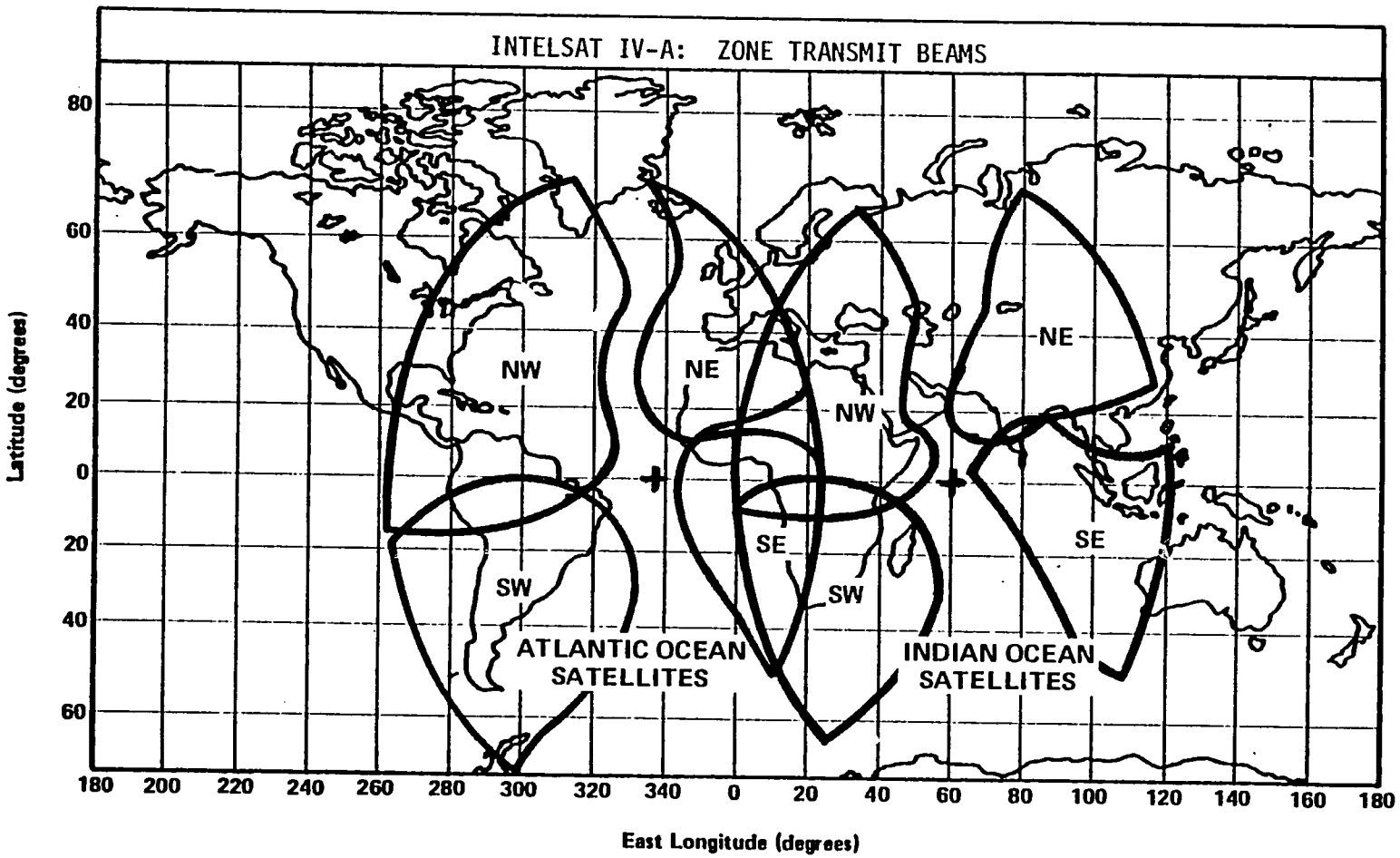
INTELSAT: SATELLITE COVERAGE AREAS

INTELSAT IV

- The global beams have a capability of covering approximately one-third the earth's surface, as seen by the satellite from geosynchronous orbit.

- Spot beams on the INTELSAT IV illuminate an area on the earth of approximately 2,000 miles in diameter (for a half-power beamwidth and beam center at a 30° latitude). These beams are steerable throughout the entire coverage area of the global beam.

INTELSAT: SATELLITE COVERAGE AREAS



INTELSAT: SATELLITE COVERAGE AREAS

INTELSAT IV-A

- Global beams of the IV-A are nearly identical in their coverage areas of the earth as those on the IV satellites.

- The zone beams on the IV-A provide regional coverage of the land areas as seen by the satellite. Two zone beams can be combined to provide hemispherical coverage. (For example, the northwest and southwest may be combined to create a western hemispherical beam.) This is achieved by the satellite "splitting" a signal from one zone beam with another zone beam in the same hemisphere. The result is western or eastern hemispherical coverage with an EIRP of the hemispherical beam 3 dB less than that of a zone beam.

INTELSAT: SERVICE CAPABILITIES

INTELSAT IVA: ZONE TRANSMIT BEAM							
SERVICE REQUIREMENTS	MASTER UPLINK			VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	G/T (dB/°K)	RF POWER (WATTS)	ANTENNA DIAMETER (meters)	G/T (dB/°K)	RF POWER (WATTS)	
TELEVISION (R/O) 1 Channel	10 m	-	1.4 kW	10 m	25.7 b)	-	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	10 m	25.7 b)	1.4 kW 2-3 W/vc	10 m	25.7 b)	2-3 W/vc	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 4 Channels	10 m	25.7 b)	1.4 kW 2-3 W/vc	10 m	25.7 b)	2-3 W/vc	FULL
TELEPHONY Multiple two-way (D) voice channels	10 m	25.7 b)	4-5 W/vc	4.57 m	19.0 b)	6 W/vc	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	-	37 W	4.57 m	19.0 b)	-	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m	25.7 b)	37 W 6 W/vc	4.57 m	19.0 b)	6 W/vc	QUARTER

a) Requires uncooled parametric preamp; noise temperature = 90°K

b) Requires GaAs FET preamp; noise temperature = 200°K

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: SERVICE CAPABILITIES

INTELSAT IV

GLOBAL TRANSMIT BEAM

- The INTELSAT IV is quite limited in the domestic service it can provide using the global transmit beam and small village site antennas. This is due to the relatively low EIRP transmitted by the satellite through the global beam and a restriction on the amount of power than can be applied to the antenna of Standard B master uplink earth terminal. Consequently, the INTELSAT IV cannot be used to provide television services through the global transmit beam using a Standard B earth terminal for a master uplink and a 10 m receive antenna at the village site. This service may be possible, however, if a Standard A earth terminal antenna is used for the master uplink and a 10 m antenna for the site.

- Telephony service is possible, although the satellite is extremely power limited, so only a small number of simultaneous channels (or active carriers) can be accommodated. For the requirements and constraints specified in this study, 3-4 active carriers (or 2 duplex channels) are possible, using the maximum available satellite EIRP of 11.0 dBw (for the quarter transponder). Note that a high RF power is necessary for both the master uplink and village site earth terminals. This is necessary in order to achieve the maximum available output power of the satellite transponder (since the transponder is operating in a linear back-off mode.

- The broadcast radio can be accommodated within the quarter transponder using the smaller village site antenna. However, because only 1 carrier is allotted to the entire quarter transponder, a slight additional back-off may be necessary to reduce any potential intermodulation problem within the remaining three-quarters of the transponder. Consequently, this service is marginal with a small antenna even if an uncooled parametric preamplifier is used.

- When broadcast radio is transmitted with one two-way voice channel, some additional back-off may be necessary (as in the case of transmitting only one program channel). However, one alternative is to increase the number of interactive simplex voice channels to a total of about four simultaneous voice channels. Since the link performance with a small antenna was marginal for a single broadcast channel, the addition of a two-way voice channel necessitates using a larger earth terminal at the village site. The result is that 4 simplex voice channels plus the broadcast radio channel can be accommodated.

INTELSAT: SERVICE CAPABILITIES

INTELSAT IV - GLOBAL TRANSMIT BEAM							
SERVICE REQUIREMENTS	MASTER UPLINK			VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	G/T (dB/°K)	RF POWER (WATTS)	ANTENNA DIAMETER (meters)	G/T (dB/°K)	RF POWER (WATTS)	
TELEVISION (R/O) 1 Channel	10 m	NOT TECHNICALLY PRACTICAL WITHIN THE OPERATING CONDITIONS OF THE INTELSAT SYSTEM.					FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	10 m	NOT TECHNICALLY PRACTICAL WITHIN THE OPERATING CONDITIONS OF THE INTELSAT SYSTEM.					FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 4 Channels	10 m	NOT TECHNICALLY PRACTICAL WITHIN THE OPERATING CONDITIONS OF THE INTELSAT SYSTEM.					FULL
TELEPHONY Multiple two-way (D) voice channels	10 m	25.7 b)	22 W/vc	4.57 m	19.0 b)	25 W/vc	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	-	65 W	4.57 m	21.1 a)	-	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m	25.7 b)	34 W 7-8 W/vc	10 m	25.7 b)	7-8 W/vc	QUARTER

a) Requires uncooled parametric preamp; noise temperature = 90°K

b) Requires GaAs FET preamp; noise temperature = 200°K

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: SERVICE CAPABILITIES

INTELSAT IV

SPOT TRANSMIT BEAM

- The INTELSAT IV spot beam provides a saturated EIRP almost 12 dB greater than that of the global antenna beam. Consequently, television service is possible using a Standard B master uplink antenna and a 4.57m village site antenna with an uncooled paramp operating with the maximum allowable power (about 1.4 k watts) that can be radiated into an uplink Standard B antenna. For purposes of this study, in order to demonstrate what might be possible if INTELSAT were to allow more power into the uplink Standard B antenna, it is shown that a smaller 4.57 m antenna using a GaAS FET preamp can provide adequate television service (in addition to several two-way voice channels). To have INTELSAT accept the higher power levels of the uplink terminal, a study would be necessary to evaluate techniques for suppressing the increased sidelobe power levels of the uplink antenna.

- Telephony service is provided efficiently using the spot transmit beam. Within a quarter transponder, operating at a maximum allocated EIRP of about 22 dBW, approximately 40 active carriers (or 20 duplex voice channels can be accommodated.

- Broadcast radio service requires additional transponder back-off from the available maximum power because only 1 carrier is active within the allotted quarter transponder capacity. However, instead of reducing the satellite's radiated power, two and possibly three additional broadcast channels can be transmitted simultaneously.

- A two-way simplex voice channel can be accommodated within the same quarter transponder as the broadcast channel, although some additional back-off is necessary. An additional 19 simplex voice channels can be accommodated if no additional back-off is applied.

INTELSAT: SERVICE CAPABILITIES

INTELSAT IV: SPOT TRANSMIT BEAM							
SERVICE REQUIREMENTS	MASTER UPLINK			VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	G/T (dB/^{o}K)	RF POWER (WATTS)	ANTENNA DIAMETER (meters)	G/T (dB/^{o}K)	RF POWER (WATTS)	
TELEVISION (R/O) 1 Channel	10 m	-	3 kW	4.57 m	19.0 b)	-	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	10 m	25.7 b)	3 kW 2 W/vc	4.57 m	19.0 b)	5 W	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 4 Channels	10 m	25.7 b)	3 kW 2 W/vc	4.57 m	19.0 b)	5 W/vc	FULL
TELEPHONY Multiple two-way (D) voice channels	10 m	25.7 b)	1-2 W/vc	4.57 m	19.0 b)	4 W/vc	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	-	15 W	4.57 m	19.0 b)	-	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m	25.7 b)	12 W 2-3 W/vc	4.57 m	19.0 b)	4 W/vc	QUARTER

a) Requires uncooled parametric preamp; noise temperature = 90°K

b) Requires GaAs FET preamp; noise temperature = 200°K

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: SERVICE CAPABILITIES

INTELSAT IV-A

ZONE TRANSMIT BEAM

- The INTELSAT IV-A, transmitting through the zone beam, has a slightly less EIRP than the INTELSAT IV spot transmit beam. However, the IV-A satellite G/T is significantly higher than the IV, and so, system performance of both satellites are somewhat comparable.

- The effect of using a Standard B master uplink antenna, with limited uplink radiated power (as specified by INTELSAT) requires use of a 10 m antenna at the village site for television service. If increased power can be applied to the Standard B uplink antenna and a further study of modulation values is conducted, then it may be possible to use the smaller 4.57 m village site antenna with a GaAs FET preamp.

- Telephony is easily provided using a small village antenna. Approximately 16 simultaneously active carriers (8 duplex channels) can be accommodated within a quarter transponder.

- The broadcast radio channel, occupying an entire quarter transponder, can be provided if additional backoff to the uplink carrier is applied. Alternatively, a second channel can be accommodated.

- A broadcast radio channel with two-way simplex voice is provided within a quarter transponder if additional backoff is again applied to uplink carrier. However, if all the available power allocated for the quarter transponder is used, about 6 simultaneous simplex voice channels can be accommodated in addition to the broadcast channel.

SYMPHONIE: SYSTEM DESCRIPTION

TOTAL SPACE SEGMENT

2 satellites

SATELLITE SERVICES

Fixed Stations:	1 Color Television Channel, or 2 Television Channels (degraded), or 600 telephone circuits
Mobile Station:	Same as fixed stations
Receive-Only:	Black-and-white television
Two-way Voice:	50-100 telephone circuits, or 6 broadcast radio channels

TOTAL EARTH SEGMENT

3 Fixed Service Stations

1 Mobile Stations

Multiple Receive-only Television Stations

Multiple Two-way Voice-only stations

EARTH STATION CHARACTERISTICS

Fixed Service:	Diameter	= 16 meters
	G/T	= 31.5 dB/^{o}K
Mobile Service:	Diameter	= 12 meters
	G/T	= 31.5 dB/^{o}K
Receive-Only:	Diameter	= 8.8 meter
	G/T	= 26.5 dB/^{o}K
Two-Way Voice:	Diameter	= 4.0 meters
	G/T	= 20.0 dB/^{o}K

SYMPHONIE: SYSTEM DESCRIPTION

- The Symphonie project is a joint activity of the governments of France and the Federal Republic of Germany, initiated by a signed agreement in June 1967. The project intended to define, develop, manufacture, launch, and utilize two flight units of an experimental communications satellite as well as the construction of multiple earth terminals.

- A joint governmental organization was established to manage and control the project. However, this joint organization is now disbanded, and each country, through its space agency, manages current project activities.

- The Symphonie project was primarily experimental. A Technical Test activity consisted of about 40 experiments to evaluate the spacecraft communications performance. An Operational Test activity sought to evaluate use of the satellite with small earth terminals for public and/or specialized communications services.

SYMPHONIE: SATELLITE SPECIFICATIONS

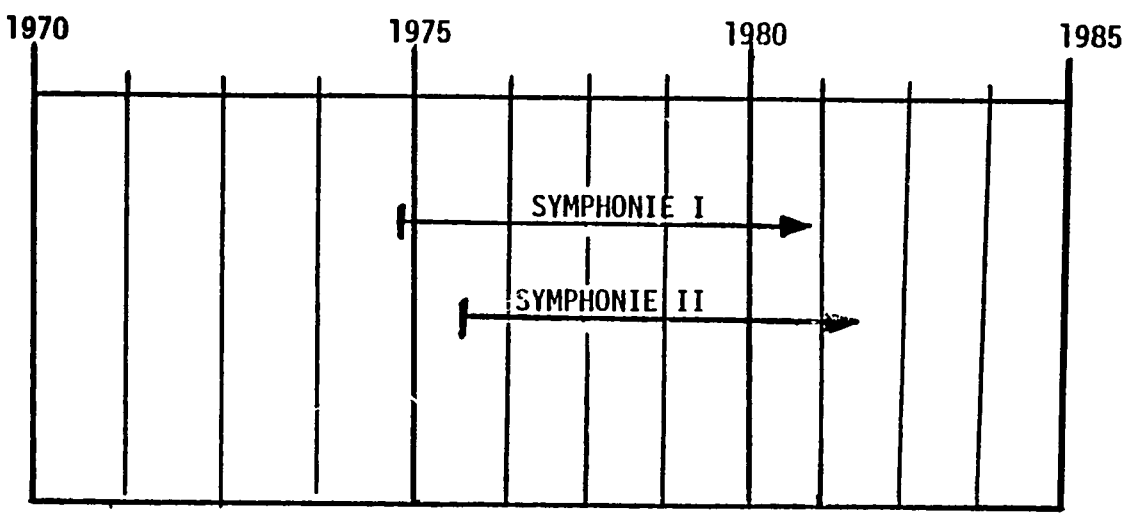
Transponders:	2 (operate simultaneously)
Bandwidth:	90 MHz/transponder
Frequency:	C-Band
Lifetime:	5 years
EIRP (@ beam edge):	29 dbw
Transmit Antenna	
Beamwidth:	$8^{o} \times 13^{o}$
Number of beams:	2
Receive Antenna	
Beamwidth:	17.2^{o} (earth coverage)
Number of beams:	1
G/T:	-15 db/^{o}K

SYMPHONIE: SATELLITE SPECIFICATIONS

- The Symphonie satellites feature 2 transponders. Each transponder transmits into a hemispherical-type antenna: one antenna covers most of Europe and Africa; the other antenna covers the eastern U.S., Canada, and parts of South America. The satellite receives signals from earth terminals through a single earth coverage antenna.

- The Symphonie plan calls for two operational satellites in orbit over the Atlantic Ocean. The transmitting and receiving frequencies of these two satellites are not identical, but interleaved. Thus, the two satellites can be placed very close to each other in orbit without mutual interference. To ground terminals, they appear as a single satellite with four transponders.

SYMPHONIE: AVAILABILITY FOR DOMESTIC SERVICE



SYMPHONIE I is located @ 348.5^{o}E Longitude for service to Central/South America and Europe/Africa.

SYMPHONIE II is located @ 40°E Longitude for service to India.

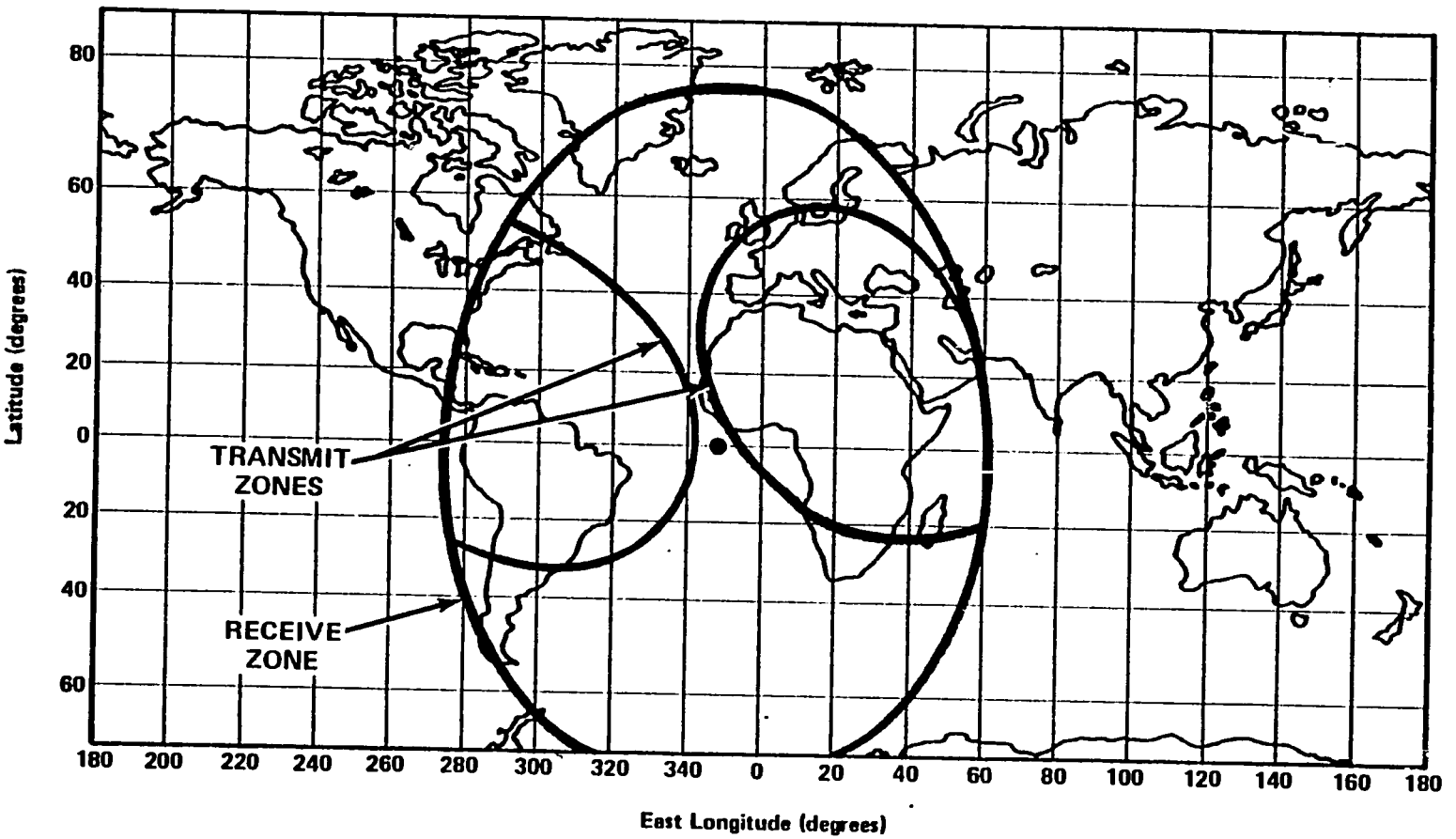
SYMPHONIE: AVAILABILITY FOR DOMESTIC SERVICE

- Both satellites were launched approximately 6 months apart over the Atlantic Ocean, and entered service together in June 1976. Later that year, one satellite (Symphonie I) was moved eastward, where it is currently providing experimental service to India. Thus, only one satellite (Symphonie II) is available for domestic service in Africa.

- Since the Symphonie satellites have about 2½-3 years of their design life remaining, they can be considered useful for domestic use. After their design life expires, they may have a residual life of several more years. This is typical of most satellites, and since both Symphonie satellites appear "healthy" at this time, a residual life is expected.

- The only problem with Symphonie for domestic availability is that no follow-on satellite service is anticipated. Thus, any investment in earth terminal facilities, could be wasted after the satellite ceases to be operational.

SYMPHONIE: SATELLITE COVERAGE AREAS



SYMPHONIE: SATELLITE COVERAGE AREAS

- The Symphonie satellite located over the Atlantic Ocean radiates two fixed transmit antenna beams. A western beam illuminates the eastern coast of the United States and all of South America. The eastern beam illuminates most of Europe and Africa.

- The satellite receive beam has global coverage and illuminates all surface area of the earth as seen from geosynchronous orbit which includes the area of coverage by two transmit beams.

SYMPHONIE: SERVICE CAPABILITIES

SERVICE REQUIREMENTS	MASTER UPLINK			VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	G/T (dB/°K)	RF POWER (WATTS)	ANTENNA DIAMETER (meters)	G/T (dB/°K)	RF POWER (WATTS)	
TELEVISION (R/O) 1 Channel	10 m	-	2 kW	10 m	25.7 b)	-	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	10 m	25.7 b)	2 kW 2-3 W/vc	10 m	25.7 b)	2-3 W/vc	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 4 Channels	10 m	25.7 b)	2 kW 2-3 W/vc	10 m	25.7 b)	2-3 W/vc	FULL
TELEPHONY Multiple two-way (D) voice channels	10 m	25.7 b)	1-2 W/vc	4.57 m	19.0 b)	7 W/vc	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	-	80 W	4.57 m	19.0 b)	-	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m	25.7 b)	2-3 W/vc	4.57 m	19.0 b)	5 W/vc	QUARTER

a) Requires uncooled parametric preamp; noise temperature = 90°K

b) Requires GaAs FET preamp; noise temperature = 200°K

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

SYMPHONIE: SERVICE CAPABILITIES

- The Symphonie satellite performance is somewhat of a combination of the INTELSAT IV and IV-A. It radiates the same EIRP as the IV-A and has the same receiver sensitivity as the IV:

- Television service can be provided with a 10 m antenna at the village site. Uplink power to the satellite from the master antenna is limited by the specified saturated flux density at the satellite. As of this time, there appears to be no other constraint on the uplink power.

- Telephony is possible with small village site antennas. A total of about 20 simultaneous carriers (10 duplex voice channels) can be accommodated, due to the limited satellite EIRP available within a quarter transponder.

- Broadcast radio service is possible and may not require any additional back-off if only one channel is within the quarter transponder bandwidth (because of the wide bandwidth of a Symphonie transponder). However, there is adequate power to provide two simultaneous broadcast channels.

- Two-way voice with a broadcast channel is easily provided. It may be possible to accommodate a total of 5-6 simplex voice channels simultaneously.

JBS: SYSTEM DESCRIPTION

TOTAL SPACE SEGMENT

1 satellite

SATELLITE SERVICES

Television Distribution

TOTAL EARTH SEGMENT

2 Transportable receive-and-transmit terminals.

Several receive-only terminals with community-size antennas.

10-100 receive-only terminals with small-size terminals.

EARTH TERMINAL CHARACTERISTICS

Small-Size:	Diameter	= 4.5m
	G/T	= 25 dB/^{o}K
	EIRP	= 81 dBw
Transportable:	Diameter	= 1.6m
	G/T	= 15 dB/^{o}K
Community:	Diameter	= 4.5m
	G/T	= 25 dB/^{o}K
Main Uplink	Diameter	= 12.0m
	EIRP	= 83 dBw

JBS: SYSTEM DESCRIPTION

- The "Medium-Scale Broadcasting Satellite for Experimental Broadcasting Purposes", or more commonly referred to as the Japanese Broadcast Satellite (JBS), is a program sponsored by the National Space Development Agency of Japan (NASDA) with participation of the Japanese Broadcasting Corporation (NHK), the Japanese Ministry of Post and Telecommunications (MOPT), and the Radio Research Laboratories (RRL).

- Main objectives of the program are: (i) achieve a new performance level in TV broadcasting through development of satellite broadcast communications technology; and (ii) the determination of procedures for operating the satellite in orbit.

- Concepts in satellite TV systems will be evaluated to measure the potential for:

  (1) Economic coverage of a large, defined geographic area with mountainous and remote areas where terrestrial systems would require transmitters for relatively few users.

  (2) High quality TV reception within all regions of the broadcast area, with no ghosts from nearby buildings and no signal degredation due to rebroadcast by multiple ground transmitters.

  (3) Individual home reception of high power satellites transmission using small low cost and low noise receivers.

  (4) Ability to work around difficult environmental conditions (eg., heavy rain) by alternate ground-to-satellite transmission techniques and power adjustments.

JBS: SATELLITE SPECIFICATIONS

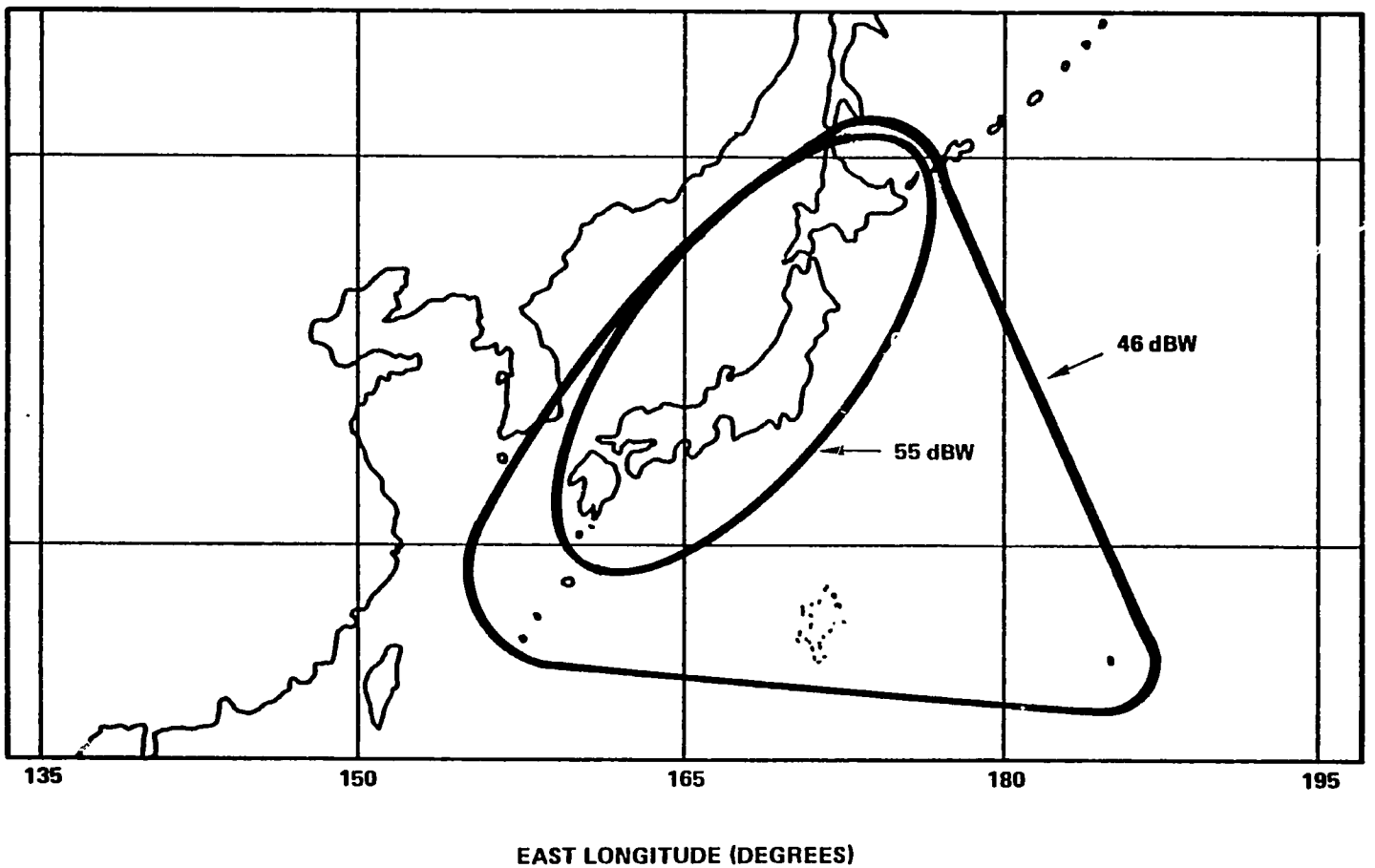
Transponders:	3 (2 active; 1 standby)
Bandwidth:	1 - 50 MHz/transponder 1 - 80 MHz/transponder
Frequency:	Ku-Band
Lifetime:	3 years
EIRP (@ beam edge):	55 dbw minimum, for primary area 46 dbw minimum, for fringe areas
Transmit Antenna:	
Beamwidth:	$1.4^{o} \times 2^{o}$ (@ - 4dB)
Number of beams:	1

JBS: SATELLITE SPECIFICATIONS

- The JBS features two active transponders capable of transmitting two independent TV channels. One transponder has a 50 MHz bandwidth and transmits 1 TV channel. (Tests will be conducted to show whether it can accommodate two simultaneous separate TV channels of satisfactory quality). The other transponder, with an 80 MHz bandwidth, will be used to test new transmission and modulation techniques (such as digital television modulation).

- The JBS transmitter uses a 100 watt high power TWT amplifier which operates at 50 percent efficiency. It results in a peak effective radiated power of 59 dBw (which is the same as the US/Canada Communications Technology Satellite).

JBS: SATELLITE COVERAGE AREAS



JBS: SATELLITE COVERAGE AREAS

- The JBS satellite transmit antenna consists of a three-horn feed. It results in a shaped beam with optimized gain on the Japanese main islands and the remote islands of Okinawa and Ogasawara. The sharp gain drop-off on the beam's western edge enables the JBS to satisfy international requirements, while providing weaker, but adequate coverage,of the southern and southeastern islands.

JBS: SERVICE CAPABILITIES

SERVICE REQUIREMENTS	MASTER UPLINK			VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	G/T (dB/^{o}K)	RF POWER (WATTS)	ANTENNA DIAMETER (meters)	G/T (dB/^{o}K)	RF POWER (WATTS)	
TELEVISION (R/O) 1 Channel	5 m	--	120 W	1.8 m	16.2	--	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	5 m	25.1	120 W <1 W/vc	1.8 m	16.2	<1 W/vc	FULL
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 4 Channels	5 m	25.1	120 W <1 W/vc	1.8 m	16.2	<1 W/vc	FULL
TELEPHONY Multiple two-way (D) voice channels	5 m	25.1	<1 W/vc	1.8 m	16.2	<1 W/vc	QUARTER
BROADCAST RADIO (R/O) 1 Channel	5 m	--	3 W	1.8 m	16.2	--	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	5 m	25.1	3 W <1 W/vc	1.8 m	16.2	<1 W/vc	QUARTER

Requires GaAs FET preamp; noise temperature = 660° K.

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

JBS: SERVICE CAPABILITIES

- The Japanese Broadcast Satellite is designed for distribution of broadcast television to small diameter, low-cost, village site terminals. Consequently, the satellite performs exceptionally well for telephony and broadcast radio service.

- The JBS may not be economically practical for most of AID's required services because it can accommodate only two transponders. (In comparison, the RCA SATCOM satellite generates almost the same electrical power from its solar arrays but accommodates 24 medium-powered C-Band transponders). The limited transponder capacity of JBS results in a very high cost per transponder. Thus, while the satellite is designed to operate with low-cost earth terminals, these costs may be off-set by the high costs of the satellite transponder.

- Satellite transmission in the Ku-Band is significantly affected by rain. The amount of rain attenuation varies directly with the intensity of rainfall at the uplink and village sites. For the analyses presented in this study, no rain margin was included in the RF power requirements. If a 10 db rain margin on the uplink and a 7 db margin on the downlink is assumed, the required RF power for the master uplink would increase by a factor of 10 for each service. This power increase is most noticeable for television (requiring 1.2 kw) and broadcast radio service (requiring 30 w). For telephony and two-way voice, the RF power may be increased to require a total of 1 watt.

- Telephony and two-way voice services require very little power into the earth terminal antennas (because of the high satellite EIRP). Calculations indicate that less than one watt is necessary for any voice channel.

- A minimum of at least 100 simultaneous carriers (50 duplex voice channels) can be accommodated within a quarter transponder.

- One broadcast radio channel can easily be accommodated within a quarter transponder, if appropriate TWT back-off is applied. Alternatively, less back-off may be applied and 4-6 channels accommodated simultaneously (although intermodulation may be a problem).

- Two-way voice can easily share a quarter transponder with a broadcast channel. The total number of voice carriers (simplex channels) is 20 or more.

ASSESSMENT
OF
CANDIDATE COMMUNICATIONS
SATELLITE SYSTEMS
FOR
DEVELOPING COUNTRIES

PART IV

COSTS

INTELSAT: TRANSPONDER TARIFFS

ANNUAL LEASE CHARGES FOR INTELSAT IV: GLOBAL BEAM

	TRANSPONDER CAPACITY		
	ONE-QUARTER	ONE-HALF	FULL
Preemptible*	$0.25 M	$0.5M	$1.0M
Nonpreemptible**	NOT AVAILABLE	$1.38M	$2.76 M

* Preemptible: Service is interruptible without any immediate guarantee of restoral.

** Nonpreemptible: Service is non-interruptible and must be restored as soon as possible.

INTELSAT: TRANSPONDER TARIFFS

- Space segment capacity is leased in increments of full, one-half, or one-quarter transponder.

- Base price of a transponder lease is $1M per year per transponder for preemptible service (based upon a five year commitment). Prices for less than a full transponder are proportionally pro-rated.

- Base price of a transponder lease for nonpreemptible service is 360 units/year per full transponder, where a unit value is $7380. (This price, however, is expected to decrease at the rate of 5-6% per year). Correspondingly, nonpreemptible service for a half transponder is 180 units/year. A commitment for nonpreemptible service is on an annual basis only.

- Tariffs for lease of an INTELSAT IV spot beam or a IV-A zone beam are not yet available primarily because there are no requests for this type of transponder service (although these tariffs are not expected to vary too much from the current levels). In addition, there are no tariffs available for lease of IV capacity during the satellites' residual life. However, these prices should be less than those currently being offered.

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV - SPOT TRANSMIT BEAM						
SERVICE REQUIREMENTS	MASTER UPLINK		VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	COST 1 UNIT	ANTENNA DIAMETER (meters)	COST 1 UNIT	COST 100 UNITS	
TELEVISION (R/O) 1 Channel	10 m	$ 83K	4.57 m b)	$28K	$22K	FULL
TELEVISION (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$101K	4.57 m b)	$52K	$42K	FULL
TELEVISION (R/O) 1 Channel Two-way Voice (S) 4 Channels	10 m b)	$119K	4.57 m b)	$70K	$56K	FULL
TELEPHONY Multiple two-way(D) voice channels	10 m b)	$ 65K (1 ch) $ 6K/addt'l ch	4.57 m b)	$40K (1 ch) $6K/addt'l ch	$32K (1 ch) $5K/addt'l ch	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	$ 80K	4.57 m b)	$15K	$12K	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$ 88K	4.57 m b)	$48K	$39K	QUARTER

a) Requires uncooled parametric preamp; noise temperature = $90^{o}K$

b) Requires GaAs FET preamp; noise temperature = $200^{o}K$

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV - GLOBAL TRANSMIT BEAM						
SERVICE REQUIREMENTS	MASTER UPLINK		VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	COST 1 UNIT	ANTENNA DIAMETER (meters)	COST 1 UNIT	COST 100 UNITS	
TELEVISION (R/O) 1 Channel	10 m	NOT TECHNICALLY PRACTICAL WITHIN THE OPERATING CONDITIONS OF THE INTELSAT SYSTEM.				FULL
TELEVISION (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m	NOT TECHNICALLY PRACTICAL WITHIN THE OPERATING CONDITIONS OF THE INTELSAT SYSTEM.				FULL
TELEVISION (R/O) 1 Channel Two-way Voice (S) 4 Channels	10 m	NOT TECHNICALLY PRACTICAL WITHIN THE OPERATING CONDITIONS OF THE INTELSAT SYSTEM.				FULL
TELEPHONY Multiple two-way(D) voice channels	10 m b)	$65K (1 ch) $6K/addt'l ch	4.57 m b)	$40K (1 ch) $6K/addt'l ch	$32K (1 ch) $5K/addt'l ch	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	$80K	4.57 m a)	$24K	$19K	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$88K	10 m b)	$71K	$57K	QUARTER

a) Requires uncooled parametric preamp; noise temperature = $90^{o}K$

b) Requires GaAs FET preamp; noise temperature = $200^{o}K$

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV

GLOBAL TRANSMIT BEAM

- There are no cost projections for any television service because use of 10 m antennas on both the uplink and downlink does not yield an acceptable quality signal.

- Telephony service has a base cost for the antenna, high power amplifiers (HPA's), low-voice amplifiers (LNA's), power supply, and other common equipments. Once a terminal is installed to provide one channel (duplex), several others can be added for the cost of additional SCPC equipment (which is purchased on a per channel basis). Note, however, the village site HPA has an output of 40 watts (another HPA is necessary to accommodate each additional channel).

- The village earth terminals for broadcast channel service are quite inexpensive by virture of recent developments in the U.S. in response to the plans of several broadcast ratio networks (NPR and Mutual Radio). These costs become lower (as shown for the spot beam) when a GaAs FET is used instead of an uncooled paramp. Although the costs shown for a village terminal are for one program channel, additional program channels can be added for about 5K per channel.

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV - SPOT TRANSMIT BEAM						
SERVICE REQUIREMENTS	MASTER UPLINK		VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	COST 1 UNIT	ANTENNA DIAMETER (meters)	COST 1 UNIT	COST 100 UNITS	
TELEVISION (R/O) 1 Channel	10 m	$ 83K	4.57 m b)	$28K	$22K	FULL
TELEVISION (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$101K	4.57 m b)	$52K	$42K	FULL
TELEVISION (R/O) 1 Channel Two-way Voice (S) 4 Channels	10 m b)	$119K	4.57 m b)	$70K	$56K	FULL
TELEPHONY Multiple two-way(D) voice channels	10 m b)	$ 65K (1 ch) $ 6K/addt'l ch	4.57 m b)	$40K (1 ch) $6K/addt'l ch	$32K (1 ch) $5K/addt'l ch	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	$ 80K	4.57 m b)	$15K	$12K	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$ 88K	4.57 m b)	$48K	$39K	QUARTER

a) Requires uncooled parametric preamp; noise temperature = $90^{o}K$

b) Requires GaAs FET preamp; noise temperature = $200^{o}K$

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV

SPOT TRANSMIT BEAM

- The high EIRP of the INTELSAT IV spot transmit beam make possible television service and television with two-way voice services using the least expensive village site earth terminals. Assuming that adequate uplink power can be applied to the master uplink antenna, a small antenna village earth terminal with a GaAs FET preamp can be used at the village site. Since this type of terminal is currently in use throughout the United States for cable television distribution service (more than 150 of these terminals are now in operation), their costs are well established and remarkably low.

- The earth terminals for telephony, broadcast channel, and broadcast channel with two-way voice services all use the small antennas and inexpensive preamps. Consequently, they too can utilize equipment that has been or will be installed for similar applications throughout the U.S.(both in the lower 48 states and Alaska).

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV A - ZONE TRANSMIT BEAM						
SERVICE REQUIREMENTS	MASTER UPLINK		VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	COST 1 UNIT	ANTENNA DIAMETER (meters)	COST 1 UNIT	COST 100 UNITS	
TELEVISION (R/O) 1 Channel	10 m	$83K	10 m b)	$53K	$43K	FULL
TELEVISION (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$101K	10 m b)	$77K	$62K	FULL
TELEVISION (R/O) 1 Channel Two-way Voice (S) 4 Channels	10 m b)	$119K	10 m b)	$95K	$76K	FULL
TELEPHONY Multiple two-way(D) voice channels	10 m b)	$65K (1 ch) $6K/addt'l ch	4.57 m b)	$40K (1 ch) $6K/addt'l ch	$32K (1 ch) $5K/addt'l ch	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	$80K	4.57 m b)	$15K	$12K	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$88K	4.57 m b)	$48K	$39K	QUARTER

a) Requires uncooled parametric preamp; noise temperature = $90^{o}K$

b) Requires GaAs FET preamp; noise temperature = $200^{o}K$

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

INTELSAT: EARTH TERMINAL COSTS

INTELSAT IV-A

ZONE TRANSMIT BEAM

- The INTELSAT IV-A requires use of a 10 m village site antenna primarily because its EIRP is slightly too low for a 4.5 m antenna (as compared with the IV spot transmit beam) and the uplink power is restricted. This results in a significantly higher cost for the village site than if a smaller 4.57 m antenna were used. The master uplink transmit terminal, however, is less expensive than that used for the IV spot transmit beam, reflecting the lower power applied to the antenna.

- The IV-A provides telephony, broadcast radio, and broadcast radio with two-way voice with the same equipment (but slightly different operating levels) as required for the IV global and spot transmit beams.

SYMPHONIE: EARTH TERMINAL COSTS

SERVICE REQUIREMENTS	MASTER UPLINK		VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	COST 1 UNIT	ANTENNA DIAMETER (meters)	COST 1 UNIT	COST 100 UNITS	
TELEVISION (R/O) 1 Channel	10 m	$83K	10 m b)	$53K	$42K	FULL
TELEVISION (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$101K	10 m b)	$77K	$62K	FULL
TELEVISION (R/O) 1 Channel Two-way Voice (S) 4 Channels	10 m b)	$119K	10 m b)	$95K	$76K	FULL
TELEPHONY Multiple two-way(D) voice channels	10 m b)	$65K (1 ch) $6K/addt'l ch	4.57 m b)	$40K (1 ch) $6K/addt'l ch	$32K (1 ch) $5K/addt'l ch	QUARTER
BROADCAST RADIO (R/O) 1 Channel	10 m	$80K	4.57 m b)	$15K	$12K	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	10 m b)	$88K	4.57 m b)	$48K	$39K	QUARTER

a) Requires uncooled parametric preamp; noise temperature = $90^{o}K$

b) Requires GaAs FET preamp; noise temperature = $200^{o}K$

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

SYMPHONIE: EARTH TERMINAL COSTS

- Since the Symphonie satellite has similar operating characteristics as the INTELSAT IV-A zone beam, the earth terminal requirements and costs are very similar.

- The Symphonie uses more uplink power because the satellite receive sensitivity is less than that of the IV-A zone beam; hence the cost of the uplink HPA for television service is a bit greater.

- It should be noted, that other size earth terminal antennas for village sites were designed to be used with the Symphonie satellite. However, an examination of these terminals, particularly their design, component performance, and costs, was not possible because they were European manufactured and no information from these manufacturers was readily available.

JBS: EARTH TERMINAL COSTS

SERVICE REQUIREMENTS	MASTER UPLINK		VILLAGE SITE			ALLOTTED TRANSPONDER CAPACITY
	ANTENNA DIAMETER (meters)	COST 1 UNIT	ANTENNA DIAMETER (meters)	COST 1 UNIT	COST 100 UNITS	
TELEVISION (R/O) 1 Channel	5 m	$56 K	1.8 m	$18 K	$14 K	FULL
TELEVISION (R/O) 1 Channel plus Two-way voice (S) 1 Channel	5 m	$74 K	1.8 m	$37 K	$30 K	FULL
TELEVISION (R/O) 1 Channel Two-way Voice (S) 4 Channels	5 m	$92 K	1.8 m	$52 K	$42 K	FULL
TELEPHONY Multiple two-way(D) voice channels	5 m	$33 K $6 K/addt'l vc	1.8 m	$23 K $6 K/addt'l vc	$18 K $5 K/addt'l vc	QUARTER
BROADCAST RADIO (R/O) 1 Channel	5 m	$23 K	1.8 m	$8 K	$6 K	QUARTER
BROADCAST RADIO (R/O) 1 Channel plus Two-way voice (S) 1 Channel	5 m	$41 K	1.8 m	$17 K	$14 K	QUARTER

R/O - receive-only
(S) - simplex channel
(D) - duplex channel
vc - voice channel

JBS: EARTH TERMINAL COSTS

- The high EIRP of the JBS enables use of small earth terminal antennas solid-state (GaAs FET) preamplifiers, and low-powered HPA's. This results in a total earth terminal cost that is significantly less than the cost achieved with a C-Band satellite system (particularly the INTELSAT or Symphonie satellites).

- Costs for Ku-Band satellite earth terminals is currently in transition as use of this frequency band is becoming widespread. The JBS will be deployed soon, to be followed by Ku-Band systems in the United States, Canada and Europe (particularly West Germany). Consequently, the future prices of Ku-Band earth terminals should be less expensive in the next 5-10 years in response to these new satellite systems.

- The prices of Ku-Band earth terminals that were formulated for this study reflect current market prices. Since Ku-Band is not now being used for any service other than television, cost estimates (rather than actual equipment sales) were assumed for earth terminals that provide telephony and broadcast radio.

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PART V

POLICY AND
PROCEDURES

INTELSAT: DOMESTIC LEASE POLICY

- DOMESTIC SERVICES VIA TRANSPONDER LEASE BEGAN IN 1973.
- INTELSAT CURRENTLY LEASES SPACE SEGMENT CAPACITY IN INCREMENTS OF ONE-QUARTER, ONE-HALF, OR FULL TRANSPONDERS.
- MOST CURRENT LEASES ARE FOR PRE-EMPTIBLE SERVICE.
- DOMESTIC LEASES ARE TYPICALLY FOR FIVE YEARS. ALTHOUGH NOT MANDATORY.
- NO POLICY EXISTS FOR USE OF SPOT OR ZONE BEAMS, BUT THERE ARE STRONG INDICATIONS THAT A REQUEST FOR SUCH CAPABILITY WOULD BE FAVORABLY RECEIVED.

INTELSAT: DOMESTIC LEASE POLICY

- INTELSAT Definitive Agreements, which become effective in February 1973, made provision for lease of satellite capacity in domestic service. The agreements state that INTELSAT space segment capacity not required for the global public networks shall be available for domestic services between areas separated by oceans or within areas not linked by terrestrial facilities and where natural barriers hinder and establishment of such facilities.

- Leased satellite capacity is provided on either an unused transponder in an active satellite or on a transponder in spare satellite.

- Space segment capacity is based in increments of quarter, half, and full transponders.

- Service is available on a preemptible or nonpreemptible basis, (which relates to the priority of restoration in case of satellite failure). Nearly all current leases are for preemptible service because of the proven reliability of the satellites (<1 hour outage/year) and the lower cost (one-third the preempitble rate).

- Present INTELSAT domestic leases are for transponder capacity on the IV satellites using the global beams. There is no current INTELSAT policy regarding use of the IV spot beams or the IVA zone beams, primarily because no country has yet to make a request for such use. It is anticipated, however, that such a request would receive a favorably reply in view of recent trends within INTELSAT to liberalized its policy towards domestic leasing. (For example, Nigeria is now conducting experiments for use of a IV spot beam and such lease request my be forthcoming).

INTELSAT: PROCEDURES TO ACQUIRE USE OF INTELSAT FOR DOMESTIC SERVICE

STEP 1: SUBMIT REQUEST FOR ALLOTMENT OF SPACE SEGMENT CAPACITY AND ACQUIRE APPROVAL IN PRINCIPLE.

STEP 2: SUBMIT TRANSMISSION PLAN AND EARTH STATION APPLICATION FOR REVIEW.

STEP 3: RECEIVE FORMAL APPROVAL FOR ALLOTMENT OF SPACE SEGMENT AND NEGOTIATE LEASING ARRANGEMENTS.

STEP 4: RECEIVE CONCURRENCE OF TRANSMISSION PLAN AND EARTH STATION APPLICATION.

INTELSAT: PROCEDURES TO ACQUIRE USE OF INTELSAT FOR DOMESTIC SERVICE

- The first step is to submit a request to the Director General by the appropriate Signatory for allotment of space segment capacity. This request is accompanied by a description of the system design (which includes such information as number, type, and size of earth terminals, types of signals, coverage area, basic performance requirements, etc.). Upon review of this request, approval (in principal) for lease of the requested space segment will be granted by the Board of Governors.

- Then the allottee is required to submit its transmission plan for operational use of the leased capacity to the Management Services Contractor for review prior to implementation. This will insure that interference due to intermodulation noise and emissions in the direction of an adjacent satellite will not be excessive. In addition, the allotte must submit an earth terminal application. The information in this application may vary depending on whether the earth terminal is standard or non-standard. It will be reviewed by the Management Services Contractor concurrently with the transmission plan.

- Final approval for allotment of space segment capacity is then given to the allottee with a copy of the allotment agreement. At that time, negotiations are conducted between the allottee and INTELSAT concerning the conditions and costs for use of the space segment.

- Within three months after submitting a request for allotment of space segment capacity (although 6 months is usually required if a non-standard earth terminal will be used), concurrence is reached as to the proper transmission plan and earth terminal characteristics. This may require a series of discussions with INTELSAT in order to modify the transmission plan and/or earth terminal characteristics to be compatible with the INTELSAT system.

INTELSAT: PROCEDURES FOR USE OF NON-STANDARD EARTH TERMINALS

STEP 1: ACQUIRE APPROVAL IN PRINCIPAL, FOR ALLOTMENT OF SPACE SEGMENT CAPACITY. This is governed in a separate agreement between the Allotee and the Director General.

STEP 2: SUBMIT APPLICATION FOR USE OF NON-STANDARD EARTH TERMINALS. This requires completion of prepared "Application for Approval of A Non-Standard Earth Station For Access To The INTELSAT Space Segment" to the Director General. Approximately 3 months are necessary for processing the application.

STEP 3: ACQUIRE PROVISIONAL APPROVAL. This is granted after the earth terminals are installed, operation, begins and tests are conducted to varify characteristics of the earth terminal antenna and evaluate the radio link performance.

STEP 4: ACQUIRE FORMAL APPROVAL. After the earth terminal is operational for 60 days, a full test report is submitted to the MSC for review. Recommendations are made to the Director General, who will grant formal approval.

STEP 5: OPERATIONAL CONTROL AND COORDINATION. While the earth terminal is operational, it will be periodically monitored for verification as to its whether its performance is consistent with system specifications.

INTELSAT: PROCEDURES FOR USE OF NON-STANDARD EARTH TERMINALS

- A non-standard earth terminal is defined as those stations that do not conform to the mandatory performance characteristics for operation in the specified frequency band. For C-band operation, there is a Standard A and a Standard B earth terminal.

- Operation of non-standard earth terminals is considered for approval by the Board of Governors on a case-by-case basis, subject to space segment availability and compatibility with various intersystem operational criteria. All applications are technically reviewed by the MSC (Management Services Contractor). They report to the Director General, who recommends to the BG (Board of Governors) and BG/T (Technical Committee) on the earth terminals appropriateness. The BG then decides on approval, which is conveyed by the Director General.

- Approval to access the space segment using non-standard earth terminals requires an application to the Director General, c/o INTELSAT, 490 L'Enfant Plaza, East, SW, Washington, DC 20024. The application should be submitted by the signatory to the Operating Agreement designated by the Party to the Agreement relating to INTELSAT, in whose territory the earth terminal will be located, or with respect to an earth terminal located in a territory not under the jurisdiction of a Party to the INTELSAT agreement, by a duly authorized telecommunications entity.

- Application for approval should be made at least six months prior to the intended operational date.

INTELSAT: PROBLEMS OF SMALL ANTENNA EARTH TERMINALS

- INTELSAT HAS NO RULES THAT EXPLICITLY STATE MINIMUM ANTENNA SIZE.
- INTELSAT REQUIRES THAT OFF-BEAM EIRP FROM AN EARTH TERMINAL TO A LEASED TRANSPONDER, OR PART OF A TRANSPONDER, SHALL NOT EXCEED $42-25 \log_{10} \theta$ dBw IN ANY 40 kHz BAND FOR $2.5^{\circ} < \theta \leq 48^{\circ}$ AND 0 dBw IN ANY 40 kHz BAND FOR $\theta > 48^{\circ}$, WHERE θ IS THE ANGLE FROM THE MAIN-BEAM AXIS
- FINAL APPROVAL FOR USE OF A NON-STANDARD EARTH TERMINAL ANTENNA IS REVIEWED ON A CASE-BY-CASE BASIS SUBJECT TO AVAILABILITY OF SPACE SEGMENT CAPACITY AND TO THE IMPACT ON INTELSAT OPERATIONAL PLANS
- INITIAL ENGINEERING ESTIMATES INDICATE THAT A SMALL ANTENNA (I.E., 4.57 METERS) CAN BE USED FOR TRANSMISSION OF SCPC VOICE FROM A VILLAGE SITE IF A SHROUD IS ATTACHED TO THE ANTENNA SO AS TO PRODUCE AN OFF-BEAM EIRP (I.E., LOWER VALUE) THAT IS WITHIN THE INTELSAT REQUIREMENT.

INTELSAT: PROBLEMS OF SMALL ANTENNA EARTH TERMINALS

- Any earth terminal antenna with characteristics other than those of an INTELSAT Standard A or B terminal is classified as a Non-Standard earth terminal.

- INTELSAT has no rule that explicitly states the minimum earth terminal antenna size for domestic applications. However, it does have a criteria regarding the emissions from an earth terminal into an adjacent satellite, that requires the emission level not be excessive so as produce interference in that adjacent satellite.

- This criteria is concerned with the off-beam EIRP of a transmitting earth terminal and is particularly relevant to small antenna earth stations (which have wide beamwidths and require more transmitter power then a large antenna/narrow beamwidth antenna).

- For the engineering estimates performanced in this study, the off-beam EIRP of the small antenna (4.57m) village earth terminal may exceed INTELSAT specifications. If so, specifications can be met by using a shrouded antenna. Such an antenna will produce a better off-beam EIRP (i.e., lower EIRP) that will comply with INTELSAT specifications while providing the required performance for service/

- INTELSAT should approve use of a shrouded antenna if appropriate documentation is provided that verifies its performance as being within off-beam EIRP requirements.

SYMPHONIE:DOMESTIC USE POLICY

- ANY DOMESTIC APPLICATIONS MUST BE INTENDED AS EXPERIMENTAL-IN-NATURE TO ACCOMMODATE THE EXPERIMENTAL UNCERTAINTIES OF THE SYMPHONIE SATELLITES.
- UTILIZATION OF EARTH TERMINALS MANUFACTURED IN FRANCE, GERMANY, OR BELGIUM IS CRITICAL FOR ACQUIRING APPROVAL.
- DOMESTIC USE REQUIRES CONCURRENT APPROVAL OF BOTH FRENCH AND GERMAN SPACE AGENCIES.

SYMPHONIE: DOMESTIC USE POLICY

- Since the Symphonie satellites are an experimental project, domestic use of these satellites must be considered in an experimental context (rather than as a long-term operational service.) This implies that domestic use will be constrained as to time of availability, guarantees of continuous service, priority of service, and possible outages without any restoral plans or capabilities.

- For domestic use of Symphonie, formal application must be made to the French and German space agencies; approval of both governments is required.

- A motivating factor for acquiring approval of both governments is that existing Symphonie terminals (eg; those already developed to operate with the satellite) be used. Alternatively, purchase of French, German, or Belguim manufactured earth terminals would be considered acceptable.

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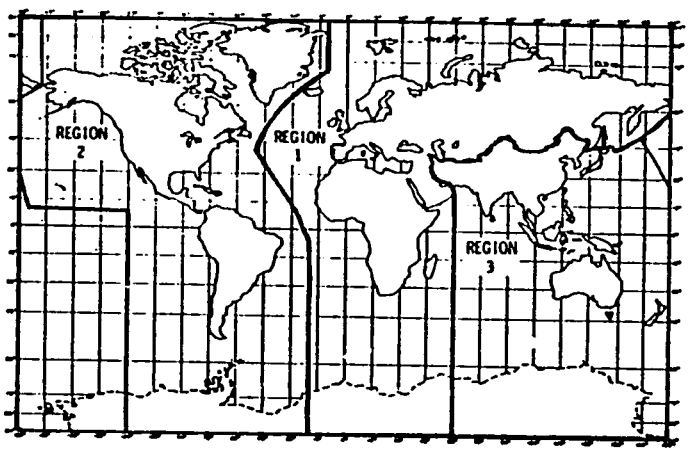
PART VI

REGULATORY PROVISIONS AND CONSTRAINTS

FREQUENCY ALLOCATIONS



REGIONS	EARTH-TO-SPACE (GHz)	SPACE-TO-EARTH (GHz)
C-BAND		
1,2,3		3.4-3.5
1,2,3		3.5-3.7
1,2,3		3.7-4.2
1,2,3	4.4-4.7	
1	5.725-5.85	
1,3	5.85.925	
1,2,3	5.925-6.425	
KU-BAND		
1	10.95-11.2	
2,3		10.92-11.2
1,2,3		11.45-11.7
1,3		11.7-12.2 /a
2		11.7-12.2 /b
1,3		12.5-12.75
2	12.5-12.75	
1,2,3	14.0-14.3	
1,2,3	14.3-14.4	
1,2,3	14.4-14.5	

All Allocations are for fixed satellite service only unless otherwise noted.

/a Broadcasting service only

/b Shared: Broadcasting-Fixed-Services

FREQUENCY ALLOCATIONS

- The International Telecommunications Union (ITU), through its WARC meetings (World Administrative Radio Conference), allocates radio frequencies according to three geographic regions. Once frequencies have been determined and allocated, the nations within each region may further divide the allocated frequencies and/or place their own restrictions/constraints on their use.

- The present frequencies for communications satellites in the C and Ku-Bands were allocated at the 1971 WARC. Changes to the Ku-Band frequencies between 11.7 - 12.2 GHz were made at the 1977 B/WARC.

- The C-Band frequencies currently in use throughout the world for all non-military communications satellite systems (except the U.S.S.R satellite systems) are uplink of 5.925-6.425 GHz and downlinks of 3.7 - 4.2 GHz. The remaining frequencies allocated at C-Band for communications satellites are being used for government terrestrial applications both in the U.S. and abroad.

- Current U.S. proposals for the 1979 WARC are evaluating ways to expand use of C-Band frequencies already allocated, but presently not in use with communications satellites. Frequencies under consideration are 3.1-3.7 GHz, 4.4-4.7 GHz, 4.7-4.9 GHz, 5.625-5.925 GHz, and 6.425-6.925 GHz.

- The Ku-Band frequencies currently or planned for domestic satellite communications throughout the world are uplinks of 14.0 - 14.5 GHz and downlink of 11.7 - 12.2 GHz. For international service, INTELSAT intends to use an uplink of 14.0 - 14.5 GHz and a downlink of 10.95 - 11.7 GHz.

- The 1977 B/WARC remained unsettled on the use of 11.7 - 12.2 GHz in Region 2. Consequently, the use of these frequencies by fixed and/or broadcasting services will be ascertained at a Region 2 Conference in 1982.

FREQUENCY COORDINATION REQUIREMENTS OF C-BAND EARTH TERMINALS

- C-BAND IS A POPULAR FREQUENCY FOR USE BY BOTH SATELLITE AND TERRESTRIAL MICROWAVE SYSTEMS
- FREQUENCY COORDINATION REQUIRES EXCHANGING OF TECHNICAL DATA BETWEEN ALL EARTH TERMINALS (BOTH TRANSMIT AND RECEIVE) AND TERRESTRIAL SYSTEMS TO PREDICT SATISFACTORY EARTH TERMINAL PERFORMANCE
- EVERY EARTH TERMINAL IN U.S. OPERATING AT C-BAND MUST BE FREQUENCY COORDINATED. SIMILAR REQUIREMENTS ARE ASSUMED FOR OTHER COUNTRIES
- FREQUENCY COORDINATION PROCEDURES ARE STANDARDIZED AND COST APPROXIMATELY $5000 PER SITE

FREQUENCY COORDINATION REQUIREMENTS OF C-BAND EARTH TERMINALS

- The most popular communications satellite frequency allocation is C-Band because equipment in this band is readily available and proven in use. However, because satellite systems share the 4-6 GHz frequencies with terrestrial common carrier systems, each must consider the other's facilities during system planning so that mutual interference may be minimized.

- Frequency coordination is the process of exchanging technical data between a planned earth terminal and a terrestrial system operating in the same frequency band.

- The main reason for frequency coordination is to determine whether or not the earth terminal will perform satisfactorily in the microwave environment. In the case of a transmitting earth terminal, additional ensurance must be made that it will not cause harmful interference to the terrestrial operator as well.

- Every earth terminal operating at C-Band in the United States must be frequency coordinated before it can become operational. In other countries, similar frequency coordination requirements are assumed to exist (but must be examined on a case-by-case basis.)

- Once a satellite earth terminal is frequency coordinated for a specified geographic location, it is protected from any new terrestrial microwave systems that may be built in the future.

- If during the frequency coordination analysis the planned site of a earth terminal (which is co-located with the final destination of the satellite transmitted signal) will result in interference, then a new geographic location must be determined. This new site may be several miles away, in which case, a terrestrial interconnect is required to carry the satellite transmission to its final destination.

- Earth terminal coordination procedures are quite common and well accepted in the United States, because computerized data bases exists for all existing terrestrial microwave systems. A typical coordination study might take several weeks, involve both an office and site evaluation, and cost approximately $5,000 per site.

PROBLEMS WITH KU-BAND ALLOCATIONS

- 1977 WARC PLANNED FOR USE OF THE 11.7-12.2 GHZ BAND.
- REGIONS 1 and 3 WILL USE THIS BAND PRIMARILY FOR BSS (BROADCAST SATELLITE SERVICE) BUT SHARING IT WITH TERRESTRIAL SERVICES. A FLUX DENSITY LIMIT WAS ESTABLISHED FOR THIS BAND IN THESE REGIONS.
- REGION 2 DEMANDED USE OF BOTH BSS AND FSS (FIXED SATELLITE SERVICE) IN THIS BAND. NO PERMANENT PLAN WAS ADOPTED FOR THIS REGION, ALTHOUGH ARC SEGMENTATION WILL BE IN EFFECT (TWO SEGMENTS WERE ALLOCATED FOR BSS). A REGION 2 WARC IS PLANNED FOR 1982, WHEN PLANS FOR SHARING THIS BAND WILL BE FINALIZED.

PROBLEMS WITH KU-BAND ALLOCATIONS

- The 1977 WARC was for planning the broadcasting satellite service (BSS) in frequency bands of 11-7-12.2 GHz (Regions 2 and 3) and 11.7-12.5 (Region 1).

- In Regions 1 and 3, "a priori" planning was favored by most of the developing countries (i.e., Europe and the USSR) so that current plan for the use of this band by terrestrial and satellite systems can continue to move forward immediately. Consequently, the Conference adopted on a priori orbital position for these two regions agreeing that the basic broadcast signal would be FM modulated, a flux density limit (for individual reception) of -103 dBw (at the edge of the coverage area), and a flux density limit (for community reception) of -111 dBw. At the -103 dBw level, a receiver with a figure of merit (G/T) of 6 dB/kilometer and an antenna of 0.9 meters, works out to a satellite EIRP of 67 dBw.

- For Region 2, an "arc segmentation" plan was adopted (based almost entirely on Canadian proposals). It sets aside two big segments of the equatorial orbit where BSS will rate as a primary service. They are 75° -100° W longitude (95° for U.S., Canada, and Mexico) and 140° - 170° W longitude. The remaining segment, 100° - 140° W longitude will be used for fixed satellite services. This plan will be in effect until 1982 when a Regional 2 WARC conference will be held to finalize (and perhaps change) the results of the 1977 WARC. The current plan for Region 2 at least guarantees all countries throughout the region that orbital positions for BSS will be available to them (each country is assumed of getting a minimum of four channels). The U.S., which preferred an "evolutionary plan" and is primarily interested in fixed satellite service (FSS), now has 5 years in which to identify its needs and requirements and to demonstrate that there can be enough technological advances to make the delay fruitful in terms of an increase in the quantity and quality of services than can be provided in this band.

ASSESSMENT OF CANDIDATE COMMUNICATIONS SATELLITE SYSTEMS FOR DEVELOPING COUNTRIES

APPENDICES

APPENDIX A: FREQUENCY PLAN

SERVICE	INTELSAT	SYMPHONIE	JBS
TELEVISION (R/O) 1 Channel	30 MHz (FULL)	30 MHz (FULL)	30 MHz (FULL)
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	27 MHz (FULL)	27 MHz (FULL)	27 MHz (FULL)
TELEVISION (R/O) 1 Channel plus Two-way Voice (S) 4 Channels	27 MHz (FULL)	27 MHz (FULL)	27 MHz (FULL)
TELEPHONY Multiple two-way (D) voice channels	9 MHz (QUARTER)	22 MHz (QUARTER)	11 MHz (QUARTER)
BROADCAST RADIO (R/O) 1 Channel	9 MHz (QUARTER)	22 MHz (QUARTER)	11 MHz (QUARTER)
BROADCAST RADIO (R/O) 1 Channel plus Two-way Voice (S) 1 Channel	9 MHz (QUARTER)	22 MHz (QUARTER)	11 MHz (QUARTER)
( ) Denotes allotted bandwidth/power per transponder	36 MHz	90 MHz	50 MHz

APPENDIX A: FREQUENCY PLAN

- The frequency plan for each satellite was designed in accordance with the service requirements as specified by A.I.D.

- The power available (EIRP) to an allocated space segment capacity of a half transponde is one-half the power of that transponder after appropriate input/output back-off. A similar ratio is used for a quarter trans ponder capacity (one-quarter capacity is allocated one-quarter of the available transponder power).

- For the service requirements of television plus one voice channel and television plus four voice channels, no back-off is assumed necessary.

- Interactive channels, occupying a quarter transponder, can operate at the full allocated EIRP for that transponder (about 10-11 dB below the level achieved at saturation). Thus, the total number of channels to be accommodated in a quarter transponder is dependent on the available power and not on bandwidth (no additional back-off is necessary).

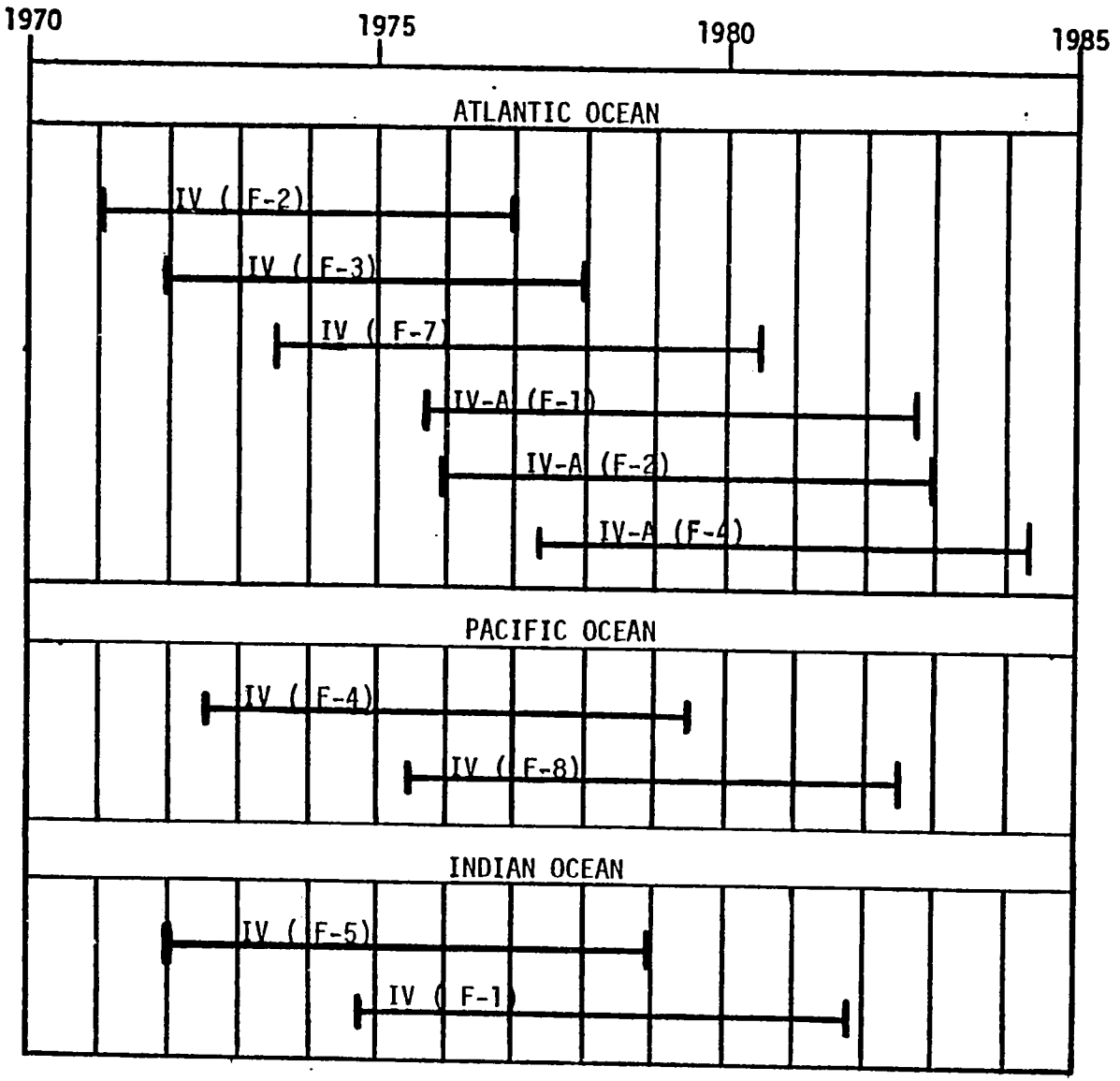
- A single program channel can occupy an entire quarter transponder, but if it were to use the entire available power, intermodulation products may become a problem. Thus, an additional 2-3 dB of output back-off was assumed. Alternatively, a second program channel can be accommodated in the same quarter transponder (for the IV spot beam and IV-A zone beam).

- For transmission of a program channel with a voice channel, it is again recommended that multiple voice channels be used (instead of just one voice channel). Otherwise, about 1-2 dB of output back-off is necessary.

- It is recognized that a technique of overdeviation can be used for transmission of television signals in order to achieve better link performance system (C/N) with a slight degradation in picture quality (S/N). Use of overdeviation requires the audio portion of the television signal to be transmitted on a separate carrier (which is transmitted through a difference transponder when small antenna earth terminals are used with C-Band satellites at moderate EIRP levels; eg, 33 dBw). For the service requirements specified by AID and the choice of allotted space segment capacities, it is doubtful that use of overdeviation would significantly change the system costs (total cost of master uplinl terminal, village site terminal, and space segment capacity) for television service. However, it is recommended that if a more efficient frequency plan is to be designed (incorporating television and a significant number of other service channels) that overdeviation of the overdeviation of the video carrier be used.

APPENDIX B: AVAILABILITY/LIFETIME OF INTELSAT SATELLITES

(System Status as of July 1977)



APPENDIX C: REQUIRED TRANSMISSION PLAN FOR USE OF INTELSAT SPACE SEGMENT CAPACITY

When a prospective lessee prepares the transmission plan for submission to INTELSAT, the technical characteristics of the transponder, or fractional part thereof as applicable, will be made known on request. These characteristics should be used as the underlying assumptions in preparing the transmission plan. To facilitate evaluation of the transmission plan and to ensure optimum utilization of the leased resources, it is requested that the following information be provided as part of the description of the domestic system:

- A frequency plan showing the frequency allocation of each carrier within the allotted frequency band.
- A list of earth stations comprising the system indicating:

  (i) the geographical coordinates of each station; (ii) prime parameters of the station such as G/T, transmit and receive gain of the antenna, type and numbers of carriers to be transmitted and received; and (iii) implementation date for each station.
- A block diagram of the earth station equipment with salient details of the high power amplifiers (such as Klystron power rating) and receive systems.

In addition to the above, a description of the planned carriers should be included. The following are the parameters of interest for the major types of carriers used in leased domestic systems:

TV Video
- Required C/N
- Expected S/N
- Receive filter IF bandwidth
- Video signal bandwidth
- overdeviation to be employed
- Energy dispersal to be employed
- Type of TV video standard to be employed (e.g., 625/50 PAL B)

SCPC
- Required C/N
- Expected S/N
- Modulation technique (e.g., companded FM, PSK, etc.)
- Receive filter IF bandwidth
- Assumed activity factor for voice activated systems

FDM/FM
- Required C/N
- Expected S/N
- Receive filter IF bandwidth
- Number of channels per carrier
- Allocated thermal plus intermodulation noise measured in pwop.

APPENDIX D: APPLICATION FOR APPROVAL OF A NON-STANDARD EARTH TERMINAL FOR ACCESS TO THE INTELSAT SPACE SEGMENT

INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION

"INTELSAT"

APPLICATION FOR APPROVAL OF A NON-STANDARD EARTH STATION FOR ACCESS TO THE INTELSAT SPACE SEGMENT

1. ADDRESSES

(Name/Mail/Telex/Cable/Phone)

a. Applicant: (Signatory or Duly Authorized Telecommunications Entity*

b. Owner :

c. Operator :

*If applicant is not a Signatory to the Operating Agreement designated by the Party to the Agreement Relating to the International Telecommunications Satellite Organization "INTELSAT", please complete attached certification as in Annex 1 to Attachment No. 3 designating a Duly Authorized Telecommunications Entity.

2. (a) Name of Earth Station: _____

(b) Antenna No. : _____

(c) Site Location :

Country : _____

Territory : _____

Nearest Town : _____

(d) Geographical Location:

Latitude : ____ Degrees ____ Minutes ____ Seconds N/S

Longitude: ____ Degrees ____ Minutes ____ Seconds E/W

(e) Height Above Mean Sea Level: _____ meters

3. Date for Commencement of Service:

____ / ____ / ____
Day Month Year

4. Proposed Satellite Operating Region:

Atlantic Ocean ☐

Indian Ocean ☐

Pacific Ocean ☐

5. Period of Operation Requested: _____

6. Is it intended to replace the Non-Standard earth station with a Standard A, B, or C earth station?

Yes ☐ No ☐

If the answer to the above is Yes, give the estimated date of replacement and the type of station:

Date : ____ / ____ / ____
Day Month Year

Type of Station: Standard A ☐

Standard B ☐

Standard C ☐

APPENDIX D: CONTINUED

7. Type of Service: International ☐
   Domestic* ☐
   Experimental** ☐

8. Description of Service for International Traffic:

   (a) Destinations/Channels for Telephony:***

	(Destination)	(Channels)	Proposed Method of Modulation/Access
1.	_____	_____	_____
2.	_____	_____	_____
3.	_____	_____	_____

   (b) Television Service:

   Receive ☐ Transmit ☐

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* Domestic Service: Attach a complete description of the planned system indicating the type of service to be provided, the proposed modulation/access mode to be employed, lease agreements if applicable, and any other pertinent information in as much detail as possible.

** Experiments and Demonstrations: Attach a complete description of the proposed experiments and/or demonstrations to be conducted. If free use of the space segment is requested, please provide complete justification in accordance with the provisions of BG-12-32 (Rev. 1).

*** Applicants should be aware that nonstandard earth stations will be reviewed on a case-by-case basis subject to availability of space segment capacity and to the impact on INTELSAT operational plans.

9. Antenna Diameter and Gain:

   (a) Antenna diameter: _____ meters

   (b) Antenna gain relative to isotropic at 4 GHz _____ dB

   (c) Antenna gain relative to isotropic at 6 GHz _____ dB

10. Gain over noise temperature ratio (G/T) at 4 GHz:

    G/T = _____ dB/K at _____ degrees elevation angle.

11. Antenna Transmit Sidelobe Pattern:*

    Will the peak gain, relative to isotropic, of the transmit sidelobe pattern comply with the requirements specified in Paragraph 4.4, Section 4 of BG-28-747

    Yes ☐ No ☐

    Irrespective of the answer given, the antenna data identified in the footnote below is required by INTELSAT; however, if the answer to this question is "no", the antenna data must be furnished as an attachment to the application.

12. Maximum Equivalent Isotropically Radiated Power (e.i.r.p.)

    Capability: _____ dBW

13. Antenna Tracking Capability:

    Tracking modes: Manual _____ Auto-tracking _____

14. Limits of Antenna Steerability:

    Azimuth: _____ (deg.) Elevation: _____ (deg.)

    (Reference to True North)

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*It is requested that the applicant submit wideangle sidelobe data (out to approximately 180°) to INTELSAT in advance of earth station verification tests via the satellite. These data might include, for instance, measurements on the antenna obtained on site using a boresite, or measurements made on an antenna of the same design on a test range at another location. This data will be used to substantiate antenna performance beyond the offbeam angles which can be measured using INTELSAT facilities.

APPENDIX D: CONTINUED

15. The total e.i.r.p. variation in the direction of the satellite from all factors causing such variation, except under severe adverse weather conditions,

will ☐ will not ☐

exceed ± 0.5 dB of the nominal value as specified in Paragraph 4.12, Section IV of BG-28-74. If affirmative, state the maximum amount of e.i.r.p. variation ± _____ dB.

16. In addition to the information requested in Paragraphs 9 through 15, list any other exceptions to the Mandatory Performance Characteristics, as specified in Section 4 of BG-28-74, and, in the case of FDM/FM carriers, as specified in the applicable portions of Section 4, BG-28-72. If there are no exceptions, so state.

17. List parts of RF bands in the frequency range 3700-4200 and 5925-6425 MHz over which it is not possible or difficult to achieve coordination in accordance with regulations described in the Final Acts of the World Administrative Radio Conference for Space Telecommunications (WARC-ST Geneva 1971).

18. List any limitations caused by terrain obstacles which may affect the positioning of the antenna in azimuth and elevation. If possible, attach a horizon profile diagram.

19. Describe any other technical or operational constraints or special arrangements which may have an impact on the operation of the earth station with the INTELSAT space segment.

20. Applicant notes that INTELSAT may require the provision of information additional to that given above.

21. Applicant agrees, with respect to the earth station/antenna for which it has submitted this application, to be responsible to INTELSAT for compliance with the rules and procedures specified by INTELSAT.

Applicant's Signature: _____

Date: ____ / ____ / ____
Day Month Year

APPENDIX E: INTELSAT DOMESTIC LEASES

SERVICES (As of December 31, 1976)	DATE OF LEASE	DURATION OF LEASE	ALLOTTED TRANSPONDER CAPACITY	SATELLITE OR REGION
DOMESTIC SERVICE				
Algeria	Feb. 1975	5 years	FULL	IV (F-5)
Brazil	July 1975	30 months	FULL	IVA (F-2)
France*	Aug. 1975	5 years	HALF	IV (F-7)
Malaysia*	Aug. 1975	5 years	FULL	IV (F-8)
Nigeria* (1st Lease)	Dec. 1975	5 years	FULL	IV (F-7)
(2nd Lease)	June 1976	5 years	FULL	IV (F-7)
Norway*	Dec. 1975	5 years	HALF	IVA (F-2)
TELEVISION SERVICE				
Spain	March 1976	1 year, minimum	HALF	IVA (F-1)
APPROVED DOMESTIC				
Chile*	Oct. 1977	5 years	QUARTER	ATLANTIC
Columbia*	June 1977	5 years	QUARTER	ATLANTIC
Nigeria* (3rd Lease)	April 1977	5 years	FULL	ATLANTIC
Saudi Arbia	Jan. 1979	5 years	QUARTER	ATLANTIC
Sudan*	Feb. 1977	5 years	FULL	ATLANTIC
Zaire*	Sept. 1977	5 years	FULL	ATLANTIC
PLANNED DOMESTIC				
India*	1978	5 years	QUARTER	INDIAN
Oman			HALF	INDIAN
Philippines*	1978	5 years	FULL + HALF	PACIFIC

*Leased on a pre-emptive basis

Source: Comsat Annual Report to the President and the Congress, 1976

APPENDIX F: LISTING OF COMPANIES/ORGANIZATIONS CONTACTED

INTELSAT Headquarters
Washington, DC

Embassy of France
Scientific Attache
Washington, DC

Aerospatiale
Les Mureaux, France

EUROSPACE
Paris, France

RCA Alaska Communications, Inc.
Anchorage, Alaska

Alaska Public Broadcasting Commission
Anchorage, Alaska

Alaska Native Health Service
Anchorage, Alaska

Alaska Public Utilities Commission
Anchorage, Alaska

Office of Telecommunication
State of Alaska
Anchorage, Alaska

Harris Corporation
Melbourne, Florida

Bell Telephone Manufacturers
Antwerp, Beligum

California Microwave, Inc.
Sunnyvale, California

Philco-Ford
Western Development Laboratories Division
Palo Alto, California

General Electric Company
Valley Forge, Pennsylvania

Hughes Aircraft Company
El Segundo, California

Andrews Corporation
Orland Park, Illinois

Scientific Atlanta
Atlanta, Georgia

Westinghouse Electric Corporation
Annapolis, Maryland

Varian
Santa Clara, California

Nippon Electric Corporation
Falls Church, Virginia

LNR Communications, Inc.
Hauppauge, New York

Comtech Laboratories, Inc.
Smithtown, New York